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LEADING THE WAY

Detailed Unexploded Ordnance Risk Assessment

Site: **Wrexham Solar Farm**

Client: **Wrexham Solar Farm Ltd**

Ref: **8506 RA**

Date: **2nd April 2020**

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This Report has been produced in compliance with the Construction Industry Research and Information Association guidelines for the preparation of Detailed Unexploded Ordnance Risk Assessments in the management of UXO risks in the construction industry.

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Glossary of Terms

AAA	Anti-Aircraft Artillery
ARP	Air-raid Precautions
BDO	Bomb Disposal Officer
EOD	Explosive Ordnance Disposal (current term for "bomb" disposal)
HE	High Explosive
HG	Home Guard
IB	Incendiary Bomb
Kg	Kilogram
LCC	London County Council
LM	Land Mine
LSA	Land Service Ammunition (includes grenades, mortars, etc.)
Luftwaffe	German Air Force
m bgl	Metres Below Ground Level
MoD	Ministry of Defence
OB	Oil Bomb
PM	Parachute Mine
RAF	Royal Air Force
SI	Site Investigation
SAA	Small Arms Ammunition (small calibre cartridges used in rifles & machine guns)
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V-1	"Doodlebug" the first cruise type missile, used against London from June 1944. Also known as 'Flying Bomb'
V-2	The first ballistic missile, used against London from September 1944
WWI	First World War (1914 -1918)
WWII	Second World War (1939 – 1945)

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Executive Summary

THE SITE:	
Address	Spectrum Industrial Park, Wrexham Industrial Estate, Rhosnesni, Cross Lanes, Wrexham, Wales, LL13 9QA
OS National Grid Reference	SJ 38074 48386
Details	The site is predominantly occupied by areas of both soft and dense vegetation, unused open ground and several routes composed of hard-standing. A large portion of the centre and south of the site is also occupied by numerous solar panels and several buildings of unknown usage. A single river covered by peripheral vegetation also passes through the north and west of the site. The surrounding area is largely rural in nature, in addition to Wrexham Industrial Park located adjacent to the north-west of the site.
PROPOSED WORKS:	
Proposed works involve carrying out civils works on site to create natural habitat for newts and other wildlife.	
Risk Assessment Methodology: In accordance with CIRIA guidelines this assessment has carried out research, analysed the evidence and considered the likelihood that the site has been contaminated with unexploded ordnance; that such items remained on site; the risk that they could be encountered during any intrusive works and the consequences that could result. Appropriate risk mitigation measures have been proposed.	
Explosive Ordnance Risk Rating	MEDIUM
THREAT OF CONTAMINATION FROM GERMAN AIR-DELIVERED UXO:	
• By the end of WWII, the town of Wrexham (within which the site was historically located), sustained a relatively low bombing density, as can be assumed from the lack of anecdotal bombing evidence. No official bombing statistics could be found to cover this area. • The site was located in a predominantly rural setting but was located on the periphery of ROF Wrexham, an ordnance factory in use during WWII. This factory would have constituted as a significant Luftwaffe bombing target; however, no evidence could be found to suggest that the factory suffered any bomb damage during the war. • Historical aerial photography and OS mapping also shows no evidence of ground disturbance or damage consistent with bomb / UXB strikes on site. However, one Ruin is located within the surrounding area, but due to the date of the OS map this is likely to just be a derelict building. • The site predominantly comprised several agricultural fields, a section of a river and a number of buildings in use by ROF Wrexham. The use of these buildings on site, however, are unknown. The majority of the site is unlikely to have been regularly accessed or checked for any UXB's during WWII.	

- Had a UXB fallen within the site, the entry hole could have become obscured within soft ground or unmaintained vegetation. Note the entry hole of an SC50 (the most commonly deployed German HE bomb) could be as little as 20cm in diameter. However, although It cannot be entirely discounted that an unrecorded UXB fell within open ground on site, considering the overall low bombing density over the area, such a scenario is considered highly unlikely.

THREAT OF CONTAMINATION FROM BRITISH / ALLIED UXO:

- During WWII, the site was located on the periphery of ROF Wrexham, one of the largest British ordnance factories in use during WWII.
- Among the materials manufactured at the facility were solvent-based and solvent-less cordite and rocket cordite. The cordite section of the factory was served by three nitro-glycerine factories, and apparently two large nitrocellulose sections. However, this section of the facility was located approximately 1.6km north of the site.
- Records suggest that the factory was also defended by several type 22 & 24 pillboxes, four of which were located on site. These were manned twenty-four hours a day by HG personnel who deployed a range of both conventional and unconventional weapons. These included conventional rifles, machine guns, mortars and grenades, the Spigot Mortar, the Smith Gun, SIP grenades and Fougasse bombs. It is also possible that the HG may have buried munitions including those mentioned above, close to the site.
- The site was occupied by a mixture of open agricultural ground, a section of a river and a number of buildings likely in use by the factory. It is unlikely that any training exercises occurred close to these buildings, however as a large portion of the site was occupied by open ground, typical of the that used by HG battalions for training exercises, it cannot be entirely discounted that activities occurred on site.
- As large quantities of ordnance were produced at ROF Wrexham during WWII and summarily transported from the site, it cannot be discounted that similar ordnance may have been disposed of on site or stored close to or within the buildings located on site during WWII.
- No known permanent HAA batteries were located within 5km of the site during WWII. However, the possibility cannot be discounted that mobile HAA guns were positioned temporarily in closer proximity to the ordnance factory during the war.
- It is possible that mobile AA guns were in place close to ROF Wrexham to protect the ordnance factory in the event of an air raid. Whilst no evidence could be found to suggest this, the possibility of these having been located in the surrounding area cannot be discounted. The possibility of these having been used during the war is however, considered unlikely due to the very low local bombing density.

BOMB PENETRATION ASSESSMENT:

It has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between **9-11m** below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

THE LIKELIHOOD THAT UXO REMAINS ON SITE:

Within the footprints of the post-war redevelopment / ground works, the risk of shallow buried UXO (especially German 1kg incendiaries) remaining will have been partially mitigated since any such items could have been encountered and removed during soil stripping and levelling. As such works appear to have taken place post-WWII across the areas of hard standing on site, these areas could be considered partially mitigated of shallow

buried UXO. However, as the majority of the site remains undeveloped since WWII, these areas are considered unlikely to have been mitigated.

Only within the volume of any post-war basement level bulk excavations and at the precise locations of any post-war pile foundations / boreholes, will the risk from deeper buried German HE UXBs have been completely mitigated. As no bulk excavations have been carried out onsite, the risk from deep buried UXO remains unmitigated to the maximum bomb penetration depth.

THE RISK THAT ORDNANCE MAY BE INITIATED:

The most violent activity on most construction sites is percussive piling or deep mechanical excavations. If an item is struck with a significant enough impact, be it direct or through friction/vibration, it risks detonation. Drilling of boreholes or similar activities also have the potential to initiate ordnance in this manner, either through impact or vibration.

Soil levelling and shallow excavation such as trial pits can pose a similar risk, since UXO can be found at any depth between ground level and the maximum bomb penetration depth. In addition to risk of initiation by violent impact or vibration, detonation can also occur if discovered items are mishandled by unqualified personnel. This is particularly common when onsite personnel are not trained in the recognition of ordnance.

For works that are not intrusive, little risk is posed by items of UXO that are buried beneath the ground. However, risk can arise from unburied munitions, particularly items of ordnance discarded in periphery areas of military sites. These items are frequently discovered by onsite personnel and remain live and liable to activate if mishandled.

RECOMMENDED RISK MITIGATION MEASURES:	
Site Specific Explosive Ordnance Safety and Awareness Briefings (UXO Toolbox Briefing) to all personnel conducting intrusive works	✓
Site Specific Safety Instructions (SSSI)	✓
Explosive Ordnance Disposal (EOD) Engineer On-Site Support	✓
Explosive Ordnance Disposal (EOD) Engineer to support site investigation works	✓
Search & Clear	✓
Non-Intrusive Magnetometer Survey and Target Investigation (greenfield land only)	✓
Intrusive Magnetometer Survey of all pile locations down to the maximum bomb penetration depth	✘

In making this assessment and recommending these risk mitigation measures, the proposed works outlined in the 'Scope of the Proposed Works' section were considered. Should the planned works be modified, or

additional intrusive engineering works be considered, SafeLane Global should be consulted to see if re-assessment of the risk or mitigation recommendations is necessary.

Annexes

Annex A Site Location Maps

Annex B Recent Aerial Photograph / Current Site Plan

Annex C Pre and Post-WWII OS Maps

Annex D German Air-Delivered Ordnance

Annex E Recent WWII-era German UXB Finds in the UK

Annex F The J-Curve Effect

Annex G WWII-era RAF Aerial Photography

Annex H Recent UXO Incidents – Home Guard

Annex I Land Service Ammuniton

Annex J Small Arms Ammunition

Annex K Anti-Aircraft Artillery

Annex L UXO Press Articles

Detailed Unexploded Ordnance Risk Assessment

In Respect of

Wrexham Solar Farm

1 Introduction

1.1 Background

Wrexham Solar Farm Ltd has commissioned SafeLane Global to conduct a Detailed Unexploded Ordnance Risk Assessment of Wrexham Solar Farm.

Unexploded Ordnance (UXO) presents a significant risk to construction projects in parts of the UK as a result of enemy actions during the two 20th Century World Wars and historic British and Allied military activity.

One of the legacies of this conflict is buried unexploded air-dropped bombs or anti-aircraft projectiles resulting from the failure of a proportion of the weapons to function as designed. It is commonly accepted that the failure rate of these munitions was approximately 10% and, depending on their shape, weight, velocity and ground conditions, many penetrated the ground and came to rest at depth.

In addition, it is estimated that over 20% of the UK landmass has been used by the military at some point and between 2006 and 2009, over 15,000 items of British / Allied ordnance (excluding small arms ammunition) were found on UK construction sites (CIRIA).

Intensive efforts were made during and after the war to locate and render safe all UXO but, unsurprisingly, not all were found and dealt with. This is evidenced by the regular, on-going discoveries of UXO during construction-related intrusive ground works.

As a result of a generally increased risk awareness amongst professionals involved in ground engineering works and proactive health and safety measures, the risk to life and limb from UXO has been minimised. However even the simple discovery of a suspected device during on-going works can cause considerable disruption to production and cause unwanted delays and expense.

Such risks can be more fully addressed by a better understanding of the site-specific risk and the implementation of appropriate risk mitigation measures.

2 Construction Industry Duties and Responsibilities

2.1 The UK Regulatory Environment

There is no legal requirement for the control and mitigation of UXO risk in the construction industry, but guidelines for good practice, information, and solutions with regards to UXO risk are detailed within CIRIA (C681).

These guidelines provide the construction industry with a set process for the management of risk associated with UXO, from preliminary risk assessment to implementation of site-specific risk mitigation strategies.

Specific legislation does however exist for health and safety, and is addressed under a number of regulatory instruments, as outlined below.

In practice, the regulations impose a responsibility on the construction industry to ensure that they discharge their obligations to protect those engaged in ground-intrusive operations (such as archaeology, site investigation, drilling, piling or excavations) from any reasonably foreseeable UXO risk.

2.2 The Health and Safety at Work Act, 1974

The Act places a duty of care on an employer to put in place safe systems of work to address, as far as is reasonably practicable, all risks (to employees and the general public) that are reasonably foreseeable.

2.3 Construction (Design and Management) Regulations 2015

CDM 2015 ensures that health and safety within the construction industry is continually improved:

- Works are sensibly planned and managed.
- Competent staff are engaged in the works.
- Risks are identified and managed.
- All parties cooperate and coordinate activities.
- Communication flows to those who require it.
- Workers are consulted and engaged about risks and how they are being managed.

In line with CDM 2015 legislation, SafeLane Global are able to assist parties in their discharge of CDM duties as follows:

- Assist Principal Designers with pre-construction information and risk assessments.
- Assist the Designer with the Designer's Risk Assessment.
- Issue UXO risks as have been identified and manage risks accordingly.
- Assist the Principal Contractor with the construction phase information, in particular risk assessments and mitigation strategies.
- Plan, manage and monitor survey and clearance works under SafeLane Global's control.

2.4 Other Legislation

Other relevant legislation includes the "Management of Health and Safety at Work Regulations 1999" and "The Corporate Manslaughter and Corporate Homicide Act 2007".

3 The Role of the Authorities and Commercial Contractors

3.1 The Authorities

The Police have the responsibilities for co-ordinating the emergency services in the case of an ordnance-related incident on a construction site. They will make an initial assessment (i.e. is there a risk that the find is ordnance or not?) and if they judge necessary impose a safety cordon and/or evacuation and call the military authorities (JSEODOC - Joint Services Explosive Ordnance Disposal Operations Centre)

to arrange for investigation and/or disposal. In the absence of an EOD specialist on site many Police Officers will use the precautionary principle, impose cordon(s)/evacuation and await advice from the JSEODOC.

The priority given to the request by JSEODOC will depend on their judgement of the nature of the risk (ordnance, location, people and assets at risk) and the availability of resources. They will respond immediately or as resources are freed up. Depending on the on-site risk assessment the item of ordnance may be removed or demolished (by controlled explosion) in situ. In the latter case additional cordons and/or evacuations may be necessary.

Note, that the military authorities will only carry out further investigations or clearances in very high profile or high-risk situations. If there are regular ordnance finds on a site, the JSEODOC may not treat each occurrence as an emergency and will encourage the construction company to put in place alternative procedures (i.e. the appointment of a commercial contractor) to manage the situation and relieve pressure from the JSEOD disposal teams.

3.2 Commercial Contractors

In addition to pre-construction site surveys and follow-on clearance work, a commercial contractor is able to provide a reactive service on construction sites. The presence of a qualified EOD Engineer with ordnance recognition skills will avoid unnecessary call-outs to the authorities and the contractor will be able to arrange for the removal and disposal of low risk ordnance. If high risk ordnance is discovered actions will be co-ordinated with the authorities with the objective of causing the minimum possible disruption to site operations whilst putting immediate, safe and appropriate measures in place.

4 This Report

4.1 Aims and Objectives

The aim of this report is to examine the possibility of encountering any explosive ordnance during any intrusive works at the site. Risk mitigation measures will be recommended in line with the CIRIA C681 guidelines, to reduce the risk of initiating UXO, and the subsequent risk of harm / damage during the envisaged works to as low as reasonably practicable (ALARP).

4.2 Risk Assessment Methodology

The following issues will be addressed in the report:

- The likelihood that the site was contaminated with unexploded ordnance.
- The likelihood that unexploded ordnance remains on site.
- The likelihood that ordnance may be encountered during any intrusive works.
- The risk that ordnance may be initiated.
- The consequences of initiating or encountering ordnance.

Risk mitigation measures, appropriate to the assessed level of risk and site conditions, will be recommended.

4.3 Approach

In preparing this Unexploded Ordnance Risk assessment, SafeLane Global has considered general and, as far as possible, site specific factors including:

- Evidence of German bombing and delivery of UXBs.
- Site history, occupancy and conditions during WWII.
- The legacy of Allied military activity.
- Details of any known EOD clearance activity.
- The extent of any post war redevelopment.
- Scope of the current proposed works.

4.4 Sources of Information

SafeLane Global has carried out detailed historical research for this Unexploded Ordnance Risk Assessment including accessing military records and archived material held in the public domain and in the MoD.

Material from the following sources has been consulted:

- The National Archives.
- The National Assembly for Wales via WYG Group.
- Groundsure Limited.
- Relevant information supplied by the client.
- Available material from 33 Engineer Regiment (EOD) Archive.
- SafeLane Global's extensive archives built up over many years of research and hands-on Explosive Ordnance Disposal activities in the UK.
- Open sources such as published books, local historical records and the internet.

4.5 Reliability of Historical Records

4.5.1 General Considerations

This report is based upon research of historical evidence. Whilst every effort has been made to locate all relevant material SafeLane Global cannot be held responsible for any changes to the assessed level of risk or risk mitigation measures based on documentation or other information that may come to light at a later date.

The accuracy and comprehensiveness of wartime records is frequently difficult or impossible to verify. As a result, conclusions as to the exact location, quantity and nature of the ordnance risk can never be definitive but must be based on the accumulation and careful analysis of all accessible evidence. SafeLane Global cannot be held responsible for inaccuracies or gaps in the available historical information.

4.5.2 Bombing Records

During WWII, considerable efforts were expended in recording enemy air raids. Air Raid Precautions (ARP) wardens were responsible for making records of bomb strikes either through direct observation or by post-raid surveys. However, their immediate priority was to deal with casualties and limit damage, so it is to be expected that records are often incomplete and sometimes contradictory. Record keeping in the early days of bombing was not comprehensive and details of bombing in the early part of the war were sometimes destroyed in subsequent attacks. Some reports may cover a single attack, others a period of months or the entire war.

Records of raids that took place on sparsely or uninhabited areas were often based upon third party or hearsay information and are not always reliable; records of attacks on military or strategic targets were often maintained separately from the general records and have not always survived.

5 The Site and Scope of Proposed Works

Site Address	Spectrum Industrial Park, Wrexham Industrial Estate, Rhosnesni, Cross Lanes, Wrexham, Wales, LL13 9QA
National Grid Reference Centre Point	SJ 38074 48386
Site Description	The site is predominantly occupied by areas of both soft and dense vegetation, unused open ground and several routes composed of hard-standing. A large portion of the centre and south of the site is also occupied by numerous solar panels and several buildings of unknown usage. A single river covered by peripheral vegetation also passes through the north and west of the site. The surrounding area is largely rural in nature, in addition to Wrexham Industrial Park located adjacent to the north-west of the site.
Proposed Works	Proposed works involve carrying out civils works on site to create natural habitat for newts and other wildlife.
Maximum Depth of Ground Works	At least 1.8m bgl.
Site Location Maps, a Recent Aerial Photograph of the site / Current Site Plan are presented in **Annexes A and B.**	

6 Ground Conditions

Data Source		Description
British Geological Survey Borehole	**Borehole Reference**	SJ34NE41/B
	Location	20m north-east
	Date	Not Specified
	Recorded Shallow Geology	• 0.27m of TOPSOIL • 3.08m of SAND

		• 4.2m of GRAVEL • 0.20m of SAND • 0.9m of SILT + GRAVEL • 3.6m of SAND
British Geological Survey Mapping	**Superficial Deposits**	• Alluvium – Clay, Silt, Sand and Gravel. • Till, Devensian – Diamicton. • River Terrace Deposits, 3 – Sand and Gravel.
	Bedrock	Kinnerton Sandstone Formation – Sandstone.

7 Site History

7.1 Pre-WWII

The following pre-WWII OS map was reviewed.

Date	1912	**Scale**	1:2,500	**Source**	Groundsure Ltd
Observations	• The site is predominantly occupied by a number of agricultural fields, small wooded areas and several farm buildings. *Brook House* is located within the north of the site, whilst the *River Clywedog* travels through from the west to the north of the site. • Several *Cottages* and *Parkey Hall* are located close to the boundaries of the site approximately 65m north and 30m east of the site respectively.				
A section of the map showing the site and immediate surrounding area is presented in **Annex C-1**.					

7.2 Post-WWII

The following post-WWII OS map was reviewed.

Date	1960	**Scale**	1:2,500	**Source**	Groundsure Ltd
The following are indicative of serious bomb damage on early post-WWII OS mapping:					
Ruins	✓	A single *Ruin* is present approximately 25m north-west of the site.			
Clearance	✓	A number of buildings located outside of the site have been cleared, located approximately 55m north, 50m south and 31m east.			
Redevelopment	✗	n/a			
Further Observations	• A significant level of development has occurred on site since 1912, with a number of buildings now located across the site and in the surrounding area. Several buildings labelled as '*Works*' are located toward the south of the site. These buildings are likely to have been built during the construction of ROF Wrexham in WWII, many of which were subsequently abandoned before other large factories and estates were built on site and in the surrounding area into Wrexham Industrial Estate.				

	• The *River Clywedog* passing through the site has also undergone adjustments, largely within the west of the site.
A section of the map showing the site and immediate surrounding area is presented in **Annex C-2.**	

8 The Threat from Aerial Bombing

8.1 General Bombing History of Wrexham

8.1.1 First World War

The UK suffered aerial bombardment during WWI, beginning with indiscriminate night raids by Zeppelin airships. However as British defensive measures became more effective and aircraft development progressed, the German military switched to daylight raids by fixed wing aircraft in June 1917. Wales however did not experience any raids during WWI.

WWI bombs were generally smaller than those used in WWII and were dropped from a lower altitude, resulting in limited UXB penetration depths. Aerial bombing was often such a novelty at the time that it attracted public interest and even spectators to watch the raids in progress. For these reasons, there is a limited risk that UXBs passed undiscovered. When combined with the relative infrequency of attacks and an overall low bombing density the risk from WWI UXBs is considered low and will not be further addressed in this report.

8.1.2 Second World War

At the start of WWII, the Luftwaffe planned to destroy key military installations, including RAF airfields and Royal Navy bases, during a series of daylight bombing raids. After the Battle of Britain these tactics were modified to include both economic and industrial sites. Targets included dock facilities, railway infrastructure, power stations, weapon manufacturing plants and gas works. As a result of aircraft losses, daylight raids were reduced in favour of attacking targets under the cover of darkness.

As the war progressed, the strategy changed to one of attempting to destroy the morale of the civilian population by the "carpet bombing" of London and several other cities and industrial sites. The Blitz on London began on 7th September 1940 with concentrated attacks coming to an end in May 1941 as the Luftwaffe was diverted east to prepare for 'Operation Barbarossa'; the invasion of the Soviet Union.

Wrexham is the largest town in Wales north of the Brecon Beacons, and has a history as an ecclesiastical centre, an agricultural market town and a centre for heavy industry. As well as ROF Wrexham, the town had several additional potential Luftwaffe bombing targets including the coalfields, the numerous brickfields and the Brymbo Steelworks to the north of the town.

Wrexham and the ROF were defended against air attack by Royal Air Force (RAF) Wrexham, approximately 3km north-west of the facility. The Luftwaffe was using a route which took them over sparsely populated parts of Wales to attack the industrial towns of the north-west, and the airfield was sited to cover this approach. As with the ROF, no records can be found to indicate that the airfield was targeted or attacked.

Research has identified only modest bombing of the town. However, the bombing of Ministry of Defence (MoD) land such as the RAF station and ROF was often not recorded in the public domain for reasons of national security. Given that the ROF was such a large target and was on route to primary targets such as Liverpool, it is it probable that the facility and town received more bombing than is recorded.

8.2 Generic Types of WWII German Air-delivered Ordnance

The nature and characteristics of the ordnance used by the Luftwaffe allows an informed assessment of the hazards posed by any unexploded items that may remain today. Detailed illustrations of German air-delivered ordnance are presented in **Annex D**.

- HE Bombs: In terms of weight of ordnance dropped, HE bombs were the most frequent weapon deployed. Most bombs were 50kg, 250kg or 500kg (overall weight, about half of which was the high explosive) though large bombs of up to 2,000kg were also used. HE bombs had the weight, velocity and shape to easily penetrate the ground intact if they failed to explode. Post-raid surveys would not always have spotted the entry hole or other indications that a bomb penetrated the ground and failed to explode, and contemporary ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded 50kg bomb. Unexploded HE bombs therefore present the greatest risk to present-day intrusive works.
- Blast Bombs/Parachute Mines: Blast bombs generally had a slow rate of descent and were extremely unlikely to have penetrated the ground. Non-retarded mines would have shattered on most ground types, if they had failed to explode. There have been extreme cases when these items have been found unexploded, but this was where the ground was either very soft or where standing water had reduced the impact. SafeLane Global does not consider there to be a significant risk from this type of munition on land.
- Large incendiary bombs: This type of bomb ranged in size from 36kg to 255kg and had a number of inflammable fill materials (including oil and white phosphorus), and a small explosive charge. They were designed to explode and burn close to the surface, but their shape and weight meant that they did have penetration capability. If they penetrated the ground, complete combustion did not always occur, and, in such cases, they remain a risk to intrusive works.
- 1kg Incendiary Bombs (IB): These bombs, which were jettisoned from air-dropped containers, were just over 30cm in size and therefore highly likely to go unnoticed. They had the potential to penetrate soft ground and left a very small entry hole. Furthermore, if bombs did not initiate and fell in water or dense vegetation or became mixed with rubble in bomb damaged areas, they could have remained hidden to this day. Some variants had explosive heads, and these present a risk of detonation during intrusive works, particularly due to their shape, which leads them to often be misidentified.
- Anti-personnel (AP) Bomblets: AP bombs had little ground penetration ability and should have been located by the post-raid survey unless they fell into water, dense vegetation or bomb rubble.
- Specialist Bombs (smoke, flare, etc): These types do not contain high explosive and therefore a detonation consequence is unlikely. They were not designed to penetrate the ground.

8.3 German Air-delivered Ordnance Failure Rate

Based on empirical evidence, it is generally accepted that 10% of the German HE bombs dropped during WWII failed to explode as designed. This estimate is probably based on the statistics of wartime recovered UXBs and therefore will not have taken account of the unknown numbers of UXBs that were not recorded at the time and is probably an underestimate.

The reasons for failures include:

- Fuze or gaine malfunction due to manufacturing fault, sabotage (by forced labour) or faulty installation.

- Clockwork mechanism failure in delayed action bombs.
- Failure of the bomber aircraft to arm the bombs (charge the electrical condensers which supplied the energy to initiate the detonation sequence) due to human error or equipment defect.
- Jettison of the bomb before it was armed or from a very low altitude. Most likely if the bomber was under attack or crashing.

War Office Statistics document that a daily average of 84 bombs which failed to function were dropped on civilian targets in Great Britain between 21st September 1940 and 5th July 1941. 1 in 12 of these (probably mostly fitted with time delay fuzes) exploded sometime after they fell; the remainder were unintentional failures.

From 1940 to 1945 bomb disposal teams dealt with a total of 50,000 explosive items of 50kg and over (i.e. German bombs), 7,000 AAA shells and 300,000 beach mines. These operations resulted in the deaths of 394 officers and men. However, UXO is still regularly encountered across the UK (see recent press articles, **Annex E**).

8.4 UXB Ground Penetration

8.4.1 General Considerations

The actual penetration depth of aerial delivered bombs into the ground will have been determined by the mass and shape of the bomb, the velocity and angle of the bomb on impact (dependent on the height of release) and the nature of the ground and ground cover; the softer the ground, the greater the potential penetration. Peat, alluvium and soft clays are easier to penetrate than gravel and sand. Bombs are brought to rest or are commonly deflected by bedrock or large boulders.

8.4.2 The "j" Curve Effect

An air-dropped bomb released from normal bombing altitude (approx. 5,000m) on its curved trajectory can reach a terminal velocity of between 350-400 ms^{-1}. In this case of high-level bombing, the angle of which the bomb enters the earth is approx. 15° from the perpendicular and its exact path is difficult to trace. The bomb is being driven by its kinetic energy can unless deflected, will continue its line of flight and can turn in an upwards curve towards the ground surface as it comes to rest. The upwards curve is caused by the transfer of energy as the bomb travels through the ground. The nose of the bomb travels slower than the rear of the bomb due to the drag/friction of it passing through the ground. The rear of the bomb, having more energy due to less drag/friction is travelling much quicker.

The location of the bomb is thus "offset" from the hole of entry. This "offset" from vertical is generally understood to be about one third of the penetration depth but can reach up to (and have been found at) 15m/50 ft from point of entry, dependent on ground conditions and the bomb's angle of impact. **Annex F** depicts the various paths of UXB through homogenous ground, showing how the J-curve effect can lead to a UXB coming to rest beneath undamaged buildings.

8.4.3 Second World War Bomb Penetration Studies

During WWII, the Ministry of Home Security undertook a major study on actual bomb penetration depths, carrying out statistical analysis on the measured depths of 1,328 bombs as reported by Bomb Disposal, mostly in the London area. They then came to conclusions as to the likely average and maximum depths of penetration of different sized bombs in different geological strata.

The median penetration of 430 x 50kg German bombs in London Clay was 4.6m and the maximum penetration observed for the SC50 bomb was 9m.

They concluded that the largest common German bomb, 500kg, had a likely penetration depth of 6m in sand or gravel but 8.7m in clay. The maximum observed depth for a 500kg bomb was 10.2m and for a 1,000kg bomb 12.7m. Theoretical calculations suggested that significantly greater penetration depths were probable.

8.5 Second World War Bombing Statistics

During WWII, the site was located within the county of Denbighshire in North Wales, however no official statistics detailing the number of bombs falling across the county or within the town of Wrexham were available during the timeframe of this report. It is possible that details of these records were either lost, poorly recorded or simply that the bombing density across the area was very low.

8.6 Site Specific WWII Bombing Records

8.6.1 Wrexham ARP Bomb Census Maps

A search was conducted for a Bomb Census Map of the area of Wrexham. However, none could be found.

8.6.2 Original ARP Bombing Incident Records

Throughout WWII, records of bombing incidents were kept by the ARP and Civil Defence Office. These records were kept in the form of typed or hand-written notes and/or presented on bomb plot maps. Some other organisations, such as port authorities and railways, maintained separate records.

ARP written records were reviewed for:	Wrexham
Source:	n/a
Records of bombing on / near the site were found	✘

8.6.3 Secondary Source / Anecdotal Evidence

Anecdotal evidence of local bombing incidents was sought from publications and web resources. The following references to incidents on site or in the surrounding area were found.

Date	Weapon	Details
30th August 1940	HE bombs	Considerable night bombing activity was recorded in London and the Midlands. Manchester, ***Wrexham***, Derby and Nottingham districts were worst affected. Over 315 high explosive (HE) bombs and over 980 incendiary bombs were dropped in total during that night. More than 24 unexploded bombs (UXB) were dealt with across the country.
28/08/1940 – 01/09/1940	HE bombs	"*Between 28th August and 1st September 1940* ***Wrexham*** *suffered a sustained period of bombing, a by-product of German raids on Liverpool. In fact, German planes had been sporadically bombing the border area of what is now Flintshire, Cheshire and Shropshire from the end of June*

		1940, and it was not until August 1940 that a defensive group of aircraft was dedicated to defending north Wales.[1]"
14/15th November 1940	HE bombs	Minor bomb damage reported in ***Wrexham***.
21/22nd November 1940	HE bombs	Bombs reported in ***Wrexham***. No further information.

8.6.4 Bombing Decoy Sites

A national decoy authority headed by Colonel John Fisher Turner was set up in July 1940, and following earlier experiments in Glasgow and Sheffield, a system of urban lighting decoys was set up. These were known as "Civil" sites; Civil 'QL' for urban lighting simulation, and Civil 'QF' for dummy fires. "Q" - sites were equipped with assorted electrical and pyrotechnical apparatus to simulate the flare given from furnace doors, steelmaking, railway marshalling yards, and light given off by inefficient blackout precautions.

Other sites simulated small fires started by incendiary bombs, with oil-storage area fire simulation being developed near large oil installations. A further variation on fire decoy sites was the "SF", or "Special Fires" sites. A larger, longer-burning type of fire was provided at these sites - known as "Starfish" sites - to draw incendiary bombs, and hopefully as a consequence the full enemy payload, from falling on the larger conurbations and defence installations during heavy air raids. Decoy sites were effective in drawing the Luftwaffe's attacks away from legitimate airfields – in 1940 alone 'Q' and 'Starfish' sites received nearly 200 attacks.

Records indicate that a designated bombing decoy for the ROF was located approximately 6km to the east. The presence of this facility confirms the acknowledged importance of the facility and anticipated threat of aerial attack from the Luftwaffe.

8.6.5 WWII-era RAF Aerial Photography

The following WWII-era photography of the site was reviewed.

Source	The National Assembly for Wales via WYG Group	**Image Type**	Aerial	**Quality**	Small-scale
Date	2nd April 1946				
Observations	• WWII-era aerial photography of the site is largely consistent with conditions seen in post-WWII OS mapping. Upon comparison, it appears that between this imagery and post-war OS mapping, further development on site and the surrounding area was conducted. Numerous buildings associated with ROF Wrexham are visible on the image, particularly to the north-west of the site. • No significant damage or ground disturbance consistent with bomb strikes appears to be present on site or within the surrounding area.				

[1] *https://www.bbc.co.uk/blogs/waleshistory/2010/07/wales_battle_of_britain_1940.html*

This image is presented in **Annex G.**

8.6.6 Abandoned Bombs

A post-air raid survey of buildings, facilities and installations would have included a search for evidence of bomb entry holes. If evidence were encountered, Bomb Disposal Officer teams would normally have been requested to attempt to locate, render safe and dispose of the bomb. Occasionally evidence of UXBs was discovered but due to a relatively benign position, access problems or a shortage of resources the UXB could not be exposed and rendered safe. Such an incident may have been recorded and noted as an Abandoned Bomb.

Given the inaccuracy of WWII records and the fact that these bombs were 'abandoned', their locations cannot be considered definitive, nor the lists exhaustive. The MoD states that 'action to make the devices safe would be taken only if it was thought they were unstable'. It should be noted that other than the 'officially' abandoned bombs, there will inevitably be UXBs that were never recorded.

SafeLane Global holds records of officially registered abandoned bombs at or near the site.	✘
Additional comments:	n/a

8.7 Site Specific Bomb Penetration Considerations

When considering an assessment of the bomb penetration at the site, the following parameters would be used:

- Geology – 0.27m of TOPSOIL, 3.08m of SAND, 4.2m of GRAVEL, 0.20m of SAND, 0.9m of SILT + GRAVEL, 3.6m of SAND.
- Impact Angle and Velocity – 80-90^0 from horizontal and 267 metres per second.
- Bomb Mass and Configuration – The 500kg SC (General Purpose) HE bomb, without retarder units or armour piercing nose. This was the largest of the common bombs used against Britain.

Taking into account the above-mentioned factors it has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between **9-11m** below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

8.8 Likelihood of Post-raid UXO Detection

Utilising the available historical bombing records as reviewed in *Section 8.6*, it is possible to make an assessment of the likelihood that evidence of UXO would have been noted on a site during the war and the incident dealt with or recorded at the time. Factors such as bombing density, frequency of access, ground cover, damage and failure rate have been taken into consideration.

8.8.1 Density of Bombing Assessment:

Bombing density is an important consideration for assessing the possibility that UXBs remain in an area. A very high density of bombs will have increased the likelihood of errors in record keeping at the time, as civil defence personnel and emergency services may have been overwhelmed. A higher density of bombing also increases the number of UXBs actually occurring in a given area.

The type and specific location of recorded bomb strikes is also an important consideration. If a stick of bombs (one individual aircraft's bomb load) is plotted in line with a site or is shown to straddle a site, then this raises the possibility that an unrecorded UXB from the same stick struck that site.

Density of Bombing Assessment	
Based on wartime records or secondary source information, what was the bombing density over the site?	Very low
Was the site ever subjected to one or more large-scale (>100 tons of ordnance) night time Blitz raids?	✖
Were any HE bomb strikes recorded on site?	✖
What is the distance between the site boundary and the closest recorded large bomb strike?	Unknown
How many HE, Parachute Mine, Oil Incendiary, Phosphorus Incendiary or Fire Pot bombs (large bombs) were recorded within a 300m radius of the site?	0
Were any nearby sticks of large bombs recorded in line with the site?	✖
Were any 1kg incendiary bomb showers recorded over the site?	✖
Additional comments:	n/a

8.8.2 Bomb Damage Assessment:

In Blitzed cities / towns throughout Britain, bomb sites were often not cleared of rubble until after the war and mid-war repairs to buildings were only carried out on the most vital facilities (power stations, gas works, weapons factories etc.). However, if a building only sustained bomb damage to its upper floors, any subsequent UXB strike to the structure will still have caused obvious damage, at ground floor level, which would have been reported and dealt with at the time.

HE bomb strikes to open ground will have resulted in a large crater and local soil disturbance. Any subsequent UXB strike will not have resulted in an easily identifiable entry hole and as such is likely to have gone unnoticed amongst the disturbed ground.

In London and south-east England, the German V1 Flying Bomb and V2 Long Range Rocket campaigns caused widespread devastation. However, as these weapons began to be utilised after the final significant Luftwaffe air raids had occurred, any serious damage caused by such weapons does not necessarily indicate an increased risk of Luftwaffe freefall UXB contamination. However, it is quite

possible that serious damage inflicted during the 1940-1944 campaigns by Luftwaffe freefall bombs could have been erased by a subsequent V Weapon strike.

Bomb Damage Assessment	
A comparison of the historical records confirms that buildings within the site boundary sustained serious bomb damage.	✖
Direct or indirect evidence of HE bomb craters in open ground (within the site boundary) has been found.	✖
Buildings on site were seriously damaged by a V1 and / or V2 strike.	✖
Buildings on site could have been seriously damaged prior to the nearby V1 or V2 strike?	n/a
Additional comments:	n/a

8.8.3 Frequency of Access Assessment:

A UXB strike at a site where human access was infrequent would have had a lower chance of being observed, reported and recorded compared to a site which was developed and subject to regular access. UXB strikes during night time raids (when German planes could more easily evade anti-aircraft defences) are also more likely to have fallen unobserved than ones dropped during a daylight attack.

In frequently bombed cities / towns, ARP Wardens were tasked with carrying out searches for UXBs within recently bombed residential areas and schools. Similarly, many important home front facilities (factories, gas works, power stations, docks etc.) had their own dedicated ARP teams or Fire Watchers tasked with observing local air raids. Fire Watchers were mainly responsible for extinguishing 1kg incendiary bombs as well as reporting any UXB strikes. Anecdotal evidence however indicates that Fire Watchers did not always turn up for their shifts and therefore such UXB mitigating activities should not be assumed in the absence of site-specific evidence. Less important buildings sustaining bomb damage would have been abandoned until after the German bombing campaign in that area had ceased and repairs could be made, greatly decreasing the level of access to that site.

Schools closed due to the evacuation of children were often requisitioned by the Civil Defence authorities to be utilised as night time First Aid posts and reception centres (providing emergency accommodation for bombed out civilians). Therefore, an increased level of access is likely at these locations.

Frequency of Access Assessment	
The site was situated in a densely populated urban area during WWII and therefore would have been accessed at the outbreak of WWII.	✖
The site was exclusively or partially developed during WWII.	✓

Buildings on site survived WWII intact and therefore likely remained inhabited or in use, suggesting these localities and their immediate environs were accessed throughout the war.	✓
The site was crossed by roads / pavements or footpaths which would have been regularly used / subject to daily footfall.	✓
The site was occupied by small residential back yards / gardens, likely to have been put to use for cultivation as a result of the government's Dig for Victory Campaign.	✗
The site was occupied by a school during WWII.	✗
Part of the site is likely to have been subject to post-raid searches for UXO.	✗
Buildings on site sustained serious bomb damage and as a result were likely abandoned (along with any associated gardens / open ground) for the remainder of the war.	✗
The site was occupied by peripheral open ground / wasteland, with no apparent use, which may have been neglected.	✓
The site may have been occupied by recreational land / sports fields which may have only experienced seasonal access.	✗
The site was occupied by a graveyard which would have experienced limited access.	✗
The site was occupied by agricultural land, rural countryside or woodland which would not have been accessed in full, either regularly or frequently.	✓
The site was occupied by railway sidings which may not have been as regularly checked for buckling as mainline railway tracks.	✗
The site was occupied by soft railway embankments which are likely to have been neglected during the war.	✗
Additional comments:	n/a

8.8.4 Ground Cover Assessment:

The entry hole of a 50kg UXB (the most commonly deployed German HE bomb) could have been as little as 20cm in diameter. Wartime records also confirm that small German Incendiary Bombs, weighing just 1kg, were capable of significant penetration into soil, resulting in very small entry holes (5cm) or complete burial.

The quantity and type of ground cover present on a site during WWII would have had a significant effect, at ground level, on the visual evidence of buried UXO.

Evidence of UXO could be obscured in dense vegetation, soft ground, rubble, railway ballast or amongst stockpiled material (such as aggregate, coal or refuse heaps). A UXB strike to waterlogged ground or open water would have been immediately obscured from view beneath the waterline. Had such an incident occurred within a tidal mudflat or river bank, the resulting entry hole will have remained only temporarily, before becoming in-filled by water and sediment. Any HE UXB strike to elevated risk ground

cover could potentially have come to rest beneath neighbouring undamaged buildings or hard-standing due to the 'J-Curve' Effect.

UXB strikes to undamaged/superficially damaged buildings and hard-surfaced ground will still have caused substantial damage or an easily identifiable and persistent entry hole. Similarly, it is unlikely that an HE UXB entry hole on well-maintained / manicured lawns (tennis courts, bowling greens, golf course fairways / greens, gardens in affluent areas etc), would have been overlooked. Such incidents would have been reported and the UXB subsequently removed.

Ground Cover Assessment	
The site was partially or entirely abandoned, due to bomb damage, resulting in associated open ground likely becoming overgrown.	✖
The site was occupied by dense, inaccessible vegetation during WWII.	✓
The site may have been susceptible to waterlogged conditions during WWII.	✓
The site was occupied by (possibly) unmaintained grass field during WWII.	✓
The site was part occupied by a canal, river, dock basin, lake or reservoir during WWII.	✓
The site was occupied by tidal mud or marshland during WWII.	✖
The site was occupied by railway tracks crossing soft ground during WWII.	✖
The site was occupied by stockpiled material during WWII.	Possibly
The site was occupied by buildings, hard-standing or other manmade structures that did not sustain any degree of bomb damage.	✓
A comparison of the historical records confirms that buildings on site sustained inconsequential minor / moderate damage.	✖
The site was occupied by well-maintained, manicured lawn during WWII.	✖
Undamaged, developed parts of the site would have been vulnerable to the J-Curve Effect.	✓
Additional comments:	n/a

8.8.5 Bomb Failure Rate Assessment:

Based on empirical evidence, it is generally accepted that 10% of the German HE bombs dropped during WWII failed to explode as designed.

Note, due to manufacturing fault or failure of the bomber crew to correctly arm their munitions, whole bomb loads often failed to detonate. Therefore, the presence of reported UXBs increases the likelihood of an additional unrecorded UXB in the vicinity.

Bomb Failure Rate Assessment	
Evidence has been found which suggests that the bomb failure rate in the vicinity of the site would have been different from the "approximately 10%" figure normally used.	✖
Additional comments:	n/a

9 The Threat from Allied Military Ordnance

The following potential historical and modern sources of UXO contamination on site or in the surrounding area have been considered:

Potential Source of Contamination on Site	
Army, Navy and RAF Bases / Installations	✖
Military Training Areas / Weapons Ranges	✖
Ordnance / Explosives Factories and Storage Depots	✓
Sites Requisitioned for Military Use	✓
Military Fortifications and Coastal Defences	✖
Locations of Army Explosive Ordnance Clearance Tasks	✖
WWII Anti-Aircraft Batteries	✓
WWII Pipe Mined Locations and Beach Minefields	✖

The risk of contamination from Allied UXO on site is discussed below.

9.1 Wrexham Royal Ordnance Factory (ROF)

The modern-day Wrexham Industrial Estate occupies the site of the former Wrexham Royal Ordnance Factory (ROF). During WWII, the facility manufactured nitro-glycerine, cordite and guncotton (nitrocellulose) as explosive propellants for shells. It employed 13,000 people and covered approximately 1,730 acres (700 hectares) and was built over relatively level farmland (the field boundaries of which were retained in an attempt to break up the outline). Its location was governed by relief of unemployment in the region and due to its remoteness from the continent.

To connect the site to the national rail network, a large marshalling yard of 10 separate roads, connected to the works internal network of rail lines. A passenger platform was built for military usage. All the

cordite produced at the plant was taken by these sidings, along the Wrexham and Ellesmere Railway to the ROF filling factories in South Wales and the west of England.

All main buildings were designed to resist incendiary bombs and HE blast, with thick walls, no windows and only small shuttered openings with reinforced roofs. These were then surrounded with earth banks both to deflect blast and to direct any explosion from within the buildings upwards.

The site was well defended, both on the ground and from the air. Several Type 22 Pillboxes and Type 24 Pillboxes still remain in the area, found in areas untouched by modern industrial developments. RAF Wrexham was also situated 3.5km to the north-west of the site and was home to at least one fighter squadron during WWII, primarily for defending the ROF from bomber attack.

Despite the presence of such targets, research has uncovered no records to suggest that ROF Wrexham was ever targeted or bombed by the German Air Force (Luftwaffe). There is no evidence of bomb damage or craters visible on WWII-era aerial photography; however, the small resolution and limited quality of the photographs should be taken into consideration.

Among the materials manufactured at the facility were solvent-based and solvent-less cordite and rocket cordite. The cordite section of the factory was served by three nitro-glycerine factories, and apparently two large nitrocellulose sections. However, this section of the facility was located approximately 1.6km north of the site.

Following the cessation of WWII, the need for cordite ceased, and in 1945 the production facilities at Wrexham closed. Many of the buildings were left in place, abandoned, and agriculture again took over the fields surrounding the area. The large amounts of abandoned ordnance buildings attracted smaller businesses, however, in the 1950s; British Celanese opened a large acetate yarn factory on the former facility. Other large companies that came to Wrexham in later years included Firestone (which partly occupied the study site itself and closed in the 1970s), Kellogg's and JCB.

The Welsh Development Agency officially made the area an industrial estate, subsidising businesses to move there in an effort to ensure stability of employment and to counter the effects of the recession Wrexham suffered in the 1960s and 1970s.

It is unknown exactly what activities associated with the ROF occurred on site. The site appears to have been located within the south-east periphery of the facility and is occupied predominantly by open fields and a section of the river. Most of the buildings on site appear to be located within the east of the site and their usage during the war is unknown. Today, these buildings appear to be left unused and derelict.

9.2 ROF Contamination

During WWII, hazardous explosive compounds were utilised at the factory and are likely to have been disposed of within designated areas such as burning grounds which were typically located in peripheral locations due to the sensitive nature of explosive propellants on site.

Historically, on a number of MoD sites, explosive residue has been found in drainage systems, typically nitro-glycerine, which is specifically known to have been used at ROF Wrexham. If present, such substances would pose a considerable hazard.

9.3 Home Guard Activity

The Home Guard (HG) was a defence organisation of the British Army, operational between 1940 and 1944. It comprised 1.5 million local volunteers, otherwise ineligible for military service and acted as a

secondary defence force in case of enemy invasion. The HG guarded the coastal areas of Britain and other important facilities such as airfields, factories and explosives stores. They were also active in county towns and cities.

Official records were rarely kept by the HG and therefore any present-day evidence is usually anecdotal. However, it is known that HG personnel often carried out training (including weapons training) in open countryside on the outskirts of cities / towns. Today, items of ordnance related to the HG are occasionally encountered by members of the public and the construction industry in the British countryside. This suggests a culture of ill-discipline regarding live ammunition within HG units.

HG personnel are known to have purposefully buried caches of ammunition and weapons in tactical positions, to be exhumed and used in case of invasion. Records of such caches were not rigorously kept, and some were therefore forgotten about. This is substantiated by several recent HG UXO finds (see **Annex H**).

Home Guard Activity		
Nearest HG Battalion to the site.	6th Denbighshire Battalion - Wrexham	
Site Specific Details:	• One HG battalion was known to have operated within the area of Wrexham during WWII; however, the location of their headquarters could not be found. • Due to the fact that the site was located on/within close proximity of the site of ROF Wrexham, it is possible the local HG battalion operated close to the site in protection of the factory. • Records indicate that a number of strategically placed type 22 & 24 pillboxes surrounded the ROF and they were manned twenty-four hours a day by HG personnel who deployed a range of both conventional and unconventional weapons. These included conventional rifles, machine guns, mortars and grenades and the more unconventional Northover Projector (a grenade launcher), Spigot Mortar, the Smith Gun, SIP grenades and Fougasse bombs. At least 4 of these pillboxes were located on site. It is also possible that the HG may have buried munitions including those mentioned above, close to the site. • A large portion of the site was also occupied by open ground, typical of the that used by HG battalions for training exercises. Whilst no evidence could be found to suggest that any training occurred on site, it cannot be entirely discounted. • No evidence suggests that Home Guard activity occurred on site, though given the proximity of the royal ordnance factory to the site, including pillboxes, the possibility of residual UXO contamination from small arms ammunition, grenades, mortars, etc. on site cannot be completely ruled out.	
There is evidence to suggest an elevated risk of land service / small arms ammunition contamination on site.		✓

9.4 Anti-Aircraft Gun Batteries

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) and Light Anti-Aircraft Artillery (LAA). The LAA batteries were intended to engage fast low flying aircraft and were typically deployed around airfields or strategic installations. These batteries were mobile and

could be moved to new positions with relative ease when required. With four guns per battery firing several rounds per minute, AA batteries could expel numerous shells in even the shortest engagements. Numerous unexploded AAA shells were recovered during and following WWII and are still occasionally encountered on sites today.

The maximum ceiling height of fire at that time was around 11,000m however, as the war progressed, improved variants of the 3.7" gun were introduced and, from 1942, large 5.25-inch weapons were brought into service. These had significantly improved ceiling heights of fire reaching over 18,000m.

When the supply of clockwork fuses from Switzerland was cut off, Britain was forced to make its own. After four years of war, the country still lacked the engineering skills to produce a reliable fuse. This resulted in a considerable number of AA projectiles exploding prematurely, killing the gunners or failing to explode at all and falling to the ground as UXBs. In January 1944, more people in London were killed by HAA shells than by German bombs.

Anti-Aircraft Gun Batteries	
Number of HAA batteries within 5km of the site.	0
Additional Comments:	• Although no HAA batteries were recorded to have been located within 5km of the site, many RAF airfields, training areas and ROF's were defended by light anti-aircraft batteries (as a minimum) which were usually dispersed around the perimeter and surrounding area in isolated positions. • LAA shells were high explosive (HE) projectiles, fitted with a contact fuze to make them explode on impact. If these shells failed to strike on aircraft, they would eventually fall back to earth. • It is possible that during air raids, AA fire may have occurred over the site in retaliation. However, given that the site was located within an area of relatively low bombing density (as can be assumed by the lack of anecdotal bombing incidents), it is considered unlikely that there was any large degree of AA fire occurring over the site.
There is evidence to suggest an elevated risk of unexploded AA shells contamination on site.	✘

9.5 The Threat Posed by Allied Unexploded Ordnance

9.5.1 Land Service Ammunition (LSA)

9.5.1.1 General

The term Land Service Ammunition covers all items of ordnance that are propelled, placed or thrown during land warfare. They may be filled or charged with explosives, smoke, incendiary or pyrotechnics. They can be broken into five main groups:

a. Mortars

b. Grenades

c. Projectiles

d. Rockets

e. Landmines

Unexploded or partially unexploded Mortars and Grenades are among the most common items of UXO encountered in the UK and therefore the possibility cannot be discounted that they were stores on site. They are commonly encountered in areas used by the military for training and are often found discarded on or near historic military bases. Examples of Grenades, Mortars and Home Guard weapons are presented in **Annex I**.

9.5.1.2 Mortars

A mortar bomb is a fin-stabilised munition, normally nose-fuzed and fitted with its own propelling charge (primary cartridge). Range is increased by adding extra propellant (augmenting charges). They are either HE or Carrier and generally identified by their tear-dropped shape (older variants however are parallel sided) and a finned 'spigot tube' screwed or welded to the rear end of the body housing the propellant charge.

A mortar relies on a striker hitting a detonator for explosion to occur. It is possible that the striker may already be in contact with the detonator and that only a slight increase in pressure would be required for initiation. Discarded augmenting charges are often encountered around mortar firing areas/bases.

9.5.1.3 Grenades

A grenade is a short-range weapon which may be thrown by hand, fired from the end of a rifle or projected/propelled from a special purpose grenade launcher. They are divided into two categories; HE and Carrier (generally smoke). As with mortars, a grenade striker may either be in contact with the detonator or still be retained by a spring under tension, and therefore shock may cause it to function. A grenade can have an explosive range of 15-20m. Common older variants have a classic 'pineapple' shape; modern grenades tend to be smooth-sided.

9.5.2 Small Arms Ammunition (SAA)

The most likely type of ordnance to be encountered on site are items of SAA (bullets), especially .303" ammunition which was the standard British and Commonwealth military cartridge from 1889 until the 1950s.

However even if an item such as this functioned, the explosion would not be contained within a barrel and detonation would only result in local overpressure and very minor fragmentation from the cartridge case.

Some LAA guns and RAF fighter cannons in use with British forces during WWII utilised the 20mm round. These bullets had a small fuse and a ~4gram HE or incendiary charge. Although small, this fill quantity still has the potential to cause serious injury. Images of SAA are presented in **Annex J**.

9.5.3 Anti-Aircraft Shells

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) using large calibre weapons such as the 3.7" QF (Quick Firing) gun and Light Anti-Aircraft Artillery (LAA) using smaller calibre weapons such as 40mm Bofors gun which could fire up to 120 x 40mm HE shells per minute to over 1,800m. During the early war period there was a severe shortage of AAA so older WWI 3" and modified naval 4.5" guns were also deployed.

These shells are frequently mistakenly identified as small German air-delivered bombs but are differentiated by the copper driving band found in front of the base. Although the larger unexploded projectiles could enter the ground they did not have great penetration ability and are therefore likely to be found close to WWII ground level. With a HE fill and fragmentation hazard these items of UXO also present a significant risk if encountered.

The smaller 40mm projectiles are similar in appearance and effect to small arms ammunition and, although still dangerous, present a lower risk. Pictures of AAA projectiles are presented in **Annex K**. Details of the most commonly deployed WWII AAA projectiles are shown below:

Gun type	Calibre	Shell Dimensions	Shell Weight	HE Fill Weight
3.7 Inch	94mm	94mm x 438mm	12.7kg	1.1kg
4.5 Inch	114mm	114mm x 578mm	24.7kg	1.7kg
40mm	40mm	40mm x 311mm	0.84kg	70g

10 Ordnance Clearance and Post-WWII Ground Works

10.1 General

The extent to which any ordnance clearance activities have taken place on site or extensive ground works have occurred is relevant since they may indicate previous ordnance contamination but also may have reduced the risk that ordnance remains undiscovered.

10.2 EOD Bomb Disposal and Clearance Tasks

SafeLane Global holds a number of official records of explosive ordnance disposal operations during and following WWII, obtained from the Explosive Ordnance Disposal (EOD) Archive Information Office at 33 Engineer Regiment (EOD), British Army.

Records were found to indicate that Army EOD tasks have taken place on / in the vicinity of the site.		✘
Further Comments:	n/a	
Records of recent local ordnance finds were found.		✘
Further Comments:	n/a	
SafeLane Global have encountered UXO in the local area.		✘
Further Comments:	n/a	

10.3 Post War Redevelopment

The nature of post-WWII ground works, redevelopment and construction has been considered. Significant structural redevelopment on site can, in some cases, provide a level of mitigation, particularly

from shallow buried items. However, if a site has not undergone any extent of redevelopment, the likelihood of UXO remaining within its boundaries can remain.

The site has been redeveloped post-WWII.	✓
Further details:	The study site has remained largely undeveloped since the end of WWII, with many of the buildings present during WWII, remaining in place and likely derelict. However, adjustments have been made to hard-standing roadways on site as well as the river in the north. Numerous solar panels have been constructed across the site between 2012 and 2016, predominantly located in the south and east of the site.

11 The Overall Unexploded Ordnance Risk Assessment

11.1 General Considerations

Taking into account the quality of the historical evidence, the assessment of the overall risk to any intrusive works from UXO must evaluate the following factors:

- That the site was contaminated with unexploded ordnance
- That UXO remains on site
- That such items could be encountered during any intrusive works
- That ordnance may be activated by the works operations
- The consequences of encountering or initiating ordnance

11.2 The Likelihood that the Site was Contaminated with Unexploded Ordnance

The below is a generalised table of factors used to determine the level of UXO risk on a site. Note that additional site-specific information can increase UXO risk beyond these criteria:

Low Risk	Medium Risk	High Risk
German Air Dropped Ordnance / Allied Anti-Aircraft Shells		
No evidence of bombing / bomb damage on site coupled with low local bombing density.	Moderate to High local bombing density or evidence of bombing / bomb damage on or close to the site.	High local bombing density or evidence of bombing /bomb damage on or adjacent to the site. Confirmed finds of WWII UXB.
Ground conditions that would prevent UXB penetration or lead to easily identifiable entry holes.	Ground conditions that allow for bomb penetration.	Ground conditions that would have immediately and completely obscured the existence of UXB.
Site was occupied and accessed fully throughout the bombing campaign.	Site located in an area that was infrequently observed or accessed, with a low likelihood that a UXB strike would have been noticed.	Site may be completely obscured from view or subject to very infrequent access.

Allied Ordnance		
No evidence of Allied military activity on or near the site.	Evidence of military activity on or near the site. This can include Home Guard activities, ground defence structures, munitions factories or military sites such as airfields.	Evidence of weapons testing or disposal on or adjacent to the site.
Developed areas that are unlikely to have been used for military exercises.	Open or unmaintained ground that may have been used for disposal or caching of munitions.	Evidence of UXO finds on or in the vicinity of the site.

For the reasons discussed in *Section 8 and 9* SafeLane Global believes that there is an elevated likelihood that UXO contaminated the study area. This is based on the following:

GERMAN AIR-DELIVERED UXO
• By the end of WWII, the town of Wrexham (within which the site was historically located), sustained a relatively low bombing density, as can be assumed from the lack of anecdotal bombing evidence. No official bombing statistics could be found to cover this area. • The site was located in a predominantly rural setting but was located on the periphery of ROF Wrexham, an ordnance factory in use during WWII. This factory would have constituted as a significant Luftwaffe bombing target; however, no evidence could be found to suggest that the factory suffered any bomb damage during the war. • Historical aerial photography and OS mapping also shows no evidence of ground disturbance or damage consistent with bomb / UXB strikes on site. However, one Ruin is located within the surrounding area, but due to the date of the OS map this is likely to just be a derelict building. • The site predominantly comprised several agricultural fields, a section of a river and a number of buildings in use by ROF Wrexham. The use of these buildings on site, however, are unknown. The majority of the site is unlikely to have been regularly accessed or checked for any UXB's during WWII. • Had a UXB fallen within the site, the entry hole could have become obscured within soft ground or unmaintained vegetation. Note the entry hole of an SC50 (the most commonly deployed German HE bomb) could be as little as 20cm in diameter. However, although It cannot be entirely discounted that an unrecorded UXB fell within open ground on site, considering the overall low bombing density over the area, such a scenario is considered highly unlikely.
BRITISH / ALLIED UXO
• During WWII, the site was located on the periphery of ROF Wrexham, one of the largest British ordnance factories in use during WWII. • Among the materials manufactured at the facility were solvent-based and solvent-less cordite and rocket cordite. The cordite section of the factory was served by three nitro-glycerine factories, and apparently two large nitrocellulose sections. However, this section of the facility was located approximately 1.6km north of the site. • Records suggest that the factory was also defended by several type 22 & 24 pillboxes, four of which were located on site. These were manned twenty-four hours a day by HG personnel who deployed a range of

both conventional and unconventional weapons. These included conventional rifles, machine guns, mortars and grenades, the Spigot Mortar, the Smith Gun, SIP grenades and Fougasse bombs. It is also possible that the HG may have buried munitions including those mentioned above, close to the site.

- The site was occupied by a mixture of open agricultural ground, a section of a river and a number of buildings likely in use by the factory. It is unlikely that any training exercises occurred close to these buildings, however as a large portion of the site was occupied by open ground, typical of the that used by HG battalions for training exercises, it cannot be entirely discounted that activities occurred on site.
- As large quantities of ordnance were produced at ROF Wrexham during WWII and summarily transported from the site, it cannot be discounted that similar ordnance may have been disposed of on site or stored close to or within the buildings located on site during WWII.
- No known permanent HAA batteries were located within 5km of the site during WWII. However, the possibility cannot be discounted that mobile HAA guns were positioned temporarily in closer proximity to the ordnance factory during the war.
- It is possible that mobile AA guns were in place close to ROF Wrexham to protect the ordnance factory in the event of an air raid. Whilst no evidence could be found to suggest this, the possibility of these having been located in the surrounding area cannot be discounted. The possibility of these having been used during the war is however, considered unlikely due to the very low local bombing density.

11.3 The Likelihood that Unexploded Ordnance Remains on Site

Within the footprints of the post-war redevelopment / ground works, the risk of shallow buried UXO (especially German 1kg incendiaries) remaining will have been partially mitigated since any such items could have been encountered and removed during soil stripping and levelling. As such works appear to have taken place post-WWII across the areas of hard standing on site, these areas could be considered partially mitigated of shallow buried UXO. However, as the majority of the site remains undeveloped since WWII, these areas are considered unlikely to have been mitigated.

Only within the volume of any post-war basement level bulk excavations and at the precise locations of any post-war pile foundations / boreholes, will the risk from deeper buried German HE UXBs have been completely mitigated. As no bulk excavations have been carried out onsite, the risk from deep buried UXO remains unmitigated to the maximum bomb penetration depth.

11.4 The Likelihood that Ordnance may be Encountered during the Works

The most likely scenarios under which a UXO could be encountered during construction works is during piling, drilling operations or bulk excavations for basement levels. The overall risk will depend on the extent of the works, such as the numbers of boreholes/piles (if required) and the volume of the excavations.

Since an air-dropped bomb may come to rest at any depth between just below ground level and its approximate penetration depth there is also a chance that such an item could be encountered during shallow excavations (for services or site investigations) into the original WWII ground level.

If the proposed works are due to be undertaken within post war fill material / made ground, the risk of encountering WWII UXBs is low. However, if works are to be undertaken below WWII ground level this risk is significantly higher.

11.5 The Risk that Ordnance may be Initiated

Items of ordnance do not become inert or lose their effectiveness with age. Time can indeed cause items to become more sensitive and less stable. This applies equally to items submerged in water or embedded in silts, clays or similar materials. The greatest risk occurs when an item of ordnance is struck or interfered with. This is likely to occur when mechanical equipment is used or when unqualified personnel pick up munitions.

11.5.1 Initiation of Unexploded Bombs

In the case of unexploded German bombs discovered within the construction site environment, there are a number of potential initiation mechanisms:

- Direct impact onto the main body of the bomb: Unless the fuze or fuze pocket is struck, there needs to be a significant impact to initiate a buried iron bomb.
- Re-starting the clock timer in the fuze: Only a small proportion of German WWII bombs employed clockwork fuzes. It is probable that significant corrosion has taken place within the fuze mechanism over the last 60 years that would prevent clockwork mechanisms from functioning, nevertheless it was reported that the fuze in a UXB dealt with by 33 EOD Regiment in Surrey in 2002 did re-commence.
- Induction of a static charge, causing a current in an electric fuze: The majority of German WWII bombs employed electric fuzes. It is probable that significant corrosion has taken place within the fuze mechanism over the last 60 years such that the fuze circuit could not be activated.
- Friction impact initiating the (shock-sensitive) fuze explosive: This is the most likely scenario resulting in the bomb detonating.

11.5.2 Activities that may Result in the Initiation of Unexploded Ordnance

Unexploded bombs do not spontaneously explode. All high explosive requires significant energy to create the conditions for detonation to occur. The risk that UXO could be initiated if encountered will depend on its condition, how it is found and the energy with which it is struck. However certain activities pose a greater risk than others.

The most violent activity on most construction sites is percussive piling or deep mechanical excavations. If an item is struck with a significant enough impact, be it direct or through friction/vibration, it risks detonation. Drilling of boreholes or similar activities also have the potential to initiate ordnance in this manner, either through impact or vibration.

Soil levelling and shallow excavation such as trial pits can pose a similar risk, since UXO can be found at any depth between ground level and the maximum bomb penetration depth. In addition to risk of initiation by violent impact or vibration, detonation can also occur if discovered items are mishandled by unqualified personnel. This is particularly common when onsite personnel are not trained in the recognition of ordnance.

For works that are not intrusive, little risk is posed by items of UXO that are buried beneath the ground. However, risk can arise from unburied munitions, particularly items of ordnance discarded in periphery areas of military sites. These items are frequently discovered by onsite personnel and remain live and liable to activate if mishandled.

11.6 The Consequences of Encountering or Initiating Ordnance

Clearly the consequences of an inadvertent detonation of UXO during construction operations would be catastrophic with a serious risk to life, damage to plant and a total site shutdown during follow-up investigations.

Since the risk of initiating ordnance is significantly reduced if appropriate mitigation measures are undertaken, the most important consequence of the discovery of ordnance will be economic. This would be particularly so in the case of high-profile locations and could involve the evacuation of the public.

The unexpected discovery of ordnance may require the closing of the site for any time between a few hours and a week with a potentially significant cost in lost time. Note also that the suspected find of ordnance, if handled solely through the authorities, may also involve loss of production since the first action of the Police in most cases will be to isolate the locale whilst awaiting military assistance, even if this turns out to have been unnecessary.

Annex L-1 details UXB incidents where intrusive works have caused UXBs to detonate, resulting in death or injury and damage to plant. Whilst these recent incidents occurred internationally, there is still reason to believe that such incidents are possible in the UK without the implementation of suitable risk mitigation measures. **Annex L-2** details incidents on construction sites in the UK, at which delays, site shut-downs, evacuations and disruptions have occurred.

11.7 SafeLane Global's Assessment

Taking into consideration the findings of this study, SafeLane Global considers the UXO risk at the site to be **Medium**.

	Level of Risk		
Type of Ordnance	**Low**	**Medium**	**High**
German High Explosive Bombs	✓		
German 1kg Incendiary Bombs	✓		
Allied Anti-Aircraft Shells	✓		
British / Allied Small Arms and Land Service Ammunition		✓	

12 Proposed Risk Mitigation Strategy

SafeLane Global recommends the following minimum risk mitigation measures be deployed to support the proposed ground works at the site:

Scope-Specific Recommended Risk Mitigation Measures

Site Specific Explosive Ordnance Safety and Awareness Briefings (UXO Toolbox Briefing) to all personnel conducting intrusive works These briefings are intended to make site operatives aware of the nature of explosive ordnance that may be encountered on their project site. • Delivered by a specialist Explosive Ordnance Disposal Engineer. • Provides information on the site-specific explosive ordnance risk • Basic ordnance identification. • What to do in the event of an encounter with a suspicious object. • Provide UXO response procedures.	✓
Site Specific Safety Instruction (SSSI) For longer term projects that require Explosive Ordnance Safety and Awareness Briefings as part of the Explosive Ordnance Risk Mitigation measures for the project, SSSIs can be provided to allow nominated site representatives to deliver these briefings after initial training. • 2/3-hour presentation and training course. • Delivered by a fully qualified senior EOD Engineer. • Suitable for Project Site Manager HSE representative and supervisors. • Includes briefing pack. This provides a cost-effective solution to ensure that the Explosive Ordnance Safety and Awareness Briefings can be delivered effectively and efficiently to the required standard.	✓
Explosive Ordnance Disposal (EOD) Engineer On-Site Support In areas where the risk posed by the potential presence of explosive ordnance is low or where the conditions are not suitable for pro-active survey, EOD On-Site Support can provide a reactive response to any suspicious object that may be encountered during open excavation works. The presence of the EOD Engineer (sometimes referred to as 'high risk dig wardens') on-site in support of shallow intrusive work allows for a direct monitoring of works using visual recognition and instrumentation and provides an immediate response to reports of suspicious objects or suspected items of ordnance that have been recovered by ground workers. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings (UXO TBB) to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential incident management which would involve liaison with the local authorities and police should ordnance that presents an explosive hazard be identified. • Specialist Explosive Ordnance Disposal Engineer.	✓

• Maintains a watching brief over all excavations. • Provides safety and awareness briefings to construction personnel as required. • Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. • Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO.	
Explosive Ordnance Disposal (EOD) Engineer to support site investigation works For cost effective Explosive Ordnance Risk Mitigation for site investigation work, the EOD Engineer can survey ahead of trial pits, monitor excavations when the ground conditions are not suitable for a pro-active survey and conduct intrusive surveys for borehole and window sample locations working in conjunction with the site investigation team. The On-Site Support will also provide a reactive response to any suspicious object that may be encountered during open excavation works. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential Incident Management which would involve liaison with the local authorities and police should ordnance be identified and present an explosive hazard. • Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all trial pit excavations. • Provides safety and awareness briefings to construction personnel as required. • Works in conjunction with the drilling team to survey all borehole and window sample locations in real-time using a staged drilling and magnetometer survey procedure. • Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. • Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO. *Technical Information* 1. In optimum ground conditions each survey using the borehole technique will have a 1 metre look ahead capability.	✓

2. Any steel casing used for borehole surveys will need to be retracted by 3 metres to allow the magnetometer survey to be conducted. 3. Non-ferrous pipe will be required to support the borehole during the survey minimum diameter 60mm (to be supplied by the client).	
Search & Clear Where a non-intrusive magnetometer survey is not possible (e.g. wooded areas) SafeLane Global can deploy a two-man Explosive Ordnance Disposal Engineer team using handheld magnetometer equipment who will proactively survey either in search lanes or boxes, investigating each reading with the support of an operated excavator. The survey is suited to detecting suspicious ferro-magnetic buried objects that may be munitions and/or explosive ordnance related. All SafeLane Global personnel involved with the Search and Clearance Works will be former military personnel who have gained formal NATO Military Explosive Ordnance Disposal Qualifications, having completed training at the Defence Explosive Ordnance Disposal School (DEODS) Chattenden, Kent or similar establishment throughout their military service. The client will be responsible for: • Demarcating the areas to be searched. • Providing services clearance and permit to dig. • Providing operated excavator to access deeper targets if required (SafeLane Global can provide this service at additional cost). • Providing coordinates of positions where debris have been identified (if information required in report). • Providing storage for recovered debris. • Output will depend upon terrain and contamination (number of readings to be investigated).	✓
Non-Intrusive Magnetometer Survey and Target Investigation (greenfield land only) **Non-Intrusive Survey** This survey type is designed for use on magnetically 'clean' land commonly referred to as 'greenfield'. Brownfield land is often described as that which has had previous industrial or commercial use. In this context it specifically encompasses sites with are underlain by 'made ground' which may contain metallic contamination. Non-intrusive magnetometry or electromagnetic equipment which is used in the search for buried UXO relies upon the detection of small changes between clear ground and that containing UXO. The technique operates very successfully in environments where there is minimal ground contamination from other sources such as fired bricks, reinforced concrete, discarded scrap metal and buried services. There are also man-made ambient effects on magnetic and electromagnetic non-intrusive survey systems which include moving plant vehicles, power cables, electric trains etc.	✓

Non-Intrusive survey is carried out using either total-field or gradiometer magnetometry, dependent upon site conditions. Data is recorded and then interpreted using advanced AGSPRoc software in order to map magnetic fields and model discrete magnetic anomalies (variations in the Earth's magnetic field caused by ferro-magnetic objects electrical fields or geology). The location of such anomalies is determined, and mathematical modelling used to estimate their mass and depth. The survey will also locate any buried services with a magnetic signature and indicate any areas of gross magnetic "contamination" which may indicate the presence of unknown obstructions. Additionally, the survey can provide information on archaeological features. The system can detect the magnetic field from a 50kg WWII air-dropped bomb at a depth of 4m and smaller items such as Land Service Ammunition to depths of up to 1.5m in ground with a low ambient magnetic field. In the case of soft geology, it should be noted that a 50kg high explosive bomb may be buried greater than 4 metres below ground level and therefore may not be detected by the survey. In this instance intrusive surveys may be required. The non-intrusive survey system will be deployed utilising the pedestrian survey frame. The output for the pedestrian frame is estimated at up to 2Ha per day. *Technical information;* • Client to clearly demarcate area to be surveyed prior to start and highlight any known services/underground obstructions. • Ground must be level, free of obstacles / obstructions and clear of undergrowth. Height of any crops should be no more than 400mm and where crops are present SafeLane Global would require written approval from the landowner or client to walk over the site area. • When working adjacent to existing infrastructure the survey may be ineffective due to the ferro magnetic interference caused by passing vehicles and the presence of underground buried services. A site visit may be recommended prior to commencement. • Note: the survey will be ineffective on Brownfield sites due to the magnetic nature of building rubble, which typically masks the weaker magnetic signatures of buried objects. If parts of the site are contaminated, then alternative risk mitigation measures may need to be considered. **Target Investigation** If a buried anomaly is detected that cannot be discounted as a potential UXO / UXB then the object will need to be investigated to positively identify the item. The process will include: • Specialist two-man Explosive Ordnance Disposal Team. • Combination of manual and mechanical excavation techniques. • Excavator shafting, shoring and dewatering equipment can be provided by SafeLane Global if required. • Excavation techniques will be defined and agreed prior to the commence. • A factual report with clearance certificate will be issued on completion of the investigation.	

Intrusive Magnetometer Survey of all pile locations down to the maximum bomb penetration depth SafeLane Global can deploy a range of intrusive magnetometry techniques to clear ahead of all the pile locations. The appropriate technique is governed by a number of factors, but most importantly the site's ground conditions. The appropriate survey methodology would be confirmed once the enabling works have been completed. A site meeting would be required between SafeLane Global and the client to determine the methodology suitable for this site. Target investigation or avoidance will be recommended as appropriate.	✘
In making this assessment and recommending these risk mitigation measures, the proposed works outlined in the 'Scope of the Proposed Works' section were considered. Should the planned works be modified, or additional intrusive engineering works be considered, SafeLane Global should be consulted to see if re-assessment of the risk or mitigation recommendations is necessary.	

SafeLane Global 2nd April 2020

Bibliography

The key sources consulted during this assessment are listed below;

Bates, H, E., *Flying Bombs over England,* (Frogletts Publications Ltd. 1994).

Dobinson, C., *AA Command: Britain's Anti-Aircraft Defences of the Second World War*, (Methuen 2001).

Fegan, T., *The Baby Killers': German Air raids on Britain in the First World War,* (Leo Cooper Ltd. 2002).

Fleischer, W., *German Air-Dropped Weapons to 1945,* (Midland Publishing. 2004).

Jappy, M. J., *Danger UXB: The Remarkable Story of the Disposal of Unexploded Bombs during the Second World War*, (Channel 4 Books, 2001).

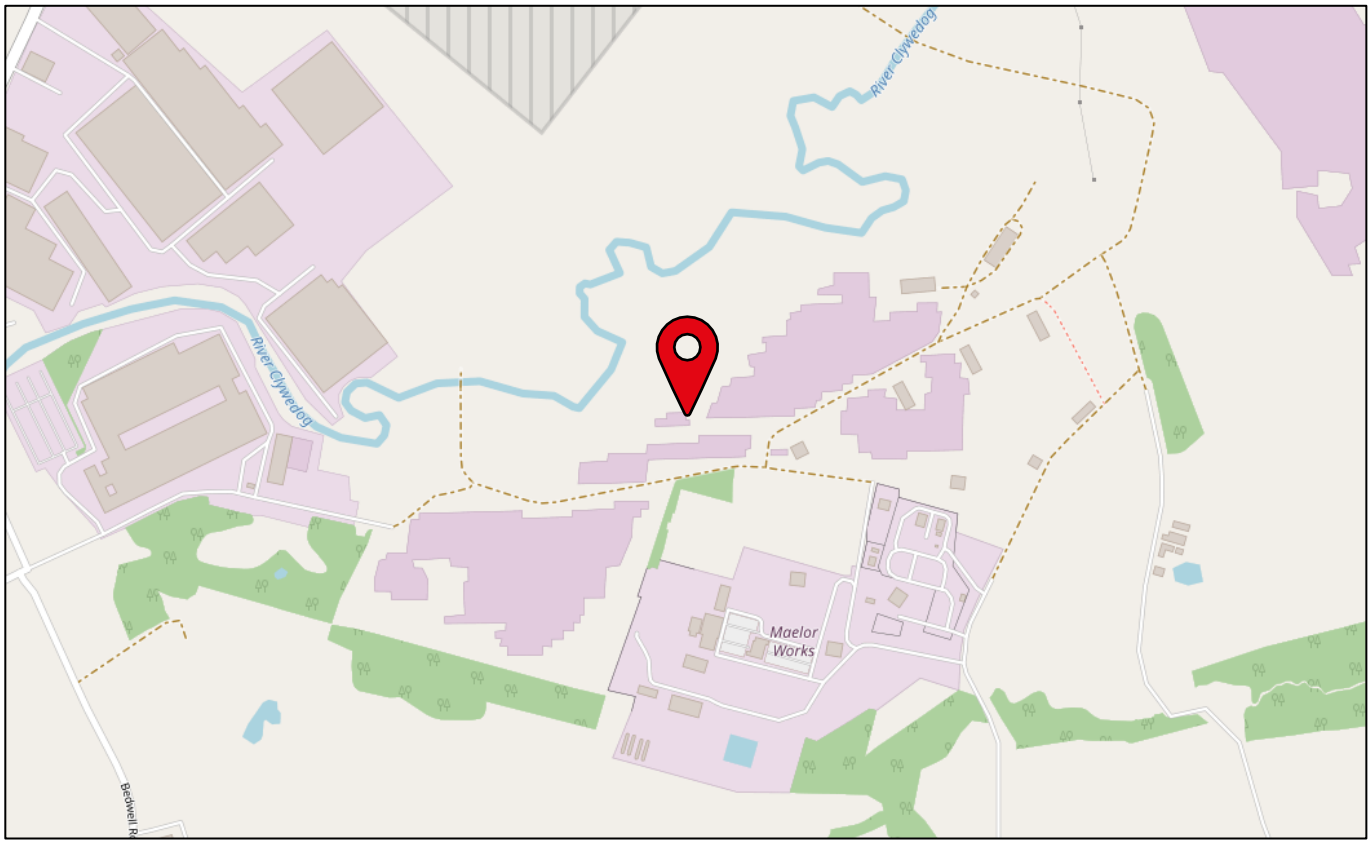
Price, A., *Blitz on Britain, The Bomber Attacks on the United Kingdom 1939 – 1945*, (Purnell Book Services Ltd. 1977).

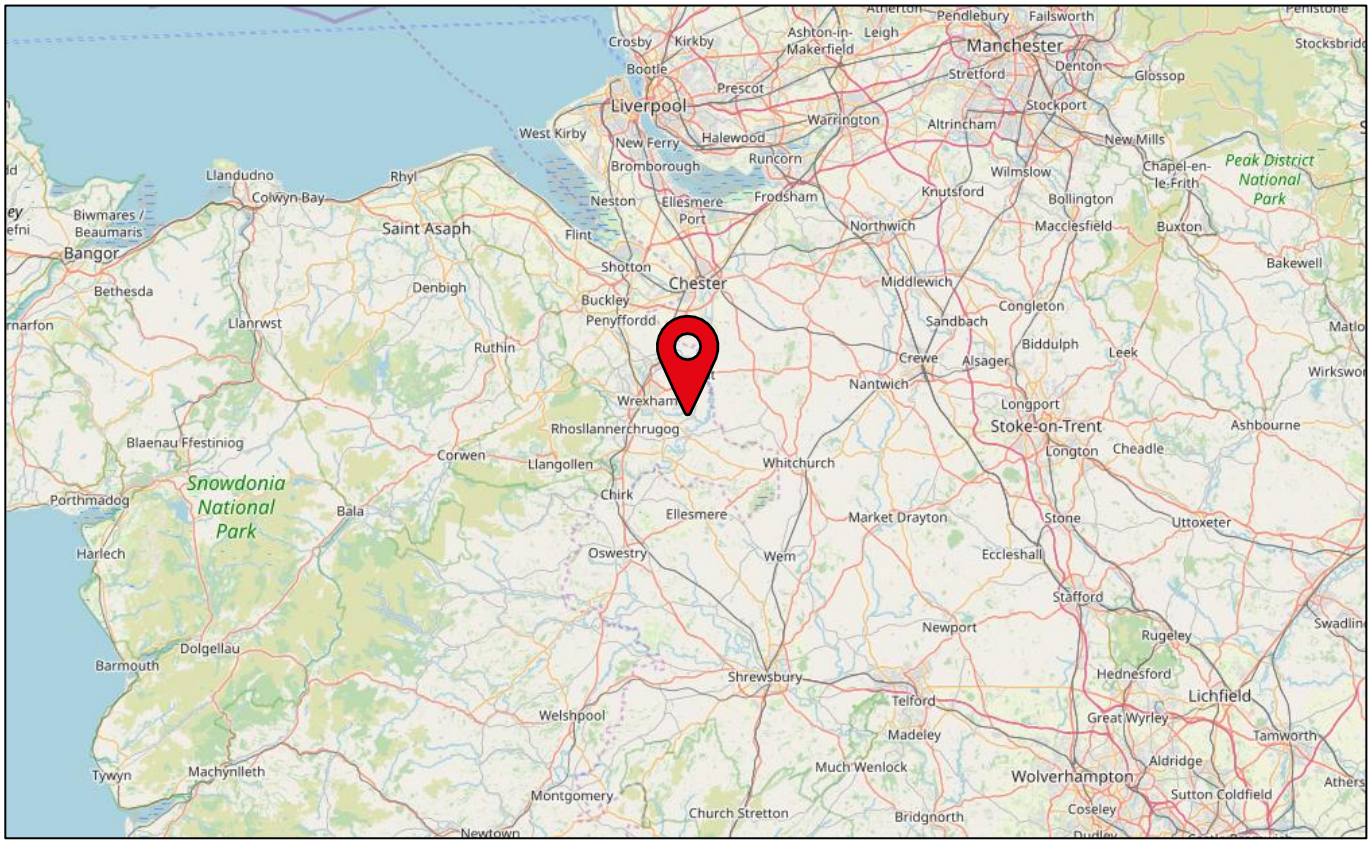
Ramsey, W., *The Blitz Then and Now, Volume 1*, (Battle of Britain Prints International Limited. 1987).

Ramsey, W., *The Blitz Then and Now, Volume 2*, (Battle of Britain Prints International Limited. 1988).

Ramsey, W., *The Blitz Then and Now, Volume 3*, (Battle of Britain Prints International Limited. 1990).

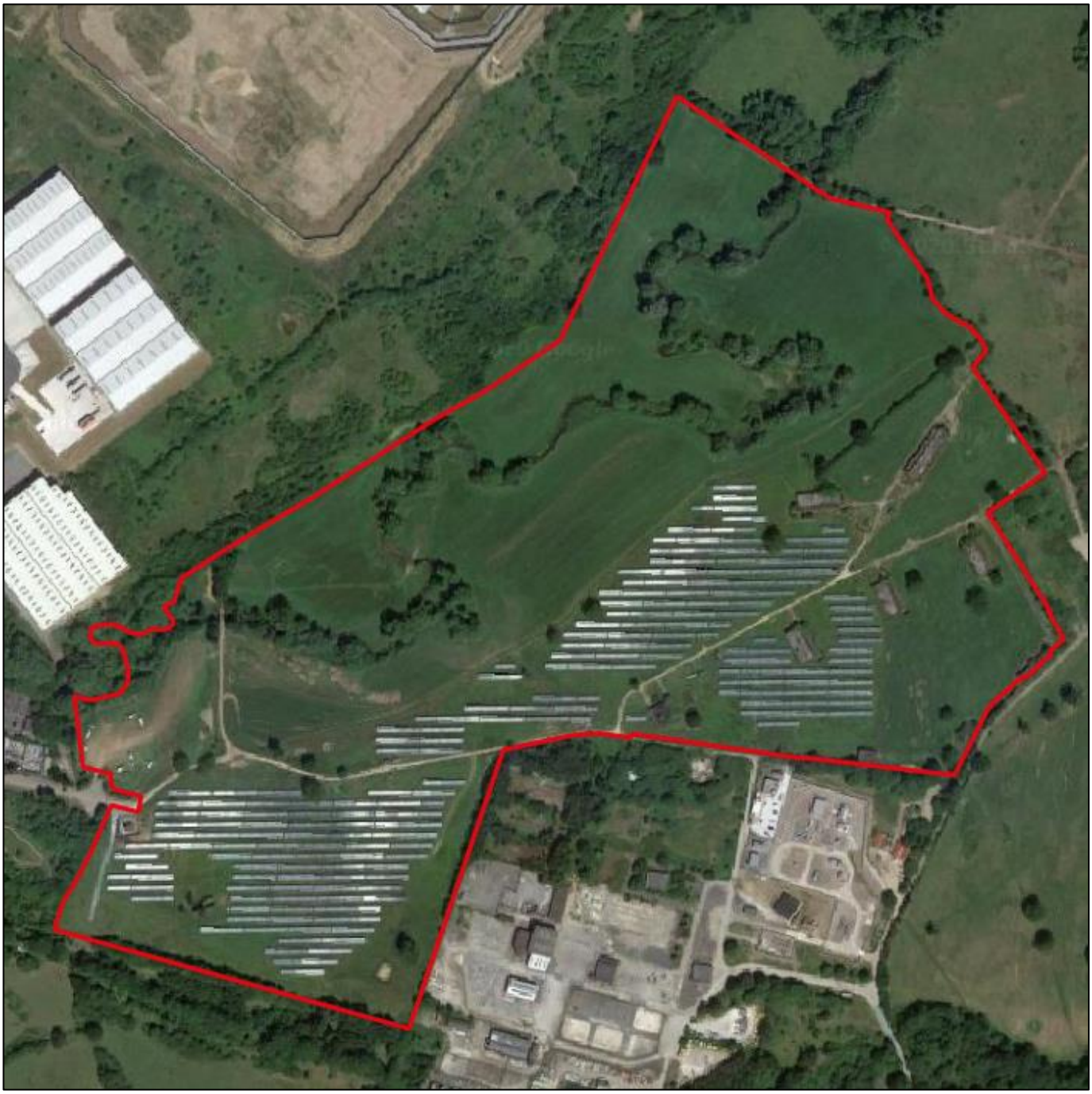
Whiting, C., *Britain Under Fire: The Bombing of Britain's Cities 1940-1945,* (Pen & Sword Books Ltd. 1999).



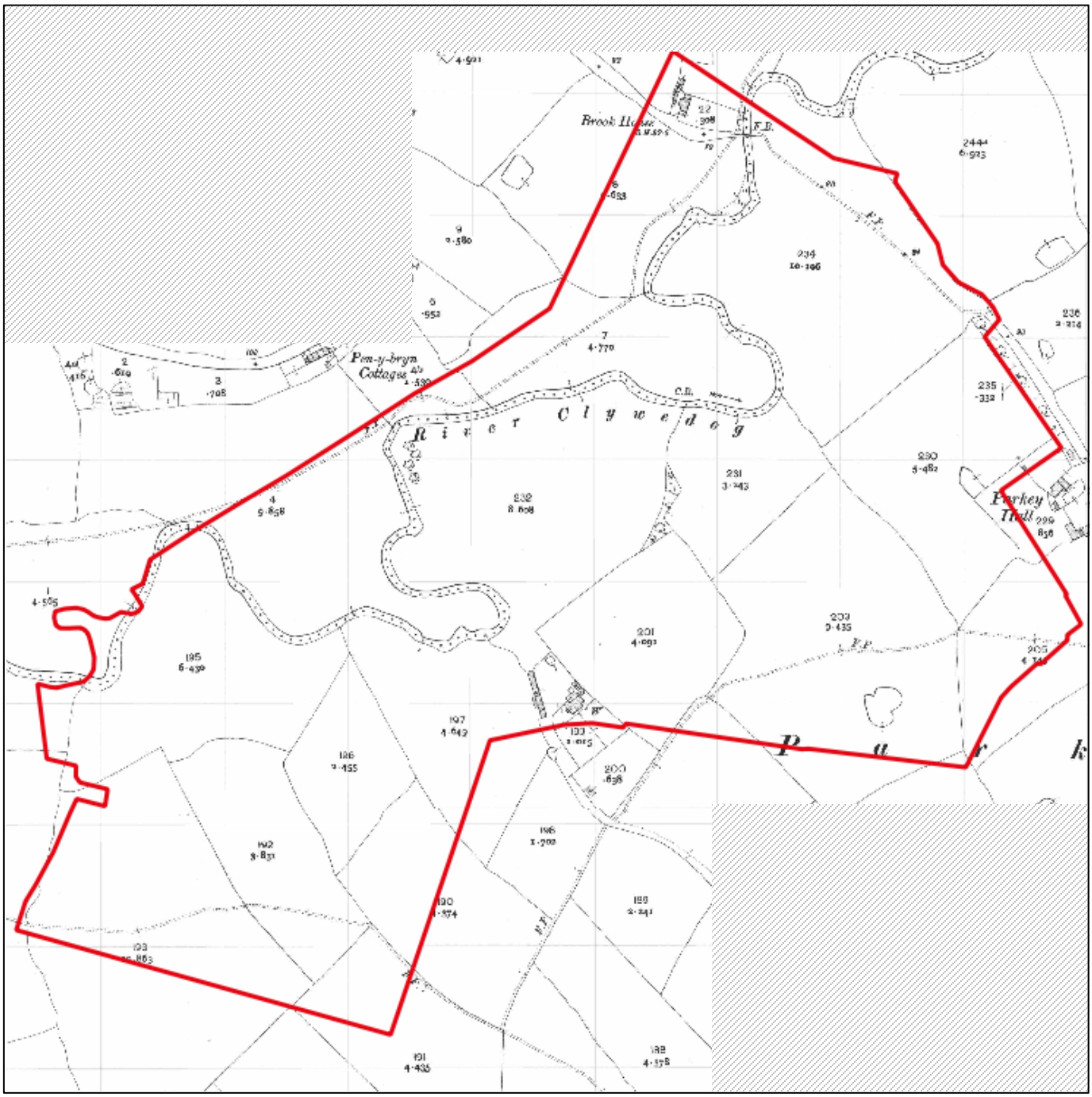


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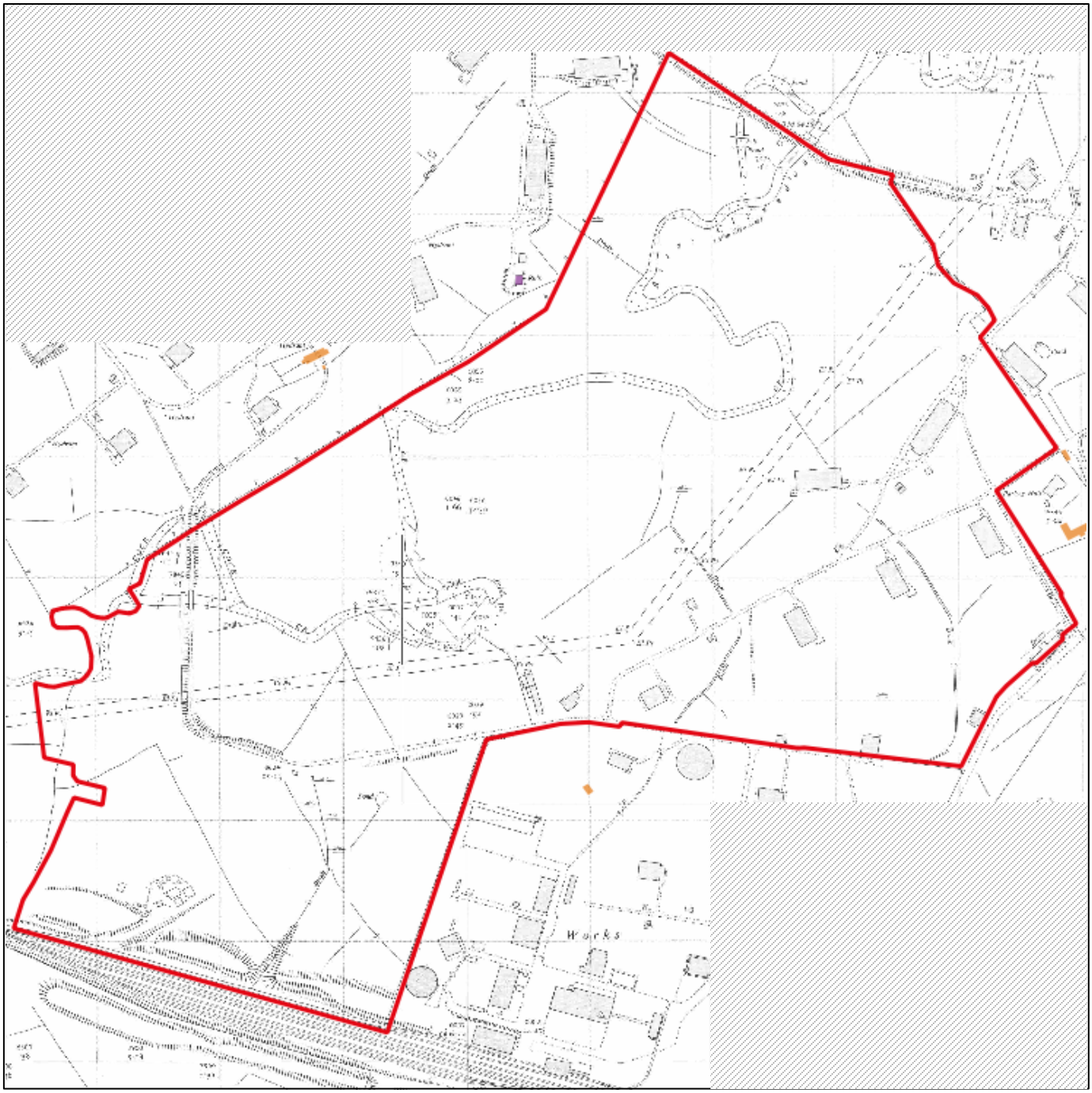
N



Approximate site boundary


N
Brook House
Pen-y-bryn Cottages
River Clywedog
Parkey Hall
Approximate site boundary
No data

N



Approximate site boundary
Clearance
Ruins
No data

Most Commonly Deployed German HE Bombs

SC 50

Bomb Weight: 40-54kg (110-119lb)

Explosive Weight: c25kg (55lb)

Fuze Type: Impact fuze/electro-mechanical time delay fuze

Bomb Dimensions: 1,090 x 280mm (42.9 x 11.0in)

Body Diameter: 200mm (7.87in)

Use: Against lightly damageable materials, hangars, railway rolling stock, ammunition depots, light bridges and buildings up to three stories.

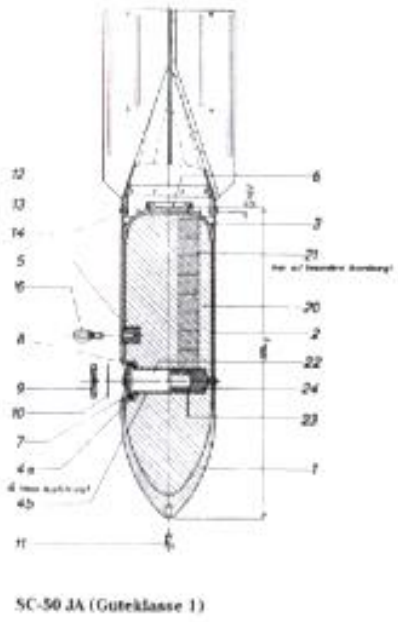
Remarks: The smallest and most common conventional German bomb. Nearly 70% of bombs dropped on the UK were 50kg.



50kg bomb, London Docklands



50kg bomb, minus tail section



SC-50 JA (Güteklasse 1)

SC 250

Bomb weight: 245-256kg (540-564lb)

Explosive weight:125-130kg (276-287lb)

Fuze type: Electrical impact/mechanical time delay fuze.

Bomb dimensions: 1640 x 512mm (64.57 x 20.16in)

Body diameter: 368mm (14.5in)

Use: Against railway installations, embankments, flyovers, underpasses, large buildings and below-ground installations.



250kg bomb, Hawkinge



SC250 attached to undercarriage of Messerschmitt Bf109



SC 250 JA (Güteklasse I)

SafeLane Global and various historical sources

1kg Incendiary Bomb

Bomb weight: 1.0 and 1.3kg (2.2 and 2.87lb)

Filling: 680gm (1.3lb) Thermite

Fuze type: Impact fuze

Bomb dimensions: 350 x 50mm (13.8 x 1.97in)

Body diameter: 50mm (1.97in)

Use: As incendiary – dropped in clusters against towns and industrial complexes

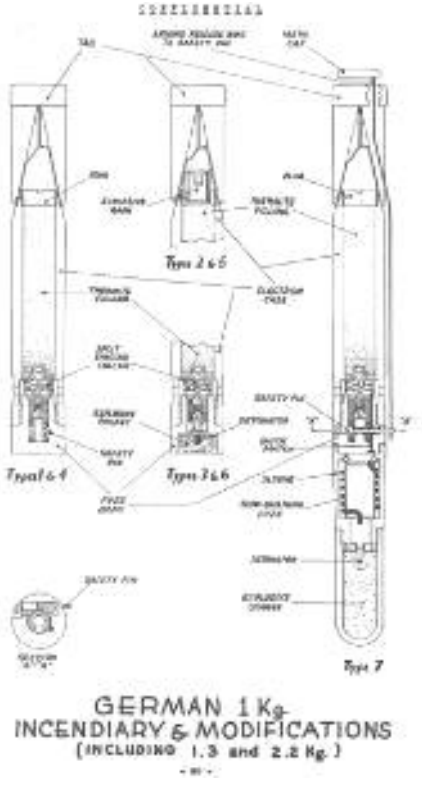
Remarks: Jettisoned from air-dropped containers. Magnesium alloy case. Sometimes fitted with high explosive charge







1. Ordinary scaffold pipe
2. 1kg incendiary bomb
3. Incendiary bomb recently found on site in UK





1kg German Incendiary Bomb next to a 30cm ruler

SafeLane Global and various historical sources

EveningStandard.

Pictured: Unexploded World War II bomb found in Brondesbury Park



EveningStandard.

Bomb disposal expert reveals dramatic details of how huge WW2 bomb found in Thames was detonated



BBC NEWS

Kingston University campus evacuated over 'WW2 bomb'



The Telegraph

Giant WWII bomb dug up by builders in London



Mail Online

Hundreds of people evacuated after a massive WWII bomb was found in the grounds of a Bath school face a weekend away from their homes



Top Left: 500lb UXB found in Brondesbury Park, London – March 2017.
Bottom Left: UXB discovered in the Thames near the Houses of Parliament – February 2017.
Top Right: The discovery of a 250kg UXB near Kingston University resulted in the closure of the University and nearby homes – May 2019
Middle Right: A 400m cordon was established after a 1,000lb UXB was found in Grange Walk, Bermondsey – March 2015
Bottom Right: 500lb UXB discovered in Lansdown, Bath – May 2016

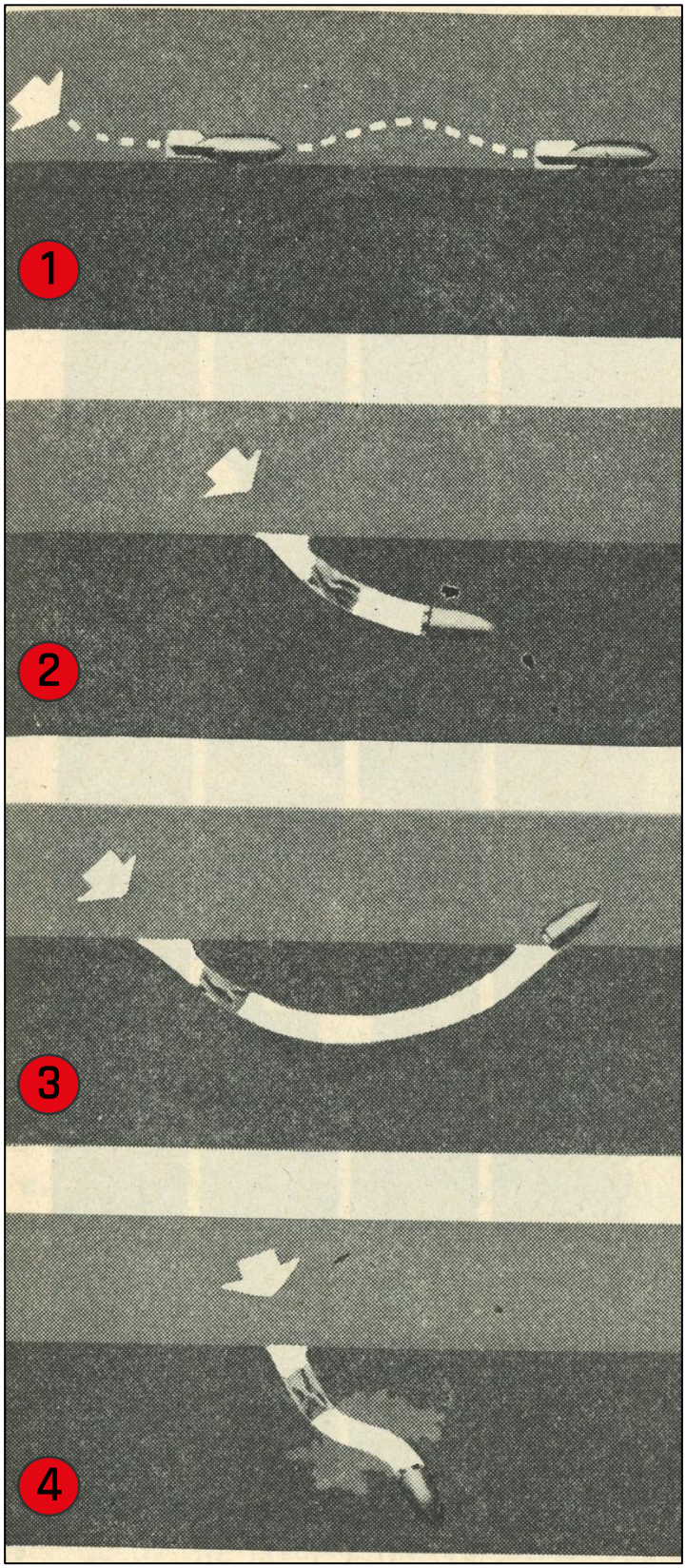
Path of UXB in soft ground

1. **Ricochet resulting from low level attack:** UXB stays perpendicular to ground and rests at surface.

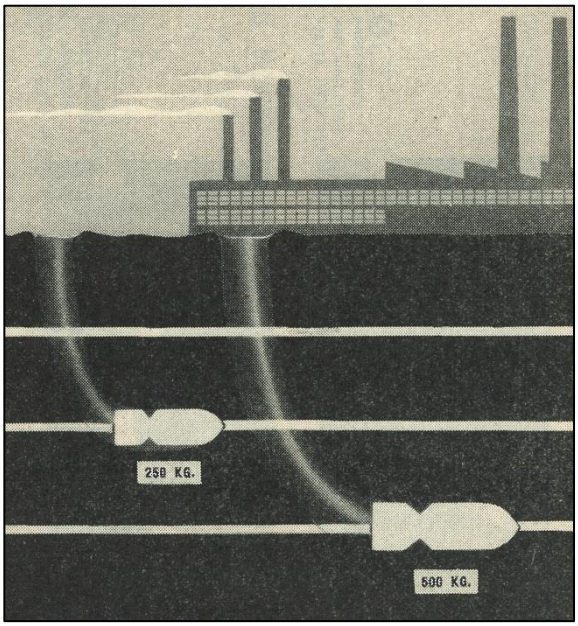
2. **Buried UXB with J-Curve:** Bomb curves horizontally and rests perpendicular to surface.

3. **UXB returning to surface due to J-Curve:** Bomb points towards surface but may remain partially or completely below ground level.

4. **UXB deflected by buried objects:** Results in unpredictable path and unusual shaft.



Below: UXB can come to rest beneath undamaged buildings due to the J-Curve effect if it lands in nearby soft ground.



Field Manual for Unexploded Bombs: Organisation and Operation For Disposal, United States War Department 1943

WWII-era RAF Aerial Photography – 2nd April 1946

N



Approximate site boundary

ROF Wrexham

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23 July 2010 Last updated at 18:28

Covert British troops 'could have buried' WWII devices

World War II incendiary devices found on a building site in Gloucestershire could have been left by covert British troops, according to researchers.



The bombs were put into vats of water to make them safe

More than 20 phosphorus bombs were unearthed in Birdlip after a digger hit one, causing it to burst into flames.

A former worker at the site said he saw a Home Guard officer burying objects there 65 years ago.

The Coleshill Auxiliary Research Team said auxiliary officers often used Home Guard uniforms as cover.

Thursday, September 10 2015

KM KentOnline
The UK's fastest-growing regional news network

Army bomb disposal team called to Blacksole Bridge in Herne Bay

Comments | 3

by Aidan Barlow abarlow@thekmgroup.co.uk 08 July 2015

It was like a scene from Dad's Army when Army bomb disposal experts found wartime explosives made by the Home Guard in makeshift bottles.

A team was called to the Blacksole Bridge in Herne Bay after the wartime bombs were found.

The team from the Royal Logistics Corps set up a 30 metre exclusion zone for pedestrians around the railway embankment after the suspected homemade phosphorous bombs were found.



EAST ANGLIAN DAILY TIMES

WATCH: Bomb squad detonate 24 Second World War grenades found buried in Suffolk field

Adam Howlett adam.howlett@archant.co.uk @EADTadam
PUBLISHED: 12:08 28 May 2019 | **UPDATED:** 13:39 28 May 2019



SIP Grenades were discovered and detonated in Sibton by British Army Bomb Disposal Experts, Suffolk Police and Suffolk Fire & Rescue Picture: SUFFOLK FIRE & RESCUE SERVICE

The bomb squad safely detonated dozens of incendiary grenades found buried in a field in Sibton near Saxmundham on Bank Holiday Monday.

Eastbourne Herald

10/09/15 | 11°C to 21°C Sunny | Like us | Follow us | Place your Ad | Subscribe

VIDEO: Explosion after 80 grenades detonated in Eastbourne



Marked 'AW Bomb 1940' the grenades were thought to have been phosphorus incendiary grenades created as improvised anti-tank weapons when Britain was facing invasion following the army's evacuation from Dunkirk in 1940.

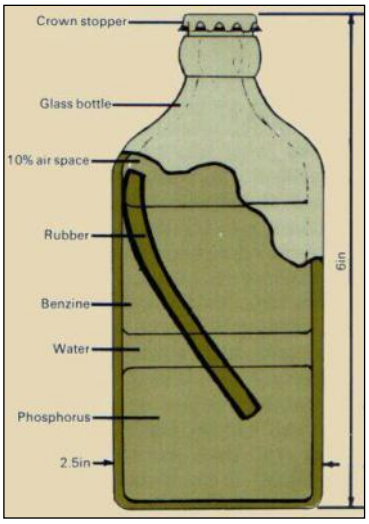
He said, "I remember the grenades being buried. It was part of the Home Guard stash, it was put there in case we were invaded. It had to be in 1943. There were a lot of them [stashes], they were all over the place."

Self Igniting Phosphorous (SIP) Grenades

The grenade comprised a glass bottle with a total volume of approximately one pint. It was filled with White Phosphorus, benzene, a piece of rubber and water. Over time the rubber dissolved to create a sticky fluid which would self ignite when the bottle broke. Fired by hand or Northover Projector. Sometimes called the "A & W" (Albright & Wilson) grenade.





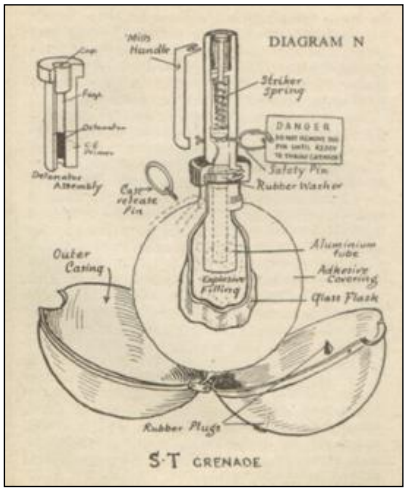


No 74 Grenade (Sticky Bomb)

Designed as an anti-tank grenade and used by the Home Guard. The grenade consisted of a glass ball on the end of a Bakelite (plastic) handle. Inside the glass ball was an explosive filling whilst on the outside was a very sticky adhesive covering. Until used, this adhesive covering was encased in a metal outer casing.



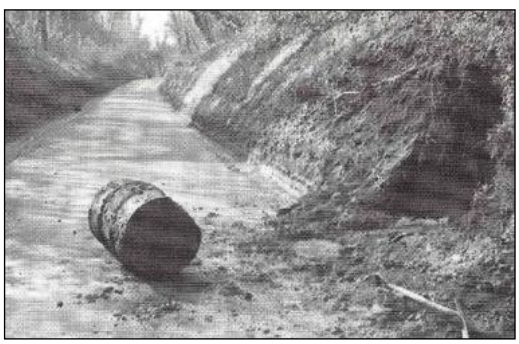


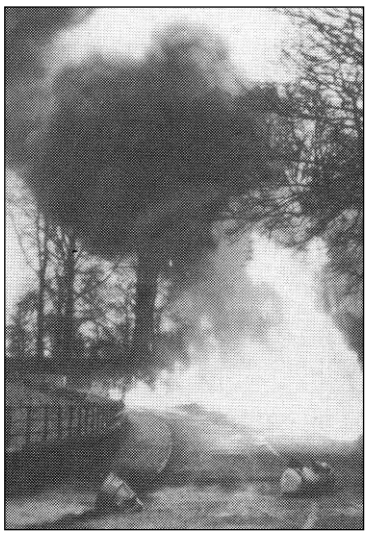


Flame Fougasse Bomb

A Flame Fougasse was a weapon in which the projectile was a flammable liquid, typically a mixture of petrol and oil. It was usually constructed from a 40-gallon drum dug into the roadside and camouflaged. Ammonal provided the propellant charge which, when triggered, caused the weapon to shoot a flame 3m (10ft) wide and 27m (30 yards) long. Initially a mixture of 40% petrol and 60% gas oil was used, this was later replaced by an adhesive gel of tar, lime and petrol known as 5B.



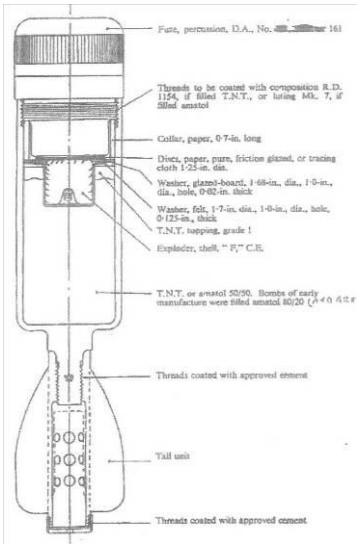




Typical 2 inch High Explosive Mortar

Bomb Weight:	1.02kg (2.25lb)
Type:	High Explosive
Dimensions:	51 x 290mm (2in x 11.4in)
Filling:	200g RDX/TNT
Maximum Range:	457m (500yds)
Remarks:	Fitted with an impact fuze which detonates the fuze booster charge (exploder) and, in turn, the high explosive charge. The main charge shatters the mortar bomb body, producing near optimum fragmentation and blast effect at the target.





Typical 3 inch Smoke Mortar

Type:	Smoke
Dimensions:	c490 x 76mm (19.3in x 3in)
Filling:	Typically white phosphorous
Maximum Range:	2515m (2,750yds)
Remarks:	On impact, the fuze functions and initiates the bursting charge. The bursting charge ruptures the mortar bomb body and disperses the white phosphorous filler. The white phosphorous produces smoke upon exposure to the air.

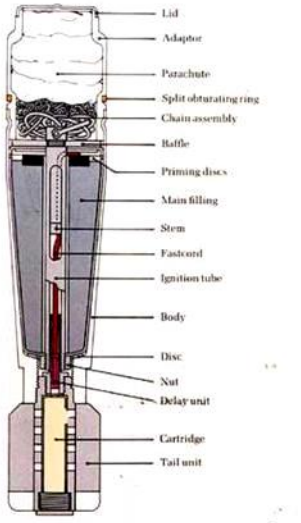




Typical 2 inch Illuminating Mortar

Type:	Illum.
Dimensions:	51 x 290mm
Filling:	Various
Remarks:	The expulsion charge ignites and ejects the candle assembly. A spring ejects the parachute from the tail cone. The parachute opens, slowing the descent of the burning candle which illuminates the target.



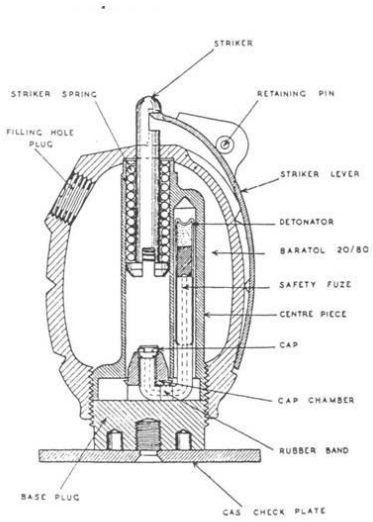


SafeLane Global and various historical sources

No. 36 'Mills' Grenade

Weight:	0.7kg filled (1lb 6oz)
Type:	Hand or discharger, fragmentation
Dimensions:	95 x 61mm (3.7 x 2.4in)
Filling:	Alumatol, Amatol 2 or TNT
Remarks:	4 second hand-throwing fuse with approximate 30m range. First introduced May 1918.





Grenade, .303 inch rifle, No. 36M, Mark I.

No. 69 Grenade

Weight:	0.38kg filled (0.8lb)
Type:	Percussion/Blast
Date Introduced:	December 1940
Remarks:	Black Bakelite body. Blast rather than fragmentation type. After unscrewing the safety cap, a tape is held when throwing the grenade releasing the safety bolt in the throwing motion. Detection is problematic due to its very low metal content.

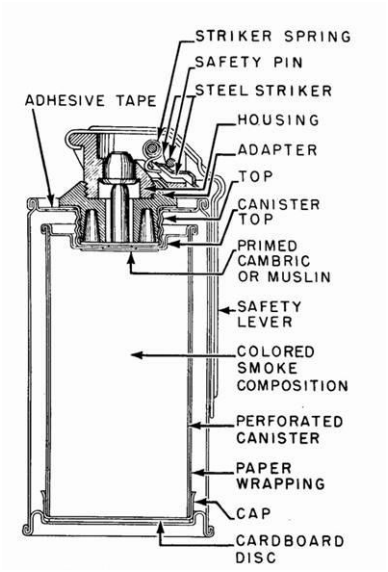




Typical Smoke Grenade

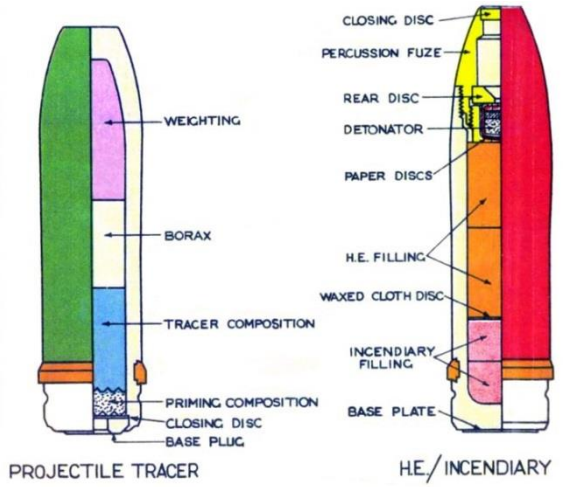
Dimensions:	Approx. 65 x 115mm (2.5 x 4.5in)
Type:	Smoke
Date Introduced:	Current MoD issue
Remarks:	Smoke grenades are used as ground-to-ground or ground-to-air signalling devices,
target	or landing zone marking devices, and screening devices for unit movement.

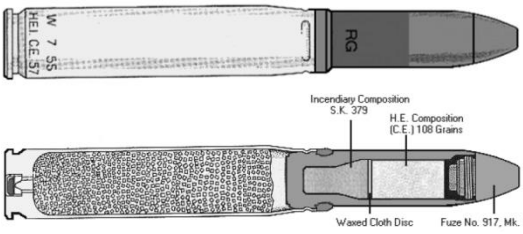




20mm Hispano HEI Ammunition

Type:	Live cannon round
Markings:	Upper half of projectile painted 'buff' colour, lower half is red.
Cartridge Weight:	256 grams
Dimensions:	Total cartridge / projectile length - 182mm
Fuzed:	Contact fuze – No.253, No.254 or No.917
Filling:	108 grains of contact explosive + 68 grains of SR.379 incendiary composition.
Threat:	Explosives within unspent cartridge as well as the projectile.
Deployment:	Royal Navy, RAF and British Army Light Anti- Aircraft guns. Also RAF aircraft canons.
Remarks:	Cartridges are belted or supplied lose in cartons.







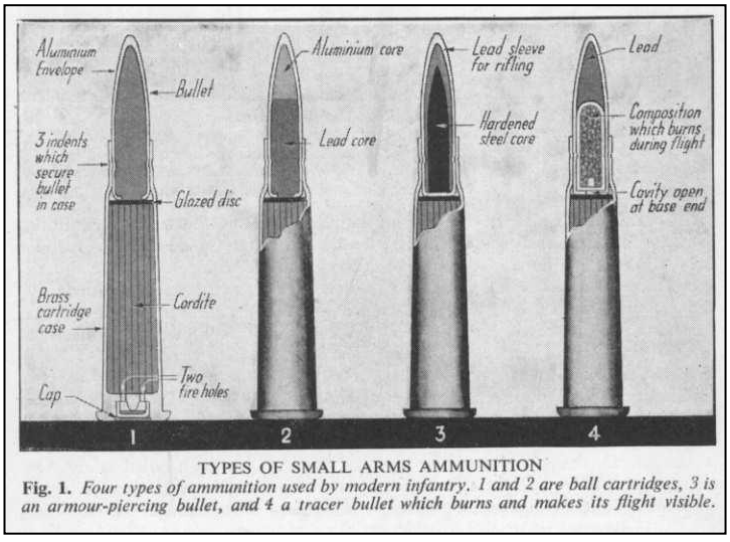
COLOUR IDENTIFICATION		
BRITISH		
NATURE OF SHELL	H.E.FILLING	COLOUR
H.E. TRACER	T.N.T.	
H.E.	T.N.T.	
PROJ. PRACTICE		
PROJ. TRACER		
H.E. INCENDIARY	T.N.T.	
H.E.INCENDIARY TRACER	T.N.T.	

.303" Ammunition

Type:	Rifle / machine gun round
Markings:	Regular round - none. Tracer round – red Primer
Bullet Weight:	150 - 180 grams
Dimensions:	Total cartridge /projectile length - 78mm
Filling:	Regular round – none. Tracer round - small incendiary fill
Threat:	Explosive cordite within unspent cartridge
Deployment:	Royal Navy, RAF and British Army Light Anti-Aircraft guns, machine guns and rifles. Standard British and Commonwealth military cartridge from 1889 until the 1950s.
Remarks:	Cartridges are belted or supplied lose in cartons.







TYPES OF SMALL ARMS AMMUNITION

Fig. 1. *Four types of ammunition used by modern infantry. 1 and 2 are ball cartridges, 3 is an armour-piercing bullet, and 4 a tracer bullet which burns and makes its flight visible.*

3.7 inch Anti-Aircraft Projectile

Weight:	12.7kg (28lb)
Dimensions:	94 x 360mm (3.7 x 14.7in)
Carriage:	Mobile and Static Versions
Rate of Fire:	10-20 rounds per minute
Ceiling:	9-18,000m (29-59,000ft)
Muzzle Velocity:	792m/s (2,598ft/s)
Remarks:	4.5 inch projectiles were also commonly utilised



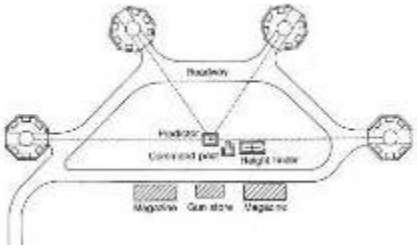
Hyde Park 1939 3.7 Inch QF gun on mobile mounting.



This AA shell was uncovered on a construction site in North London in February 2009.



3.7 inch AA Projectile, Minus Fuze.



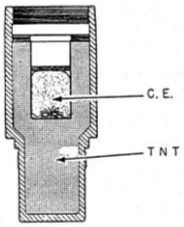
Layout plan for a typical HAA battery site.

Rockets / Un-rotating Projectiles

Weight:	Overall: 24.5kg (54lb)
Warhead::	1.94kg (4.28lb)
Dimensions:	1930mm x 82.6mm (76 x 3.25in)
Carriage:	Mobile – transported on trailers
Ceiling:	6770m (22,200ft)
Maximum Velocity:	457mps (1,500 fps)



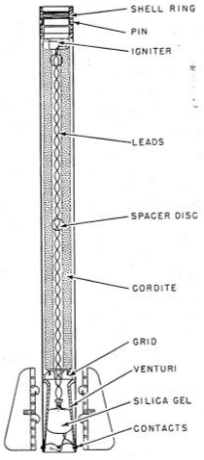
Rocket Battery in action.



MK II HE Shell (3.5kg).



Home Guard soldiers load an anti-aircraft rocket at a 'Z' Battery.



2" U.P AA Rocket.

40mm Bofors Gun Projectile

Weight:	0.86kg (1.96lb)
Dimensions:	40mm x 310mm (1.6in x 12.2in)
Rate of Fire:	120 rounds per minute
Ceiling:	23,000ft (7000m)
Muzzle Velocity:	2,890 ft/s (881m/s)
Remarks:	Mobile batteries – normally few records of where these guns were located



Unexploded 40mm Bofors projectile



40mm Bofors gun and crew at Stanmore in Middlesex, 28 June 1940.



SafeLane Global and various historical sources



RESCUE workers search for survivors after a Second World War bomb exploded at a building site in Berlin, killing three people and injuring at least eight others.

A fire brigade spokesman said he feared the final death toll could be higher. One worker was still missing, believed to be trapped under a machine. "We've found human remains 100 metres away but we can't tell if they belong to the dead already found," the spokesman said.

The blast, set off by drilling work on Frankfurter Allee, one of east Berlin's busiest avenues, trapped workers under building machinery and sent huge chunks of concrete tumbling through the air.

A large office block was being built on the site of the explosion which sent shoppers scrambling for shelter and paralysed dense afternoon traffic. One eyewitness said: "There was a bang, then silence, and then it started raining stones and dirt."

Dozens of cars within a 250-metre radius were wrecked and the top two floors of a nearby apartment block caved in.

Radio reports claimed that the total number of injured stood at 14.

Blown up by history

World War II bomb kills three in Germany

Three people have been killed and six injured trying to defuse a World War II bomb in central Germany.

Workers building a sports stadium had earlier unearthed the bomb in the town of Goettingen.

It was not immediately clear why the bomb, reportedly weighing 500kg (1,100lb), had detonated.





A World War Two bomb has exploded at a construction site near a west German town, killing a man and injuring eight others, police say.

The explosion occurred after a digger accidentally struck the device during excavation work in Euskirchen in the state of North Rhine-Westphalia.









I dead, 2 critical after explosion at Malaysia MRT construction site caused by WWII bomb

Top Left: WWII bomb killed 3 and injured 8 in Berlin – 1994.
Middle Left: WWII bomb killed 3 in Goettingen, Germany – 2010.
Bottom Left: Excavator operator killed by WWII bomb in Euskirchen, Germany – 2014.
Top Right: A highway construction worker in Germany accidentally struck a WWII bomb, killing himself and wrecking several passing cars – 2006.
Middle Right (Top) : Destroyed piling rig and dump truck after detonation of WWII UXB in Austria – 2006.
Middle Right (Bottom): WWII bomb injures 17 at construction site in Hattingen, Germany – 2008.
Bottom Right: A buried WWII-era bomb exploded during construction works in Bandar Malaysia, Kuala Lumpur – 2017.

Various News Sources

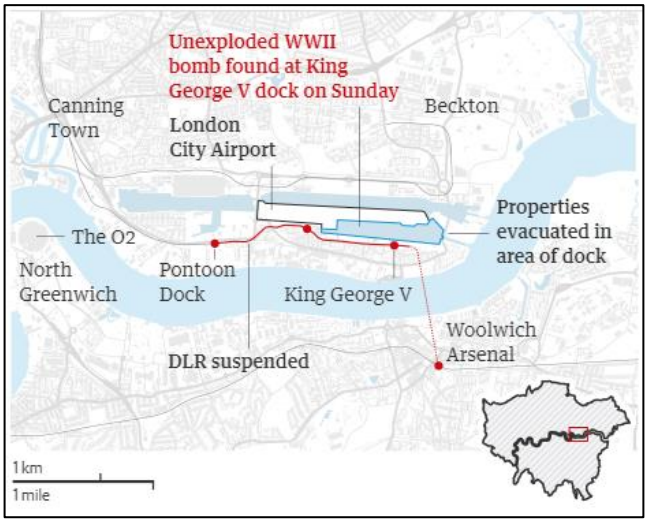
London City Airport shut: Flights cancelled after Second World War bomb found in River Thames dock

London City Airport has been closed after the discovery of an unexploded Second World War bomb, affecting tens of thousands of passengers.

All flights into and out of the airport, in east London, will be stopped on Monday after the device was found nearby in the River Thames on Sunday.

The closure led to the cancellation of more than 100 departures and was affecting up to 16,000 passengers, according to a spokeswoman. A 700ft (214-metre) exclusion zone was put in place on Sunday evening to ensure the device could be dealt with safely.

People living inside the zone were evacuated from their homes overnight, while police said a number of road cordons have been put in place in Newham.



Unexploded WW2 bomb found in Birmingham

An unexploded Second World War bomb was found in Birmingham this afternoon, causing a construction site to be evacuated.



Aston Expressway bomb: Controlled explosion carried out on Second World War shell

A Second World War bomb found near the Aston Expressway has been safely detonated, bringing 30 hours of drama to an end.
The explosion meant a gradual return to normality for the 200 residents who had been evacuated from the 1,600ft (500 metre) cordon put in place on the advice of explosives experts.

However, although the M6 was reopened after the blast, the key Aston Expressway stayed shut until 6pm - extending traffic disruption which had added 90 minutes onto many people's journeys.
The A38(M) and slip roads off Spaghetti Junction had all been shut since the large German bomb was found on Monday morning, while nearby rail services were also disrupted.



Bath WW2 bomb scare: Hundreds of homes evacuated

Up to 1,000 homes have been evacuated and a 300m exclusion zone is in place following the find in Lansdown Road.

According to reports, a 500lb (228kg) bomb was found just a metre beneath a playground at the former Royal High Junior School.

