Stage 2 Detailed Explosive Ordnance Risk Assessment

Project: Atlas Park Development, Wythenshawe | **Client:** Aviva Life and Pensions UK Limited



The Client

Aviva Life and Pensions UK Limited

Project

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EXECUTIVE SUMMARY

Conclusion	Explosive ordnance (EO) poses a **Low-to-Moderate Risk** to the anticipated ground works.
Recommendation(s)	► **Explosive Ordnance Site Safety Instructions** in support of development phase ground works only. ► **Explosive Ordnance Safety & Awareness Briefings** in support of SI phase and development phase ground works.
The Site	Site address: Simonsway, Woodhouse Park, Wythenshawe, Manchester, M22 5JT. The Site is centred on the approximate National Grid Ref: SJ 83846 85996. The Site comprises brownfield land (unmaintained grassland / shrubland), hardstanding, a section of Atlas Park (road), a small circular gatehouse (in the northeast), and a large post-WW2 constructed commercial use building with car park.
Proposed works	A commercial development comprising several large warehouse type units with loading bays / service yards, and car parks. Various shallow mechanical excavations will be required for buried services, highway construction, soft landscaping, etc. At the time of writing, the foundation solution had not yet been designed. Therefore, both traditional (shallow) and deeper foundations (piled or ground improvement techniques) will be considered. Prior to redevelopment, GI works are anticipated. As none were proposed at the time of writing, a standard GI exercise (average number of boreholes and trial pits throughout the Site) will be assumed.
Risk Assessment - Key Findings	
Historic Site occupancy	During WW2 the Site was occupied by farmland.
Likelihood of EO contamination:	► The Manchester / Salford / Stretford conurbation experienced some 41No. individual air raids during WW2. Most were small-scale, however several medium-scale and four major-scale raids were also mounted. The Site was located several kilometres south of the Luftwaffe's primary target area, however within 2km of a confirmed individual bombing target. ► Analysis of the available records confirms that the study area experienced a low bombing density, with no bombing incidents recorded within 500m of the Site. The closest incident, a pair of high explosive (HE) bombs, occurred >600m away. The orientation of this bomb-stick (not aligning with the Site) combined with its significant distance from the Site, indicates a low likelihood that the aircraft responsible flew over the Site whilst releasing an unexploded bomb (UXB). ► Up to 76No. heavy anti-aircraft (AA) guns within firing range of the Site, expended a very large quantity of ammunition during WW2. Consequently, there is an elevated likelihood of unexploded heavy AA shells striking the Site. ► Any German UXB or British unexploded heavy AA projectile strike on Site could have easily occurred unwitnessed and remained undetected (unreported). Note, the entry hole of any such UXO item could have been obscured by dense crop growth or ploughed up soil, the wider study area was sparsely populated, and all local air raids occurred during the hours of darkness. However, there is a low likelihood of German UXB strikes within the Site boundary. ► Although Home Guard (HG) soldiers were active in the local area during WW2, no evidence of such activity affecting the immediate study area has been found and the Site's wartime occupancy, indicates a low likelihood that any unrecorded activity affected the Site. Soldiers could conceivably have accessed the Site whilst on patrol or during large-scale training exercises, however they are unlikely to have carried any hazardous EO (e.g. grenades) during such activities and even less likely to have discarded / buried such EO on arable land.

Likelihood of EO remaining	► Any very shallow buried EO contamination will probably have been unearthed, observed and removed from Site during years of post-war agricultural ploughing, if not, during the subsequent construction works. ► Any British unexploded heavy AA shell contamination beneath existing greenfield land or ground laid to hardstanding post-war is more likely to remain in-situ today, at an approximate depth range of 0.5m to 1.5m bgl. Although unlikely, it is conceivable that such EO could also remain under the footprint of post-war low-rise buildings (since demolished), occupying small volumes of undisturbed WW2-era soil in between strip foundation trenches. ► Any deep buried EO (chiefly German HE bombs weighing ≥50kg) is highly likely to remain in-situ today, as the likelihood that such EO contaminated the Site in the first instance, is low.
Likelihood of EO encounter and initiation	► The EO contamination risk is uniform across the Site area, although the likelihood that EO remains in-situ today is greater within the southwest and northeast areas of existing green space. As proposed building footprints are planned for these areas, risk pathways will be created during associated ground works, exposing them to a potential EO encounter (chiefly a British heavy AA shell within natural soil at a depth within 1.5m of the current ground level). Note, the possibility of such a EO encounter cannot however be completely discounted within the brownfield areas of the Site also. ► The anticipated SI will disturb a much smaller volume of soil / geology within the zone of potential EO contamination (ZPC) than the subsequent development works. As such, there is a much lower likelihood of encountering anything buried (e.g. EO) during this initial phase of works. ► Boreholes and piling may be required. These works raise the possibility of encountering the most severe EO hazard, a very heavy (deep buried) German UXB. However, the likelihood of such EO remaining on Site today is low. ► There is a very low likelihood of encountering EO within the post-WW2 created made ground on Site. ► A borehole / pile drill head striking a relatively small, unexploded AA shell occupying shallow depth relatively soft / uncompacted soil is more likely to result in a glancing blow that pushes the EO device to one side, dissipating much of the force. Such a strike on a large / heavy German bomb occupying stiffer (deeper) geology would presumably not have the same effect. This perhaps limits the likelihood of initiating the primary Site-specific hazard item (a heavy AA shell) during the borehole and (any subsequent) piling works.

The executive summary covers the key points only. The main body of this report contains the majority of the Site-specific detail and the limitations of the assessment. Should the proposed works be significantly modified or additional works be considered, IAL should be contacted as a reassessment of EO risk may be required.

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Glossary

AA	Anti-Aircraft
AAA	Anti-Aircraft Artillery
ALARP	As Low As Reasonably Practicable
AP	Anti-Personnel
ARP	Air Raid Precautions
AT	Anti-Tank
AXO	Abandoned Explosive Ordnance
BD	Bomb Disposal
bgl	below ground level
BGS	British Geological Survey
BPD	Bomb Penetration Depth
CIRIA	Construction Industry Research & Information Association
DA	Delayed Action (bomb type)
EO	Explosive Ordnance (UXO and AXO)
EOC	Explosive Ordnance Clearance
EOD	Explosive Ordnance Disposal
FAA	Fleet Air Arm (Royal Navy)
FP	Fire Pot (WW2 German bomb)
GP	General Purpose (bomb type)
ha	hectare(s)
HAA	Heavy Anti-Aircraft (gun)
HC	High Capacity (bomb type)
HE	High Explosive
HMNB	Her/His Majety's Naval Base
HMS	Her/His Majesty's Service (shore establishment)
HO	Home Office
HQ	Headquarters
HSE	Health & Safety Executive
IB	Incendiary Bomb
kg	kilogram(s)
km	kilometre(s)
LAA	Light Anti-Aircraft (gun)
LM	Land Mine
LRRB	Long Range Rocket Bomb (V2 rocket)
LSA	Land Service Ammunition
m	metre(s)
MC	Medium Capacity (bomb type)
mm	millimetre(s)
MOD	Ministry of Defence
MU	Maintenance Unit
NEQ	Net Explosive Quantity
NFF	National Filling Factory
NGR	National Grid Reference
OB	Oil Bomb
OS	Ordnance Survey
PAC	Pilotless Aircraft (V1 missile)
PB	Phosphorus Bomb
PM	Parachute Mine (bomb type)
POW	Prisoner of War
RADAR	Radio Detection And Ranging
RAF	Royal Air Force
RDX	Research Department Explosive
REF	Royal Explosive Factory
RFC	Royal Flying Corps (1912-1918)
RN	Royal Navy
RNAD	Royal Naval Armaments Depot
RNAS	Royal Naval Air Station
ROF	Royal Ordnance Factory
SAA	Small Arms Ammunition
SI	Site Investigation
SIP	Self-Igniting Phosphorus (grenade type)
TA	Territorial Army
TNT	Trinitrotoluene (explosive)
UK	United Kingdom
UN	United Nations
UP	Unrotating Projectile (AA rocket)
USAAF	United States Army Air Force (1941-1947)
USAF	United States Air Force (since 1947)
UX	Unexploded
UX AA	Unexploded Anti-Aircraft (projectile)
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V1	Vergeltungswaffe 1 (German cruise missile)
V2	Vergeltungswaffe 2 (German ballistic missile)
WAAF	Women's Auxiliary Air Force (1939-1949)
WO	War Office (1857-1964)
WW1	World War One (1914-1918)
WW2	World War Two (1939-1945)

1 Introduction

1.1 Instruction

Aviva Life and Pensions UK Limited (referred to hereon in as the Client) has commissioned Impartial Assessments Limited (referred to hereon in as IAL) to carry out a Stage 2 Detailed EO Risk Assessment of the proposed works at the Atlas Park Development, Wythenshawe site (referred to hereon in as the Site).

1.2 Objective

The objective of this report is to assess the likelihood of encountering buried explosive ordnance (EO) during intrusive ground works and to assess the consequences of any such encounter. If an intolerable risk level is identified, risk mitigation measures will be recommended.

1.3 Using This Report

In the UK, EO risk is not always considered or fully understood and is often misunderstood. This report aims to provide a comprehensive and coherent account, including introductory text and details on location-specific types of EO. We believe it is important to provide sufficient information to allow the layman to form a good understanding of the potential EO risks.

However, we also appreciate that some readers will not require the full contextual information and therefore the report is structured with this in mind. From **Chapters 3 to 13**, all Site-specific text that affects the outcome of this risk assessment can be found under the highlighted Site-Specific subheadings.

1.4 Explosive Ordnance Risk in the UK

The term EO describes both unexploded ordnance (UXO) and abandoned explosive ordnance (AXO). The former describes devices and projectiles that have been armed (and in some cases fired, dropped, placed, etc) yet failed to function. The latter describes devices and projectiles that have simply been abandoned (discarded or buried).

Fortunately, inadvertent EO initiations (detonations) in the UK are very rare, however, buried EO can cause significant delays to construction projects with associated increases in costs. The origin of UK EO can be broadly categorised as such:

- **Enemy Action (UXO):** the German air force bombed targets throughout the UK during WW1 and WW2. The German Navy bombarded coastal targets in eastern England during WW1 and German long-range artillery bombarded Kent during WW2.
- **Allied Military Activity (UXO and AXO):** several Allied nations used the UK as a staging area for military action in the European theatre of conflict (most notably the US and Canada) during WW1 and WW2.
- **UK Military Activity (UXO and AXO):** domestic British Army, Royal Air Force (RAF) and Royal Navy (RN) training activities as well as anti-aircraft (AA) weapons used during WW1 and WW2.

1.5 Guidelines for Risk Assessment

1.5.1 CIRIA

This assessment has been designed and written in accordance with the relevant Construction Industry Research and Information Association (CIRIA) guidelines: **C681** 'Unexploded Ordnance - A Guide for the Construction Industry' (published 2009) and **C785** 'Unexploded Ordnance Risk Management Guide for Land-Based Projects' (published 2019). C681 and C785 were written (with the support of the UK Health and Safety Executive) to provide the construction industry with accurate and authoritative information regarding matters of onshore EO risk in the UK.

1.5.2 Legislation

There is no specific UK legislation covering the assessment and management of EO risk. However, there is legislation that more broadly covers the consideration of EO hazards:

- Health & Safety at Work Act (1974) and Management of Health & Safety at Work Regulations 1999
- Construction (Design & Management) Regulations (CDM) 2015
- Corporate Manslaughter and Corporate Homicide Act 2007

1.5.3 MOD

EO finds in the UK are handled by the MOD's Joint Service Explosive Ordnance Disposal Operations Centre (JSEODOC). At any site where an identifiable EO risk was not highlighted at project design stage, JSEODOC will not provide EOD services for frequent callouts to EO encounters. Instead, the client will be required to employ the services of a commercial EO risk management contractor to manage the ongoing EO risk.

The delay caused by retrospectively carrying out a risk assessment can have significant cost implications as site works are halted. Therefore, it is essential that EO risk is considered at the earliest possible stage, ideally through the commissioning of a Stage 1 or Stage 2 EO risk assessment.

1.6 Assessment Methodology

1.6.1 Introduction

This report is based on a traditional source-pathway-receptor-consequence (SPRC) assessment methodology and semi-quantitative risk model. The following subheadings describe how this risk assessment structure is applied to buried EO risk (in the UK).

1.6.2 Source

In the UK there are numerous sources of potential EO contamination. Three main factors govern the likelihood of buried EO being present at a given site today:

- **Contamination:** The likelihood that EO came to be buried at a site.
- **Subsequent Detection:** The likelihood that EO (chiefly UXO) contamination went unobserved and reported.
- **Degree of (any) Risk Mitigation:** Could subsequent earthworks or Explosive Ordnance Clearance (EOC) activities have mitigated the buried EO risk?

1.6.3 Pathway

The activities that could result in the EO hazard reaching sensitive receptors and the specific type of EO hazard.

- **Encounter:** The likelihood of buried EO being encountered during the proposed works depends on the total volume of soil disturbed and the type(s) of intrusion methodology. Note, site-specific bomb penetration depth (BPD) calculations must be conducted where appropriate.
- **Initiation:** The likelihood that an encounter results in the EO initiating.

1.6.4 Receptor

The number and sensitivity of receptors will vary from site to site. In the context of an EO initiation, the receptors present at the time of the event will almost always include the most sensitive category; human health.

1.6.5 Consequence

The consequences of an inadvertent EO initiation event vary from none to catastrophic. However, the likelihood of initiating EO is far lower than that of encountering EO. The negative consequences of an EO encounter are much more likely to be financial, resulting from project delays.

1.6.6 Semi-Quantitative Risk Calculation

Once all project-specific factors have been assessed, a semi-quantitative risk assessment (likelihood versus consequence risk matrix) will be carried out or multiple calculations will be carried out if the factors described above vary considerably across the site. In the latter scenario, a risk map will be drawn to illustrate the differing risk zones.

1.6.7 Recommendations

If a significantly elevated risk level(s) is concluded, industry standard risk mitigation measures (appropriate to the project specific intrusive methodologies) will be recommended to reduce the elevated risk level(s) to as low as reasonably practicable (ALARP) level.

1.7 Information Sources

To guarantee a robust assessment of risk, primary source records form the basis of this report. The following information types and information sources were accessed / contacted during the research process:

- The National Archives, Greater Manchester Record Office, The University of Manchester. Historic England, Council for British Archaeology, Greater Manchester Historic Environment Record, British Geological Society, The MoD, the local authority, the Client.
- Historic OS mapping, historic aerial photography and various web resources.
- Our PIEO (potential indicators of explosive ordnance) GIS map and our physical library. Note, PIEO is the result of over 15 years of research and is constantly growing.

1.8 Reporting Conditions

The accuracy of original records relating to bombing is difficult to verify. Wartime bombing records were only as detailed and accurate as the availability of time, personnel, and ease of access to information would allow. The conditions under which information was gathered in many urban locations, i.e. intense aerial bombardment, will not have been conducive to accurate record keeping. Air raids within sparsely populated locations are less likely to have been witnessed, limiting the accuracy of any corresponding records. Furthermore, such records were often based on unverifiable second-hand eyewitness accounts.

Many records of historic military activity have not survived and some of those that have are only declassified and released into the public domain decades after their creation. Consequently, pertinent records can be inaccessible at the time of requirement. Impartial Assessments cannot accept liability for any missing historic records, inaccuracies or omissions within the available historic records.

It is never possible to accurately determine, through desktop study alone, the precise location, type and condition of buried EO at a given site. Furthermore, some factors (human behavioural) make assessment of EO risk partly subjective.

2 The Site

2.1 Location

The Site address: Simonsway, Woodhouse Park, Wythenshawe, Manchester, M22 5JT.

The Site is centred on the approximate National Grid Ref: SJ 83846 85996.

A recent aerial photograph is displayed at **FIGURE 1**.

2.2 Description

The Site comprises brownfield land (unmaintained grassland / shrubland), hardstanding, a section of Atlas Park (road), a small circular gatehouse (in the northeast), and a large post-WW2 constructed commercial use building with car park.

2.3 Proposed Works

A commercial development comprising several large warehouse type units with loading bays / service yards, and car parks. Various shallow mechanical excavations will be required for buried services, highway construction, soft landscaping, etc. At the time of writing, the foundation solution had not yet been designed. Therefore, both traditional (shallow) and deeper foundations (piled or ground improvement techniques) will be considered.

Prior to redevelopment, GI works are anticipated. As none were designed / proposed at the time of writing, a standard GI exercise (average number of boreholes and trial pits throughout the Site) will be assumed.

An existing Site plan is displayed at **FIGURE 2**.

3 Site History Assessment

3.1 OS Mapping

3.1.1 Introduction

Bomb damage resulting from German air raids can be identified by comparing historic OS maps. These maps can also help identify examples of historic military activity. Note, 19th / 20th Century military structures had a typical shape and were distributed in typical patterns.

The table below includes a review of the relevant OS maps. Note, the process adopted in generating these maps (mapping intervals, scale, exclusion of some features in the interests of national security, etc), may result in an incomplete account of a site's history.

Latest pre-WW2 and earliest post-WW2 OS maps are displayed at **FIGURE 3**.

3.1.2 Site-Specific

	Date	Scale	Observations
Pre-WW1	1872	1:10,560	No evidence of military activity on Site or in the vicinity.
			The Site occupies parts of several agricultural fields in a wider undeveloped (presumably agricultural) area. A footpath crosses the Site.
	1907	1:2,500	No evidence of military activity on Site or in the vicinity.
			No significant changes on or adjacent to the Site.

Pre-WW2	1936	1:2,500	No evidence of military activity on Site or in the vicinity.
			No significant changes on or adjacent to the Site.
	1938	1:10,560	No evidence of military activity on Site or in the vicinity.
			No significant changes on or adjacent to the Site. Note, this small-scale map lacks detail.
Post-WW2	1954	1:10,560	No evidence of military activity on Site or in the vicinity.
			No significant changes on or adjacent to the Site. Note, this small-scale map lacks detail.
	1960	1:1,250	No evidence of military activity on Site or in the vicinity.
			The Site has been developed with several buildings (varying size) all labelled 'Works', hard surfaced areas and access roads all built in central positions on Site. The eastern extent of the Site encroaches into a 'Sports Field'. The southwest corner of the Site and the central northern area remain undeveloped.
	1977	1:10,000	No evidence of military activity on Site or in the vicinity.
			No significant changes on Site.
	1990	1:10,000	No evidence of military activity on Site or in the vicinity.
			Two of the larger buildings in the west have been extended.
	2010	1:10,000	No evidence of military activity on Site or in the vicinity.
			No significant changes on Site.

TABLE 1: Historical OS Mapping Review

3.2 Aerial Photography

3.2.1 Introduction

Historical aerial photography is often key in identifying temporary wartime activity. As well as clarifying historic site occupancy, aerial photographs can elucidate the degree of bomb damage to structures and show the locations of German high explosive (HE) bomb craters. Note, the latter usually only persisted for a short time.

WW2-era aerial photography is displayed at **FIGURE 4**.

3.2.2 Site-Specific

	Date	Angle	Observations
Pre-WW2	Mar 1927	Oblique	This image, showing most of the Site from the south, was taken approximately 14No. years before the first WW2 air raids in the region. The Site and its environs appear as they do on the period OS mapping. The fields occupying the Site appear to be arable use.

Post-WW2	Aug 1945	Vertical	This image was taken several months after the end of WW2 (in Europe). The Site remains largely unchanged. No obvious evidence of German bombing (craters in open ground or ruined / demolished buildings) is visible in the local area. No obvious evidence of temporary (wartime) military activity is visible on or near the Site.
	Jun 1973	Vertical	This high-resolution image records the post-war development of the Site. Much of the unbuilt ground on Site is shown to be grass covered. Two hard surfaced car parks are present on Site, in central north and central south positions. The 'works' buildings all appear to be single or two-storeys in height.

TABLE 2: Historical Aerial Photography Review

3.3 Additional Historical Information

If a site encompasses a historic landmark, significant building etc, further research might locate a written account providing details on the site's historic occupancy. Such details could prove significant when assessing the various variables relating to, for example, the likelihood of a German UXB strike going unnoticed and unreported.

No such information was located.

4 WW2 Enemy Action Assessment: Aerial Bombing

4.1 German bombing during WW2

Between 1939 and 1945, the German air force (the Luftwaffe) dropped approximately 75,000 tonnes of HE bombs and over two million incendiary bombs (IBs) on the four nations of the UK. Almost all counties were affected to some degree.

At the time, bombing was still in its infancy. Testing showed that the accuracy of daylight, level flight bombardment would put 50% of the bombload within 91m of the centre of the target from an altitude of 3,000m. At double this altitude the error exceeded 400m. In poor visibility and at night, the error could increase by >250%.

Furthermore, these tests were conducted within an uncontested environment. The various British AA defences and navigational countermeasures greatly hindered bombing. Luftwaffe aircraft frequently abandoned their intended target and jettisoned their bombloads indiscriminately. Consequently, numerous bombing incidents occurred in open countryside throughout the UK, many miles from intended targets.

Bombs were only rarely dropped individually. The normal procedure was to drop an internally carried bombload in a single sequence, with release spacings pre-set from 10m to 100m. 20No. 50kg bombs (the most numerous HE bombload) could thus extend in a line (called a bomb-stick) varying between 200m and 2km in length. These patterns (when accurately plotted) can aid in locating unreported UXBs. It should be noted however that externally carried bombs could be released individually, creating uneven bomb-stick patterns or solitary bomb strikes.

For other types of commonly deployed ordnance, inaccuracy was inherent. 1kg / 2kg IBs and parachute retarded mines (high-capacity blast bombs) were easily blown off course by the wind.

4.2 Explosive Ordnance Hazards Overview

4.2.1 Introduction

During WW2 the Luftwaffe deployed a variety of ordnance against the UK. The most frequently deployed large bombs achieved significant ground penetration due to their 'thick-skinned' steel construction and are therefore more likely to remain buried in the ground today. These HE (and some incendiary type) bombs are termed 'iron' bombs. The 50kg and 250kg 'iron' bombs accounted for approximately 93% of 'iron' bombs dropped on the UK.

Descriptions of these different bomb types are presented below. Data sheets detailing those bombs most likely to be encountered today are displayed at **APPENDIX 1**.

Note, the Italian Air Force participated in a small number of air raids in Essex and Kent during 1940. The Italian bombs were comparable to German general purpose 'iron' bombs, however any UXB find would be extremely rare.

4.2.2 More Likely to be Unearthed in the UK Today

- **High Explosive 'iron' bombs - General Purpose:** The SC series accounted for the majority of HE bombs dropped on the UK. This design had a moderate charge to weight ratio, approximately 50% charge. The most common weights were 50kg (SC50), 250kg (SC250) and 500kg (SC500). 6No. additional models (1,000kg, 1,200kg, 1,400kg, 1,800kg, 2,000kg and 2,500kg) were deployed in much smaller numbers.
- **High Explosive 'iron' bombs - Semi Armour Piercing:** The SD series were very similar in appearance to the SC bombs but had lower charge to weight ratios, approximately 30% charge. The casing was thicker, allowing for greater penetration through structures. There were six 'iron' bombs models ranging from 50kg to 1,700kg.
- **Incendiary 'iron' bombs:** The Brand C50A used a SC50 type casing but contained a mixture of incendiary liquids (including phosphorus) that ignited on contact with the air. The C50B was the same size but mostly phosphorus filled. The Sprengbrand C50 (Firepot) also utilised a thick 'iron' bomb casing, however contained both Thermite incendiary containers and a 7kg HE charge. These bombs weighed approximately 41kg and 50kg respectively and were introduced later in the war.
- **Incendiary Sub-Munitions:** The 1kg B1E IB was the most frequently dropped German bomb. Up to 620No. B1Es could be packed into a sub-munition canister, which opened at a pre-determined height, scattering the IBs over a wide area. The Thermite fill burns at extremely high temperature. The longer 2kg B2E model incorporated a small HE charge with delay fuze. The B2E is therefore more hazardous than the B1E, however was dropped in smaller numbers. Although light weight, both had the potential to fully penetrate soft ground.

4.2.3 Less Likely to be Unearthed in the UK Today

- **High Explosive 'iron' bombs - Armour Piercing:** The PC series (four models between 500kg and 1,600kg) were used against reinforced military structures and warships. Consequently, they were not commonly used against the UK mainland. Charge to weight ratios were low, approximately 15% charge.
- **High Explosive Blast Bombs - Parachute Mines:** Converted naval influence mines were dropped on urban targets. Their thin steel bodies allowed for very high charge to weight ratios, approximately 73% charge. Luftmine A (LMA) and Luftmine B (LMB) weighed 500kg and 1,000kg respectively. Each was parachute retarded, enabling detonation at ground level and therefore no ground penetration. Consequently, the only unexploded parachute mines found today, wash up along the coastline or remain on river or lake beds.
- **Oil Incendiary Bombs:** The Flam 250 and Flam 500 bombs contained a mixture of benzine and petroleum, ignited by a small HE charge. They were constructed of thin metal which broke up on impact, spreading the incendiary mixture across an area. As such they are unlikely to remain buried in the UK today. The bombs proved unreliable, often failing to ignite, and consequently were withdrawn from service in 1941.

- **Anti-Personnel (AP) Sub-Munitions:** The 2kg SD2 'Butterfly' bomb was dropped on several British cities and towns. It was a nuisance weapon incorporating both time-delay and anti-handling fuzes. It contained a small 225g HE charge, however had no ground penetration ability. A sub-munition canister could hold up to 108No. SD2s. The SD10 was a larger (10kg) AP bomb. It could achieve full penetration, however this model was dropped in very small numbers on the UK. A sub-munition canister could hold 17No. SD10s.
- **Miscellaneous:** The Luftwaffe dropped various other devices on the UK. Flares (for target illumination) were by far the most numerous, however had no ground penetration potential. Photoflash bombs (to aid reconnaissance photography) are similar in appearance to 50kg bombs. Inert concrete-filled bombs were dropped to cause disruption and unnecessarily tie up bomb disposal (BD) resources.

4.2.4 'Iron' Bomb Penetration Depths

The Research & Experiments Department of the Ministry of Home Security (MoHS) used BD records to study German HE UXB penetration depths, publishing their findings in 1949. The British Army's BD headquarters provided details of 1,304 UXB recoveries. In addition, the ministry carried out their own tests, involving 24No. bombs dropped into Chalk under controlled conditions.

The average penetration depth of 430No. 50kg bombs (the most commonly dropped HE bomb) in London Clay was 4.6m and 6.1m for the 250kg model. Note, these bombs landed in open ground and were therefore unaffected by structures or hardstanding. Once the distribution of bomb weights against penetration depths was plotted, the mean line was extrapolated for each bomb weight to produce probable maximum depth figures.

For each bomb weight, the mean average of all observed penetration depths was calculated for each geology. The resulting figures, plus the observed minimum penetration depths, are presented in the table below. Note, bombs weighing >1,000kg have been omitted from the table as only several such UXBs were recovered during WW2.

	Clay			Chalk			Gravel			Sand			Sandstone		
Bomb (Kg)	Min (m)	Average (m)	Max (m)	Min (m)	Average (m)	Max (m)	Min (m)	Average (m)	Max (m)	Min (m)	Average (m)	Max (m)	Min (m)	Average (m)	Max (m)
50	0.7	4.0	9.1	1.0	3.5	7.7	1.0	2.8	7.8	1.0	2.8	7.8	1.8	2.7	6.0
250	1.5	6.8	15.8	1.0	6.0	13.1	0.7	4.8	13.7	1.8	4.8	13.7	2.5	4.6	10.3
500	3.8	8.7	19.8	4.0	7.6	16.4	2.5	6.0	17.3	3.0	6.0	17.3	-	5.8	13.1
1,000	4.8	10.9	24.9	4.2	9.6	20.7	2.0	7.6	21.9	6.8	7.6	21.9	-	7.3	16.4

TABLE 3: WW2 German UXB Penetration Depths Data

Although most German HE UXBs came to rest after several metres travel through the ground, these weapons can be encountered at any depth between just below WW2 ground level and the maximum BPD. There are three reasons why heavy bombs might be found at surprisingly shallow depths:

- **Low Altitude Release:** Some Luftwaffe raids (particularly those involving fast fighter-bombers) were executed at very low altitudes, to avoid RADAR detection. Bombs released over soft ground from very low altitude would impact at a shallower angle, resulting in extreme J-Curve Effect (see **Subheading 4.2.5**).
- **Deflection:** 'iron' bombs had conical nosecones and were therefore susceptible to deflection. A bomb striking a structure (above or below ground), could deflect and come to rest at a shallower depth.
- **Aircraft Crash Site:** For several reasons, a pilot may not have been able to dump his bombload before impacting the ground. Any internally or externally fitted bombs could have become shallow buried on impact.

4.2.5 'Iron' Bomb J-Curve Effect

WW2 BD units reported that most deep buried German HE UXBs were observed in a horizontal or up-turned orientation. As a HE UXB penetrates the ground at an angle slightly offset from the vertical, it begins to turn, creating a curved passage through the soil.

This phenomenon can be significant when assessing the risk of UXO as the J-Curve Effect results in a horizontal offset from the point of UXB entry. A HE UXB could impact soft ground adjacent to a building and then come to rest beneath that building. The degree of lateral offset is typically one third (approximately) of the bomb's ultimate penetration depth. Therefore, for locations which experienced high-altitude bombing raids, J-Curve offsets will typically be between 2.0m and 4.0m. In extreme conditions, a low altitude attack resulting in a low angle UXB strike could produce even greater horizontal offset, up to 15.0m.

4.3 British Records of Bombing

4.3.1 Official Records

The Bomb Census was undertaken by the MoHS. The Bomb Census was compiled using information primarily gathered by ARP (Air Raid Precautions) wardens. Standardised forms were used to keep a written record of each incident. In many areas, these reports were used to create bomb plot maps. The Ministry also calculated bombing density statistics for every administrative area and created Daily Intelligence Reports, recording the date and location of every single air raid.

The Bomb Census commenced in September 1940, more than three months after the German bombing campaign commenced. Initially, only information relating to London, Birmingham and Liverpool was collated. It was not until September 1941 that the Bomb Census was extended to cover the entire UK. Consequently, many pre-September 1941 records were not standardised and, in some cases, were poor quality.

The level of detail varied greatly with location. Furthermore, the Bomb Census did not cover air raids on military property. The armed forces had no formal process for recording air raids and processing associated records.

As well as bombing incident records, some local authorities produced war damage maps. Council engineers carried out street by street surveys to create a record of the varying degrees of damage sustained by buildings.

Today, many original (archived) bombing records are incomplete, some collections are missing altogether and in some cases, entire records were destroyed at the time by German bombs.

4.3.2 Unofficial Records

In some parts of the UK where official bombing records are incomplete or missing, historic eyewitness accounts, newspaper articles, aerial photographs, etc can be used to build up a picture of WW2 air raids. The credibility of any such information, however, must be addressed and assessed.

4.4 Luftwaffe Targets

4.4.1 Brief Overview

The Luftwaffe carried out reconnaissance flights over the UK. Numerous aerial photographs were taken with subsequent German annotations earmarking various facilities for attack. Luftwaffe crews were also given British OS maps with German annotations highlighting their target area. In the absence of detailed bombing records, the presence of a known target increases the likelihood that bombs fell locally.

Although official German doctrine did not specifically target civilian residential areas, the Blitz raids on individual targets were gradually replaced by what was, for all intents and purposes, unrestricted indiscriminate bombing. This was due to the effectiveness of British countermeasures. The Luftwaffe identified city centre aiming points for some attacks, as well as identifying individual targets. Typical types of target:

- **Common Primary (strategic) Targets:** RAF airfields, Royal Navy bases, commercial docks, weapons (chiefly aircraft) factories and RADAR installations.
- **Common Secondary Targets:** engineering works, steel works, factories, depots, railway marshalling yards, gasworks, power stations, army camps / barracks, AA artillery batteries, coastal gun batteries etc.

Note, the inherent inaccuracies in WW2-era aerial bombardment resulted in many wayward bomb strikes in areas surrounding targeted facilities.

4.4.2 Site-Specific

Original Luftwaffe target maps and aerial reconnaissance photographs of the wider study area were reviewed.

Target Category	Relevance and Proximity to the Site
Confirmed primary aiming point (indiscriminate bombing)	Manchester city centre (~11km north)
Confirmed primary individual target(s)	RAF Ringway (1.6km southwest) Fairey Aviation Co Factory (1.6km southwest)
Confirmed secondary target(s)	-
Unconfirmed but potential secondary target(s)	Railway line (470m east)

TABLE 4: WW2 Bombing Targets

4.5 Bombing Decoy Installations

4.5.1 Brief Overview

British decoys were intended to draw enemy bombers away from the true targets. 839No. decoys were built at 602No. sites in England, with approximately 200No. more established in Wales, Scotland and Northern Ireland. Although success rates varied greatly, the confirmed presence of a bombing decoy significantly increases the likelihood that bombs fell near or on that location. 5No. types were fielded:

- **'K' and 'Q' Sites - Dummy Aerodromes**. 230No. were established. 'K' decoys (landing field, mock-up buildings, and inflatable aircraft) were for daylight use. 'Q' decoys used lights to create a flarepath simulating a runway at night.
- **'QL' Sites - Urban Lighting**. Electric lights were used to simulate poorly implemented blackout procedures. As a bomber force approached, the lights would be extinguished erratically.
- **'SF' and 'QF' Sites - Diversionary Fires**. The largest and most sophisticated decoys. When lit, 'Starfish' sites gave the impression of an urban area set alight by incendiary bombing. They were installed near cities. Similar to, however smaller than 'SF' decoys, 'QF's were installed near and for the protection of specific vulnerable points (VPs) such as factories, military sites, oil storage tank farms, etc. Some 100No. 'QF' sites were established in England.
- **'M' and 'C' Sites - Dummy Factories and AA Batteries**. The former comprised a scale model of a specific factory, vital to the war effort. They were made from wood and canvas and had other features, such as access roads and equipment.
- **ASQL - Assault.** During August and September 1943, 18No 'QL' sites were installed along the south coast of England during a deception operation. These temporary decoys received very little attention.

Between 1942 and 1943, most 'K' sites were dismantled, however many of the other decoys were used up until late 1944 when Luftwaffe activity over the UK had all but ceased. By the end of 1941, the airfield decoys had received 359No. attacks compared with 358No. raids carried out against the real airfields. By June 1944, approximately 730No. attacks had been recorded on all decoy types. At least 5% of the total weight of German bombs dropped are estimated to have been aimed at Britain's decoy sites.

4.5.2 Site-Specific

None within a significant distance of the Site. The closest was approximately 6.7km to the southeast.

4.6 Local Air Raids Information

4.6.1 Brief Summary

- Between 29th July 1940 and 30th July 1942, Manchester County Borough experienced 41No. individual air raids during 31No. days of local Luftwaffe activity. Most were small in scale, often executed by a solitary bomber. Several medium scale attacks and four major scale raids were also mounted. Note, 'major' was a Luftwaffe designation that described a raid delivering >100No. tonnes of HE (in addition to incendiaries) onto a target area.
- The first significant (medium-scale) raids affecting the borough, occurred on the 28th August and 1st October 1940. Two consecutive major attacks on the nights of the 22nd / 23rd and 23rd / 24th December 1940 (the 'Christmas Blitz') devastated parts of Manchester, Salford and Stretford. These two attacks saw 441No. German bombers drop 272No. tonnes of HE on the first night and 195No. tonnes of HE on the second night. Seven conflagrations and 600No. smaller fires were reported, the result of tens of thousands of small (1kg / 2kg) incendiary bombs (IBs).
- During 1941, two additional major* raids targeted Manchester on the 9th January and 1st June. Although each involved half as many aircraft as the 22nd December 1940 raid, they still delivered a further 208No. tonnes of HE bombs and thousands of IBs. Three medium-scale raids were also mounted during the spring of 1941.

  *The fourth and final major raid actually only delivered 97No. tonnes of HE, however is close enough to 100No. tonnes to be considered 'major'.
- The Christmas Blitz alone caused the total destruction of >4,000No. houses with a further 12,000No. sustaining serious damage. Manchester County Borough suffered 1,546No. casualties during these two raids.
- This intensity of air raid activity resulted in many indiscriminate 'tip and run' bombing incidents in the surrounding districts. Such incidents were the result of solitary aircraft either lost or under fire, jettisoning remaining ordnance, mostly indiscriminately, before flying back to base. Therefore, even though the study area was predominantly insignificant farmland, it would still have been vulnerable to bombing.

4.6.2 Bombing Density

The table below records the MoHS's bombing density calculations for the former administrative areas of Manchester County Borough and Cheadle & Gatley Urban District. Note, the Site was located within the former however just 150m west of the border with the latter. It gives a breakdown of the number of large Luftwaffe bombs reported within the administrative area. These figures do not include UXBs, 1kg / 2kg IBs, or 2kg AP bombs. The adjacent table displays IAL's bombing density parameters.

Administrative Area	M.CB	C&G.UD
Administrative Area Size (Acres)	27,255	5,299
HE 'iron' bombs (all types)	712	36
HE Parachute Mines	18	0
'Flam' Oil IBs	17	0
Phosphorus IBs	0	0
'Fire Pot' Phosphorus IBs	0	0
V1 Flying Bomb	1	0
V2 Long Range Rocket	0	0
Total (excluding V Weapons)	737	36
Bombs Per 1,000 Acres (405ha)	**27**	**6.8**

Qualitative	Quantitative
Very Low	<5 bombs per 1,000 acres (405ha)
Low	5 to 15 bombs per 405ha
Low to Moderate	15 to 30 bombs per 405ha
Moderate	30 to 75 bombs per 405ha
Moderate to High	75 to 150 bombs per 405ha
High	150 to 300 bombs per 405ha
Very High	>300 bombs per 405ha

TABLE 5: Bombing Statistics and Parameters - National Source

Secondary source data (Cooper G. 2018) states that during the first major air raid alone, some 37,000No. small IBs were dropped. Luftwaffe records list 1,925No. 1kg / 2kg IB canisters dropped during the four heaviest raids on the conurbation. The smallest Luftwaffe canister held just 36No. 1kg IBs and therefore it can be said that at least 70,000No. 1kg / 2kg IBs were dropped. Note, this number is likely far greater, as larger models of IB canister (containing hundreds of IBs) were almost certainly used and small IBs would have been dropped during the many small and medium-scale raids.

4.6.3 Site-Specific

Note, the bombing density figure for a whole administrative area is not always a good indication of the bombing density over a specific site. Within larger districts, particularly rural districts, bombing density figures may be skewered by the presence of a heavily bombed target.

Despite the major-scale air raids, the overall bombing density figure for Manchester Borough is not high because the Luftwaffe's primary target area incorporated parts of Manchester County Borough, Salford County Borough (to the west) and Stretford Municipal Borough (to the south-west). Consequently, the weight of Luftwaffe ordnance dropped was divided between these three administrative areas, for reporting purposes. Furthermore, Manchester County Borough was a very large administrative area, most of which did not contain any Luftwaffe bombing targets and as a result was not specifically targeted.

According to the bombing density calculation above, the Site occupied an area that experienced a low or low to moderate bombing density. Further analysis indicates that **the study area experienced a low bombing density**.

4.7 Bomb Failure Rate

4.7.1 Brief Overview

There are three reasons why German 'iron' bombs dropped during WW2 failed to function as designed:

- **Human Error:** failure of the aircraft's crew to charge the electrical condenser in the fuze.
- **Very Low Altitude Release:** the fuze would not have enough time to arm itself before impact.
- **Faulty Fuze:** inadvertently during manufacture or sabotage by POWs working in German factories.

The Bomb Census recorded a daily average of 84No. German 'iron' bomb UXBs dropped on civilian targets throughout Britain, between 21st September 1940 and 5th July 1941. 8.5% of these were Delayed Action (DA) bombs (time bombs) which exploded sometime later. The remainder were unintentional 'duds' (UXBs).

By the end of WW2, the MoHS calculated a total figure of 200,195No. HE bombs recorded as exploded in Britain. An additional 25,195No. HE UXBs were recorded, giving a HE bomb failure rate of 12.6%.

The Luftwaffe figure for the total number of bombs dropped on the UK was approximately 11% higher than the number observed and reported by UK authorities. This suggests that the total number of UXBs remaining buried in the UK today is greater. However, anecdotal evidence suggests that German sources overstated their bombing statistics for propaganda reasons.

The average HE bomb failure rate of all boroughs and districts making up the London Civil Defence Region (the most heavily bombed part of the UK) was calculated as 10%, with rates ranging from 6% to 15%. Note, those areas of the capital that suffered the most damage, had the most ruins into which subsequent UXBs could fall unnoticed / go unrecorded. This limits the accuracy of the observed failure rates in those areas.

The discrepancy between the British and German records combined with the fact that HE UXBs are still consistently being discovered in the UK today (averaging five per year), confirms that the UK's 12.6% rate is inaccurate and is in fact higher. As rates of 15% were observed in some areas, this is considered to be a more accurate estimate of the true failure rate.

4.7.2 Site-Specific

No evidence has been found to suggest that the local HE bomb failure rate differs significantly from the national average. Note, records of exploded and unexploded HE bombs dropped on Manchester, Salford and Stretford during the Christmas Blitz produce a failure rate of 16.6% (Smith P J C. 2003).

4.8 Site-Specific Bombing Incident Records

4.8.1 Introduction

The catalogues of relevant archive offices were searched. No complete collection of original incident reports, describing all individual bomb strikes within the study area (produced locally by the ARP, police, fire service or borough engineer and surveyor) were held. One complete record of bomb strikes locations for Manchester Borough was available, however no such record for Cheadle & Gatley Urban District was available.

4.8.2 Manchester Borough Council - Bomb and Damage Plot Maps

This series of maps were produced by Manchester City Council's Architect's Department (Building Surveyor's Division) during the war and were updated throughout the conflict to reflect all raids on the county borough.

No original legend / key accompanies the maps, however contemporary descriptions confirm most of the symbols. No symbol for UXBs was identified and the degrees of damage sustained are unidentified. Any IB strike symbol with a number written within it represents the number of individual IBs falling at that location.

All maps covering the wider study area were accessed and two maps (stitched together) showing the closest plotted incident are displayed at **FIGURE 5**.

- No bomb strikes are plotted and no structural damage is highlighted within 500m of the Site boundary.
- The closest incident to the Site (a pair of two HE bombs) is recorded 740 to 860m southeast. These bombs were dropped by the same aircraft on the 11th October 1940.

4.8.3 Manchester Borough Council - Damage to Property Report Cards

Two collections of original report cards detailing German bomb and British anti-aircraft (AA) shell damage to individual properties throughout the county borough, was accessed. This record type, produced by the borough council's Building Surveyor's Division, is understood to cover the entire bombing campaign.

These collections were searched for those road names local to the study area, however no such report cards were included.

4.8.4 MoHS - Regional Situation Reports

A complete collection of original reports describing all air raids on Civil Defence Region 10 (created by a central government department) was accessed. These reports represent a broad record of local air raids and do not list the precise locations of individual bomb strikes and any damage caused. Only general locations affected are given.

A review of this collection highlights several raids affecting the wider study area:

- **11th October 1940** - HE bomb(s) at Wythemshawe (940m - 2.8km north of the Site). Cottage demolished. Some casualties.
- **11th October 1940** - at 22:40hrs. 50No. IBs at Cheadle (probably >2km northeast of the Site). No casualties. Fires under control by the 12th October.
- **18th November 1940** - at 21:45hrs. six HE bombs in Wythemshawe (940m - 2.8km north of the Site). Two houses demolished. 15No. casualties.
- **22nd December 1940** - Whythenshawe hit (940m - 2.8km north of the Site).
- **23rd December 1940** - at 21:00hrs. HE bomb damaged three houses and injured one person at Gatley (probably >1.5km north of the Site). Also, at Cheadle (probably >2km northeast of the Site), one HE bomb demolished three houses. Three dead and 10No. injured.

Note, this record confirms that the RAF Ringway / Fairey Aviation Factory site (the closest confirmed bombing target to the Site) was never the specific subject of a medium or large-scale air raid, involving numerous aircraft. Instead, it experienced just three solitary aircraft attacks.

4.8.5 MoHS - Bombing Incident Reports

Multiple air raid incident and damage reports relating to several air raids on Manchester Borough (created by a central government department) were accessed. None of these detailed reports describe bombing incidents within close proximity to the Site. Note, this record only represents a fraction of all the bombing incidents that occurred in the borough during WW2. One report for the 11th October 1940 raid includes the following information:

The air raid occurred between 22:00hrs and 23:11hrs. Several planes dropped 25No. HE bombs (mostly 50kg variant with a few 250kg), three oil 'Flam' IBs and a large number of 1kg IBs. Most bombs fell on a densely populated district. The assumed target was the Fairey Aviation Factory and possibly a nearby railway line. The nearest bombs to the factory fell ¼ mile away and another group fell close to a nearby railway line.

Note, this latter remark may relate to the pair of HE bomb strikes closest to the Site.

4.8.6 MoHS - Bomb Census Trace Maps

A collection of trace maps (created by a central government department) covering Manchester Borough was accessed. This collection includes maps that plot bombing incidents during 14No. air raids. However, each map is specific to a part of the borough and does not necessarily plot all bombs dropped during that raid.

A search of this collection confirms that none of the maps cover the study area and no bomb strikes are plotted within 1km of the Site.

4.8.7 Manchester Civilian Fatalities Records

A contemporary digital map of Greater Manchester recording the locations of every 'Christmas Blitz' bombing incident that resulted in at least one fatality, was reviewed. This map (published by the Manchester Evening News) was compiled using data from the Commonwealth War Graves Commission, however only covers the two heaviest air raids on the city. No fatalities are recorded within 2km of the Site.

A separate 'Christmas Blitz' fatalities record - collection of official casualty records (CWDs) - was also accessed and searched, however again no local incidents were included.

4.8.8 Anecdotal and Secondary Source Evidence

A search of online resources and local history publications was carried out with the intention of locating any relevant anecdotal / eyewitness accounts or secondary source information relating to local bombing incidents. Local history publications detailing the air raids against Greater Manchester were accessed, however no relevant information relating to the study area was included.

4.9 Abandoned Bombs

4.9.1 Brief Overview

When a WW2 BD team arrived at the scene of a confirmed UXO strike, they would classify the incident by its potential hazard, Categories A, B, C and D, with A the highest priority for immediate removal and disposal. Occasionally, BD engineers could not find or recover the UXO and its location was simply recorded as an 'abandoned bomb'. The reasons for abandonment could be inaccessibility, extremely soft ground (extreme burial depth) or simply a harmless location (e.g. an isolated field). Note, BD teams in heavily bombed areas were constantly overstretched due to the sheer number of UXBs reported.

The archive office of the British Army's 29 EOD&S Group holds an Abandoned Bomb Register for Britain, as does the Ministry of Housing, Communities & Local Government. The registers lack detail, particularly with regards to locations. A general address rather than a precise position (grid refence) is usually given. Some of the abandoned bombs are likely to have been subsequently recovered or discredited, however remain on the register.

4.9.2 Site-Specific

No abandoned bombs are listed in the vicinity. The closest is approximately 4.6km away.

4.9.3 WW2 Bombing Incident Records Conclusion

- **Number and intensity of local air raids**: a comparison of the available records suggests that just one medium-scale raid (experienced locally as a single aircraft sortie) probably affected a 1km radius around the Site.
- **Number of local bombing incidents**: within Manchester Borough, no bomb strikes occurred within 500m of the Site boundary. Although the available records indicate a low likelihood, the possibility cannot be completely ruled out that a bomb(s) fell within 500m of the east Site boundary, within the adjacent urban district.

- **Local bomb-stick orientations**: the orientation of the one confirmed local bomb-stick does not align with the Site. Furthermore, these bombs fell a significant distance from the Site. This greatly reduces the likelihood that the aircraft responsible dropped a third bomb over the study area (unwitnessed / unrecorded) that landed within the Site boundary and failed to detonate. Note, although unlikely it is not inconceivable that the aircraft changed course and did fly over the Site.

4.10 Aircraft Crash Sites

4.10.1 Brief Overview

Numerous German aircraft came down over the UK during WW2. In most cases, the pilot was able to jettison any remaining bombload prior to impact or the aircraft belly-landed resulting in only superficial damage to the fuselage. However, in some cases, mechanical malfunction and / or crew injury meant bombs were not released. If the aircraft struck the ground at a steep angle and at high velocity, high density objects (engines and bombs) became buried, sometimes to significant depths.

4.10.2 Site-Specific

No Luftwaffe aircraft crashes occurred locally.

5 WW2 Enemy Action Assessment: Other

5.1 V Weapons

5.1.1 Brief Overview

In mid-1944 Germany launched the V1 Flying Bomb campaign. The V1 was a primitive cruise missile carrying an 848kg HE warhead. Between 13th June 1944 and 29th March 1945, V1s were launched from static sites in France and Belgium. 5,823No. missiles landed in England, 2,419No. of which reached London, their intended target.

Not long after, Germany launched the V2 Rocket campaign. The V2 was a primitive ballistic missile carrying a slightly smaller HE warhead (735kg). Between 8th September 1944 and 27th March 1945, V2s were launched from static and mobile sites in Holland. 1,102No. rockets landed in England, 516No. of which hit London, the initial target area. Later on, Norwich was targeted, sustaining 43No. strikes.

Both weapons were constructed of thin sheet steel and consequently had very limited ground penetration ability, if they failed to function. Therefore, V Weapons do not themselves pose a UXO risk, however the damage they caused can hamper the accurate assessment of Luftwaffe UXB risk.

5.1.2 Site-Specific

The closest V1 Bomb landed >3km north of the Site. V weapons can be discounted as a direct UXO hazard (due to the Site's wartime ground conditions) and as an indirect UXO risk indicator.

5.2 Artillery Bombardment

5.2.1 Brief Overview

Six German Navy artillery batteries (comprising 20No. guns of between 21cm and 40.6cm calibre) were established in the German occupied Pas-de-Calais area from July 1940. In addition, the German army brought railway-mounted guns to this area of France, seven of which (six 28.0cm calibre guns and one 21.0cm gun) were capable of striking inland targets in Kent.

The first shells were fired at Kent on the 12th August 1940 with frequent attacks occurring during each of the next four years until the final bombardment on the 26th September 1944. In all, at least 1,000No. attacks (each involving multiple projectiles fired) were recorded, an average of one every two days. The towns of Folkestone, Deal and Dover were targeted, however many shells landed in the surrounding countryside. UXO finds of this type are rare.

5.2.2 Site-Specific

The study area was located beyond the range of the German cross-channel artillery batteries.

6 WW1 Enemy Action Assessment

6.1 Aerial Bombing

6.1.1 Brief Overview

Between December 1914 and August 1918, the German navy air wing and army air wing carried out 51No. Zeppelin airship raids and 52No. fixed-wing aircraft raids (involving multiple aircraft) against England and south-east Scotland. Note, many more attacks involving solitary fixed-wing aircraft occurred. An estimated total of 9,000No. HE bombs and IBs were dropped, with London and the east Kent towns experiencing the most raids. During the four years long campaign, Britain suffered 4,820No. casualties.

The German bombing campaign of WW1 was significantly smaller in scale than the WW2 campaign, in terms of the number of raids, number of aircraft per raid, and size of bombloads (for fixed-wing aircraft). As it was the first time Britain had experienced aerial bombardment, the small-scale daytime attacks often attracted spectators, which increased the chance of any UXB being observed and reported. When combined with the fact that most WW1 bombsites have been redeveloped, c

6.1.2 Site-Specific

Neither Manchester Borough or Cheadle & Gatley Urban District were bombed during WW1.

6.2 Naval Bombardment

6.2.1 Brief Overview

Several coastal towns in Yorkshire, Norfolk, Suffolk, and Kent were subjected to naval bombardment from German warships during seven raids in 1914, 1916 and 1917. These raids varied in intensity, both in terms of duration (number of shells expended) and calibre of artillery employed. The heaviest attack resulted in >1,000No. shells fired, with the lightest raid expending only several rounds. The relatively short firing distances during these bombardments resulted in many shells failing to explode, as there was not enough time for some shells to arm themselves before striking the coast. German WW1 UX naval shell finds are extremely rare.

6.2.2 Site-Specific

The study area was not subjected to naval bombardment during WW1.

7 Domestic Military Activity Assessment

7.1 Sources of Potential Explosive Ordnance Contamination

The table below lists all the modern and historical sites and activities that could have potentially resulted in British / Allied UXO and AXO contamination in the UK.

Source of EO	Examples	Associated EO Hazard Items	Relevance
Military Bases and Installations	Army camps, RAF, RN or USAAF airfields, RN shore establishments, signals or communications installations, military training centres, etc.	Various conventional and chemical EO. The types of EO will depend on the type of site and branch of the military utilising it. Plus AXO (SAA, LSA and AA ammunition) for WW2 site defence, if applicable.	INSIGNIFICANT
Military Training Areas and Weapons Ranges	Inland and costal RAF and USAAF bombing ranges. Army / Royal Marines / RAF Regiment etc weapons ranges.	Various conventional and chemical EO. The types of EO will depend on the type of range / training area and branch of the military utilising it.	INSIGNIFICANT
Munitions and Explosives Factories	Royal Ordnance Factories, National Filling Factories, National Explosives Factories, Royal Naval Cordite Factories, etc.	Various conventional and chemical EO. The types of EO and explosives contamination will depend on the type of factory. Potentially plus AXO (SAA, LSA and AA ammunition) for WW2 defence.	INSIGNIFICANT
Munitions Storage Depots	Royal Naval Armaments Depot, Royal Naval Ordnance Depots, RAF Ammunition Depots, Air Ammunition Parks, Reserve / Forward Ammunition Depots, Central Ammunition Depots, etc	Various conventional and chemical EO. The types of EO potentially present will depend on the branch of the military utilising it. Potentially plus AXO (SAA, LSA and AA ammunition) for WW2 defence.	INSIGNIFICANT
Fortifications and Defence Measures	Pillboxes, fortified houses, various earthworks (e.g. trenches) etc at: Nodal Points, Stop-Lines, VPs, etc.	SAA, regular army LSA, AA ammunition, Flame Fougasse, and Home Guard-specific weapons / ammunition.	**UNLIKELY**
Military Requisitioned Sites: WW1 and WW2	During WW1 and WW2 many private properties were requisitioned by the War Office for military use, including training.	SAA, regular army LSA and Home Guard specific weapons / ammunition.	INSIGNIFICANT
Pipe Mines and Conventional Minefields: WW2	Pipe mines and improvised mines at military bases. Conventional minefields at beaches and some Nodal Points.	Canadian pipe mines, various British landmines (AT and AP) and IEDs.	INSIGNIFICANT
RAF and USAAF Crash Sites	Numerous British and American aircraft crashed in the UK, chiefly during WW2. Munitions and ammunition not always fully recovered.	Various conventional air-delivered ordnance (bombs and rockets) and machine gun / autocannon ammunition.	INSIGNIFICANT
Home Guard Activity: WW2	Volunteer army tasked with home defence during WW2. An armed branch of the British Army. Battalions were active in all British counties.	SAA, regular army LSA, Home Guard specific ammunition e.g. 29mm Spigot Mortar, 3-inch Smith Gun, No.73, No.74, No.75 and No.76 grenades, etc.	**POTENTIALLY SIGNIFICANT**
Anti-Aircraft Weaponry: WW1 and WW2	Light AA (machine gun and autocannon), Heavy AA (QF guns), and ZAA (rocket projectors).	SAA, autocannon shells (20mm, 37mm, 40mm), QF shells (3, 3.7, 4.5-inch), UP rockets (2 and 3-inch).	**POTENTIALLY SIGNIFICANT**

TABLE 6: Sources of Potential Domestic Explosive Ordnance

Potentially significant sources of EO contamination are discussed under **Subheadings 7.2** and **7.3**.

7.2 WW2 Invasion Defence Activities

7.2.1 Brief Overview

From mid-1940, the threat of imminent German invasion resulted in the fortification of many coastlines, cities and towns in Britain. Army units were concentrated in the most vulnerable / likely invasion areas and local Home Guard (HG) battalions were raised throughout the country.

Urban centres were ringed with roadblocks, rail-blocks, pillboxes and anti-tank obstructions. Trenches and weapons pits were dug, barbed wire entanglements were placed and minefields were laid. Such defence measures were also established along inland stop-lines and around the most important vital / vulnerable points (VPs).

The HG comprised men either too old or young, or in reserved occupations. Almost all populated areas in Britain stood up a HG battalion and some organisations (infrastructure organisations and large industrial works) created their own private units.

By mid-1940, over one million had signed up. Initially, only basic and improvised weapons were available, however by mid WW2, weapons specifically designed for the HG (e.g. SIP grenades and the Blacker Bombard spigot mortar) as well as conventional weapons, were widely deployed.

HG soldiers patrolled their areas of responsibility and manned fixed defence positions. They guarded local VPs, aided local Civil Defence when necessary and (later in the war) operated HAA / ZAA batteries. HG units visited military bases and large established training areas to conduct training. A variety of other locations were requisitioned by the War Office for smaller scale ad-hoc training (including live firing of weapons). The HG also participated in anti-invasion training exercises in both urban and rural locations.

Historically, an ‘out of sight out of mind’ culture (with regards to ammunition disposal) has been widespread in the British armed forces (including the regular army and HG). This is evidenced by numerous post-war AXO finds in the UK. Troops appear to have discarded unwanted or faulty items (including surplus ammunition) on civilian land, most likely when the threat from invasion had passed and when the HG was disbanded in 1944. Ammunition caches are also believed to have been buried at defended positions, for quick / easy access in the event of an invasion. Inevitably some were forgotten and can therefore remain in-situ today.

7.2.2 Site-Specific

- The study area was the responsibility of the 47th Lancashire (Wythenshawe) HG Battalion. Although details of this unit’s defence scheme are unavailable, the Site could conceivably have been accessed by armed HG soldiers on patrol and / or during large-scale training exercises.
- Original WW2 army war diaries describing invasion defence activities in the region do not reference the study area.
- No written, mapped, photographic or archaeological evidence of wartime defence measures / fortifications within 1km of the Site boundary has been identified.
- No reference to local land requisitioned by the War Office for ad-hoc military training has been found. As arable land, the Site is highly unlikely to have been a candidate for military requisition.

7.3 British Anti-Aircraft Weaponry

7.3.1 WW1

AA artillery was in its infancy during WW1 and therefore British AA gun deployments were on a far smaller scale than during WW2. Initial activity saw guns installed on top of some buildings and at other key facilities in London and Kent during 1914. By the end of WW1, the London Air Defence Area comprised 286No. guns.

London was the most heavily defended region. Some other cities were defended, however Kent had the most AA batteries outside of the capital. Note, many of Britain's AA guns were not static. Single guns were mounted on trucks and moved around. RN installations also received protection. At the beginning of the conflict, 58No. guns were distributed between naval facilities at Dover, Harwich, Liverpool, the Tyne and the Humber.

The 3-inch QF gun was the mainstay of British AA artillery. UX 3-inch shells typically landed between 8km and 10km away. The smaller calibre 1-Pounder QF autocannon was also used in the LAA role.

7.3.2 WW2

During WW2, the British Army's AA Command utilised three types of AA weapon for home defence: heavy AA (HAA) guns, light AA (LAA) guns, and Unrotated Projectile (UP) rocket projectors. From 1940 to 1945, BD units dealt with approximately 7,000No. UX AA projectiles in the UK, however such UXO is still unearthed today.

- **HAA Guns:** The vast majority of HAA guns (3.7 and 4.5-inch calibre) were deployed in static batteries of between four and eight guns. HAA batteries were used to engage bombers at high altitudes and were the main constituent of most city's (and some town's) Gun Defence Area (GDA). Mobile gun mounts were also available for temporary deployments to key military and civilian targets. Note, a very small number of British 5.25-inch guns were deployed from 1942 onwards, as well as batteries of US Army 90mm guns during 1944.

  Some 2,000No. of these guns were available during the 1940 / 1941 Blitz. GDAs could expend vast quantities of ammunition during each engagement. The most numerous 3.7-inch gun variant had a firing ceiling of approximately 9km. Although a number of factors will have affected the range of falling UX shells, most typically landed 10km to 15km away. Note, greater distances were achievable.

- **LAA Guns:** Smaller calibre guns (machine guns, 20mm and 40mm autocannon) were used for point (individual target) defence of strategic targets / vulnerable points (VPs). At the time, government policy mandated that (where possible) every VP should be protected, however in reality, a chronic shortage of effective LAA guns (autocannon) during the early years meant that only priority VPs received adequate protection. These smaller guns were easily transportable, and LAA regiment deployments were often temporary. British WW2 40mm guns had a firing ceiling of approximately 7.1km. Although a number of factors will have affected the range of falling UX shells, most typically landed <10km away.

- **ZAA Rockets:** A ZAA battery comprised a grid of typically 64No. UP rocket projectors firing single and (later) multiple 2-inch (UP-2) and 3-inch (UP-3) rockets in a volley, creating a 'box of effect' at preselected altitudes. Although a number of factors will have affected the range of falling UX rockets, they typically landed within 10km of the battery.

  Prototype ZAA weapons were fielded in late 1940 and deployed in cities around Britain from 1941. However, they were only deployed in significant numbers after the initial nine-month Blitz campaign had ended. Consequently, ZAA batteries saw far less action than AA guns. By the end of the war, >50No. ZAA batteries were operational across Britain.

7.3.3 Site-Specific

- One static HAA battery (comprising a single 3-inch calibre gun) was active within firing range of the Site during WW1. Some WW1 AA guns were mounted on trucks and therefore mobile. However, these were prioritised for the most vital vulnerable points, none of which were present within firing range of the Site. The lack of air raids over the Greater Manchester area suggests that a negligible quantity of ammunition was expended.

- 19No. static HAA batteries (totalling up to 76No. gun emplacements) were active within firing range of the Site during WW2. Firing between 10No. and 20No. rounds per minute over a frequently and heavily bombed British city, these guns would have expended a very large quantity of ammunition over Greater Manchester. Consequently, there is an elevated likelihood of UX HAA shells striking the Site.
- One LAA battery (defending RAF Ringway) was active within autocannon firing range of the Site. During the 1940 air raids, this airfield was only protected by machine guns (posing no UXO hazard). However, it is possible (although unlikely) that later in the war defences at this base were upgraded to 20mm or 40mm calibre guns. These AA guns probably expended ammunition on a few occasions, with each engagement relatively short. There is a low likelihood that a UX autocannon shell struck the Site.
- Two ZAA rocket batteries were active within firing range of the Site during WW2. However, these appear to have been established during July 1942, after almost all air raids on the region had occurred. Therefore, it is considered highly unlikely that any UX AA rockets fell locally.

7.4 Explosive Ordnance Hazards Overview

7.4.1 Introduction

The following subheadings detail the EO hazards most likely to be relevant to the study area. Note, this is not an exhaustive list of potential local EO contaminates.

7.4.2 Artillery Projectiles: Anti-Armour and Anti-Aircraft

AT guns, AA guns, and howitzers have been in use with the British Army for over a hundred years. The former ranged from the Ordnance QF 2 Pounder (40mm) to the Ordnance QF 17 Pounder (76mm) in calibre. The latter ranged from the Ordnance QF 25 Pounder (87.6mm) to the BL 60 Pounder (127mm). HAA gun calibres are medium. Note, from 1942 / 1943, many HG units were armed with a variety of small / medium calibre AT guns.

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

Solid shot falls into four categories, mainly for gun proofing, target practice, and AT use, however as they are inert they are relatively irrelevant with regards to present day UXO risk. Historically, there were three types of WW2-era British artillery shell:

- **Bursting Type** - The filling (or part of it) caused the shell to burst. The most common filling was HE where the shell caused damage to material by the force of the burst or to personnel and aircraft by fragmentation of the shell casing producing shrapnel. WW2 HAA shells were of the bursting type. Note, bursting shells were also used with chemical fillings.
- **Shrapnel Type** - These usually burst in the air and projected their 'payload' forwards acting like a shotgun. The usual payload was shrapnel bullets however Thermite 'pots' were used during WW1. By the start of WW2 shrapnel shells were obsolete for field artillery.
- **Carrier Type** - These also burst in the air, however ejected their payload backwards after blowing the base plate off the shell. The most common fills used were smoke, star and flare shells. The latter two being designed to illuminate an area or target. Smoke shells were used to produce smoke screens and used various fillings (the most common being white Phosphorus).

Artillery projectiles were always painted, this protected the steel from rust but was also used to indicate the nature of the ammunition. The basic body colours for artillery were; Yellow (HE), Light Green (smoke), Black (Flare / Star) and Grey (chemical). Note, artillery shell fuzes found on their own can also represent a hazard. Although small, such items can contain enough HE to cause serious injury if mishandled.

With regards to HAA shells, British mechanical time-delay and barometric pressure fuzes of WW2 were poorly designed, resulting in high HAA ammunition failure rates (around 30%) during 1940 and 1941. By 1944 however, new fuzes had reduced the rate to approximately 2%.

Unlike bombs, AA shells were not designed to strike the ground nose first and therefore UX AA shell strikes on soft ground did not always create recognisable circular entry holes. This, combined with their lower mass (compared to a UXB) resulted in shallower ground penetration depths, typically <1.0m bgl in soil. Although, in very soft / saturated ground, UX HAA shells were observed to penetrate to >1.5m bgl.

Data sheets detailing examples of this EO type are displayed at **APPENDICES 2** and **3**.

7.4.3 Grenades

Grenades are the most commonly encountered type of WW2-era British LSA in the UK. Other types of LSA include mortars, artillery projectiles (e.g. AT guns), infantry rocket systems and mines (AP and AT).

Hand grenades and rifle (projected) grenades are small devices with a delay fuze that detonates three to five seconds after initiation / launch. They are divided into two categories, explosive (fragmentation or blast) and carrier. The latter are used for signalling (smoke) and incendiary (chiefly white phosphorus for AP and AT use).

A wide variety of grenades have been deployed in the UK historically. The first modern British fragmentation grenade (the Mills Bomb) was used from 1915 onwards, with later models used well into the post-WW2 period. Consequently, this model accounts for the majority of UX grenade finds in Britain. A Mills Bomb (the No.36 grenade in British service) is approximately 95mm x 61mm and contains approximately 71g of HE.

Another common UK grenade find is the No.76 Self-Igniting Phosphorus (SIP) grenade. These cheap and simple devices comprised a glass bottle (152mm x 63mm) containing a composition that reacts with air (when broken) creating an intense white phosphorus incendiary effect (burns hazard). They equipped most HG units during WW2.

Data sheets detailing examples of this EO type are displayed at **APPENDIX 3**.

7.4.4 Mortars

A mortar is a compact infantry support weapon that fires a projectile (mortar bomb) in a high-arcing ballistic trajectory, at low velocity. The first British mortars were used during WW1.

A mortar bomb / round is usually tear-drop shaped or cylindrical, nosed-fused and fitted with its own propelling charge. A small tail fin assembly stabilises the round in flight and a ‘spigot tube’ containing the propellant charge is screwed or welded to the base of the round.

During WW2, the 2-inch and 3-inch calibre mortars were the most commonly used by the British Army. These systems utilised several different types of ammunition (HE, smoke, illumination, signal, chemical and drill). The most commonly deployed round (the 2-inch HE variant) weighed approximately 1kg, 200g of which was the HE bursting charge. As such, mortars pose a hazard similar to grenades.

Data sheets detailing examples of this EO type are displayed at **APPENDIX 3**.

7.4.5 Autocannon Shells

In Britain, two types of autocannon were used in the LAA home defence role by the Royal Artillery and later the RAF Regiment, the Hispano (20mm calibre) and Bofors (40mm calibre). These guns are similar to machine guns, however fire larger calibre rounds at a lower rate of fire (<750 rounds / min and 120 rounds / min, respectively).

Although cannon ammunition looks similar to SAA, these larger projectiles incorporate a small, simple impact fuse and hazardous charge. 20mm projectiles were typically 41mm in length and included a 6g - 11g HE and / or incendiary composition charge. 40mm projectiles were typically 130mm in length and included a 70g HE charge. Although small, when compared to artillery shells, each projectile still has the potential to cause serious injury.

Most WW2 autocannon ammunition incorporated a self-destruct mechanism, detonating the projectile after five seconds if no impact occurred. This resulted in less collateral damage and far less unexploded shells falling back to earth. If this mechanism failed, a UXO strike would occur at ground level.

Data sheets detailing examples of this EO type are displayed at **APPENDIX 2**.

7.4.6 Small Arms Ammunition

SAA (or bullets colloquially) is primarily cartridge-type ammunition with a calibre of <20mm. Each 'round' comprises a cartridge case, projectile (bullet), propellant and primer. Side arms (pistols), rifles and light to heavy machine guns utilise SAA.

Generally, SAA poses a relatively low EO hazard due to the small amount of explosive contained within the cartridge case and the low sensitivity / stable nature of the complete round. Although a cache of unspent rounds subjected to high temperatures (e.g. fire) could function and create a hazard.

Expended SAA (the projectile) is almost always solid shot, i.e. inert. Note, During WW1, experimental incendiary and explosive .303-inch SAA saw limited use with the Royal Flying Core and the RAF. Consequently, such SAA encounters today are very rare.

In the UK, the most commonly encountered historic SAA is .303-inch calibre. This was the standard cartridge used by British and Commonwealth armed forces from 1889 until the 1950s. However, many other calibres have been deployed in the UK by British and Allied forces.

8 Explosive Ordnance Migration

8.1 Introduction

Any fill material deposited on a site is unlikely to be contaminated with EO, as the material will have experienced excavation, transport, and processing during which any large objects are likely to have been observed and removed. However, EO encounters within such material do occur, confirming that items can be missed.

One known reason is WW2 Blitz rubble. The Blitz resulted in vast quantities of bombsite rubble. This material was put to use in a variety of ways. >750,000No. tonnes of London’s rubble were used to build runways for new military airfields and Liverpool’s rubble was used to create and maintain flood defences throughout Merseyside. Blitz rubble was also commonly used for smaller scale construction works, immediately following WW2.

In 2010, two German HE UXBs were encountered in, what was later identified as, Blitz rubble at a Plymouth building site. Such incidents are rare however, and such contamination is much more likely to take the form of smaller items e.g. UX AA projectiles or UX 1kg / 2kg German IBs.

8.2 Site-Specific

There is a very low likelihood that any bombsite rubble was deposited on Site during or post-WW2.

9 Local Explosive Ordnance Encounters

9.1 Introduction

Even if research does not identify potential sources of EO contamination at a given site, knowledge of a recent EO encounter in the vicinity could indicate an elevated risk at that site. EO encounters on civilian land are often reported in the media and therefore a web search of media outlets was carried out.

9.2 Site-Specific

No evidence of an EO incident on or adjacent to the Site has been identified.

However, in March 2013, a dog dug up a WW2-era No.36 type hand grenade in the back garden of a residential property on Peakdale Avenue, Heald Green (410 to 570m east northeast of the Site).

Every year, a small number of items of wartime LSA (e.g. grenades, artillery projectiles, etc) are unearthed in the back gardens of residential properties all over the UK. Most of these finds appear to be the result of previous occupants burying inherited (unwanted) war souvenirs. As the area now occupied by Peakdale Avenue was a couple of agricultural fields bound by residential streets with no evidence of invasion defences nearby, during WW2, it is more likely that this grenade was buried in the garden at a later (post-war) date, and would therefore not be indicative local military activity.

10 Site-Specific Risk Assessment

10.1 Introduction

Two key Site-specific considerations must be assessed, the likelihood of an EO linkage (source-pathway-receptor) becoming complete and the severity of the resulting consequences. The 'likelihood' consideration itself is a function of the likelihood of contamination, the degree of subsequent risk mitigation (if any), the likelihood of encounter and the likelihood of initiation. These factors (in relation to the Site) are assessed at **Subheadings 10.2 to 10.5**.

10.2 The Likelihood of Contamination

10.2.1 Hazard Items

The table below details the most common EO types encountered in the UK today. The / those EO type(s) relevant to the Site (the Site-specific hazard item / items) are:

- German WW2 bombs
- British WW2 AA projectiles
- British LSA and SAA

EO Type	NEQ or Incendiary Hazard	Likely Contamination Depth	Hazard Class
German HE 'iron' bombs	25kg to 220kg HE (most common) 530kg to 990kg HE (least common)	Deep (3.0m to 10.0m+)	**Very High**
German 41kg and 50kg Incendiary 'iron' bombs	13kg incendiary composition or 7kg HE	Shallow / Deep (2.0m to 6.0m)	**High**
British HE HAA Shells and Rockets	1.1kg - 2.2kg HE	Shallow (0.5m to 2.0m)	
Some British HE Land Service Ammunition	1 - 2kg HE	Very Shallow (<1.0m)	

Some British HE Land Service Ammunition	<1kg HE	Very Shallow (<1.0m)	**Moderate**
German 2kg Incendiary + HE Bombs	680g thermite (incendiary) + 100g HE	Very Shallow (<1.0m)	
German 1kg Incendiary Bombs	680g thermite	Very Shallow (<1.0m)	**Low to Moderate**
British HE LAA Autocannon Shells	4g to 70g HE and / or incendiary composition	Very Shallow (<0.5m)	
British Small Arms Ammunition	Small quantity of black powder. Inert projectile or <1g incendiary composition	Very Shallow (<0.5m)	**Low**

TABLE 7: Most Common Hazard Items

10.2.2 Subsequent Detection

There are many variables that affect the likelihood that a German UXO or British UX AA projectile strike was detected and reported, either as it fell to the ground or subsequently. Accurately assessing the precise conditions that existed at a given site >75 years ago is problematic. The most pertinent variables are addressed below.

Historic Ground Cover	
Risk Elevating Ground Cover	Site-Specific Comment
Bombsite: a UXO strike to a building in ruin will likely have remained undetected. The entry hole of a UXO will have been easily obscured under the rubble / debris. However, a small UX AA projectile or UX 1kg / 2kg IB may not have achieved ground penetration, instead coming to rest within the rubble.	n/a
Water: UXO landing in a stream, canal, river, pond, lake or the sea would have been immediately lost beneath the waterline and would not have resulted in any persistent evidence of its incidence.	A very small pond existed in the southeast corner of the Site during WW2.
Soft / Waterlogged / Unconsolidated Ground: a UXO entry hole within marshland, tidal riverbank sediment, tidal coastal sediment / sand dunes, etc will have closed up / collapsed relatively soon after it occurred.	n/a
Dense Vegetation: Peripheral unmaintained vegetation or woodland in an urban location. Or rural forest, heathland, etc. A UXO entry hole within inaccessible vegetation could have been overlooked. Note, WW2-era woodland obscures the view of the ground cover beneath and therefore it must be assumed that vegetation exists beneath the canopy.	The fields on Site appear to have been bound by hedgerows.
Arable Land: a field under dense crop growth or ploughed soil. A UXO entry hole within this dense foliage or broken soil could have been overlooked.	The Site appears to have been occupied by arable farmland during WW2.
Risk Reducing Ground Cover	Site-Specific Comment
Undamaged Building / Structures: any UXO strike would have caused substantial damage and incontrovertible evidence of the incident.	n/a
Undamaged Hardstanding: A UXO strike on historic hard surfacing (roads, pavements, commercial yards, etc) would have created an easily recognisable entry hole.	n/a

Maintained Grass Lawns: a grass lawn known to have been in use throughout WW2 and therefore subject to regular grounds maintenance, e.g playing fields, parkland, sports pitches, golf course fairways. A UXO strike would have created an easily recognisable entry hole.	n/a
Less Easily Assessed Ground Cover Types	Site-Specific Comment
Waste / scrap / aggregate etc storage area: a UXO strike to a heap of unconsolidated material could have collapsed / become obscured. However, if the ground cover beneath was hard surfaced, a large UXB entry hole could have been subsequently observed and reported.	n/a
Wasteland: the ground cover on such land may not be easily identifiable. Weed-covered bare earth or broken up made ground could conceivably obscure a UXO entry hole. Alternatively, a UXO strike to hard unvegetated earth ground could have been recognisable.	n/a
Railway Tracks: a small UXO entry hole within unconsolidated track ballast material in between tracks could conceivably have collapsed. Alternatively, a large UXB strike to rail track would have caused obvious damage.	n/a
Quarry: clay pit, gravel pit, etc. The type and condition of the ground cover might not be easily identifiable. Note, disused quarries could easily become flooded.	n/a

TABLE 8: Historic Ground Cover

Historic Site Occupancy and Access	
UXO Observed as it Occurred	Site-Specific Comment
Air Raid Timing: If most local air raids occurred during the hours of darkness, there is a greater chance that any UXO fall occurred unobserved. If the study area only experienced daylight attacks, there is a greater chance that any UXO strike was witnessed as it occurred.	All local raids occurred during the hours of darkness.
Population Density: If the study area was sparsely populated, there is a greater chance that any UXO strike could occur unobserved. Within a densely populated built up area, the opposite is true. Note however, most people would have been sheltering during large scale night raids.	The study area was sparsely populated during WW2.
Civil Defence and Military Defence: Many vital facilities (factories, dockyards, etc) had their own teams of Fire Watchers tasked with extinguishing small IBs. These observers would have also reported any UXB strikes. AA batteries, searchlight batteries, barrage balloon sites, and Royal Observer Corps posts. Associated personnel would have reported any UXB strikes.	n/a
Civil Defence Requisition: many schools, churches and other public buildings in frequently bombed areas were requisitioned by Civil Defence for use as first aid posts, reception centres and canteens for bombed out civilians. Such buildings were therefore in use during night raids.	n/a
UXO Subsequently Observed	Site-Specific Comment
Bomb Damage: If substantial bomb damage occurred, parts or all of a site would have been abandoned for the remainder of the war. Any subsequent evidence of a UXO strike is more likely to have remained unobserved for a significant period.	n/a

Site Occupancy: If a site was occupied by buildings that survived the war intact, it likely remained inhabited or in use during the bombing campaign. Probably accessed on a daily basis, evidence of a UXO strike is highly unlikely to have gone unreported. Undeveloped sites could have been neglected for significant periods. Any UXO is more likely to have remained unobserved and gone unreported.	As arable land, the Site would have been neglected for long periods.
UXB Searches: the Luftwaffe used delayed-action (DA) bombs, designed to detonate up to 72hrs after impact. As a result, ARP wardens, residents and workers often carried out specific searches for DA / UXB entry holes within the environs of their buildings, following local raids. Undeveloped isolated land is unlikely to have been searched.	Highly unlikely to have been conducted on Site.

TABLE 9: Historic Site Occupancy and Access

10.2.3 Site-Specific Conclusion

- Any German UXB or British UX AA projectile strike on Site could have easily occurred unwitnessed and remained undetected (unreported). Note, the entry hole of any such UXO item could have been obscured by tall and / or dense crop growth, the wider study area was sparsely populated, and all local air raids occurred during the hours of darkness.
- However, although the possibility that a German UXB was released over the Site and landed within its boundary during WW2 cannot be ruled out entirely, bombing incident records analysis suggests that such a scenario is unlikely. There is however an increased probability of unexploded HAA shells striking the Site during WW2.
- Although Home Guard soldiers were active in the local area during WW2, no evidence of such activity affecting the immediate study area has been found and the Site's wartime occupancy indicates a low likelihood that any unrecorded activity affected the Site. Soldiers could conceivably have accessed the Site whilst on patrol or during large-scale cross-country training exercises, however they are unlikely to have carried any hazardous EO (i.e. LSA) during such activities and even less likely to have discarded / buried such EO on arable land.

10.3 Degree of Risk Mitigation

10.3.1 Ground Works

Ground works on an EO contaminated site could have resulted in the partial or complete removal of the buried EO threat. If EO was uncovered during intrusive ground works, the incident would have been reported and dealt with by the armed forces. Note, it is usually not possible to accurately determine the volume of soil disturbance associated with historic or even recent ground works at a given site.

10.3.2 Explosive Ordnance Clearance

EOC was not as effective historically as it is today. Surveys were not always undertaken to set parameters and degrees of certainty. Recent EO finds on land known to have been previously surveyed for EO confirm that older detection equipment was ineffective. Furthermore, some EOC tasks did not result in 100% clearance of all EO, by design. Magnetometer surveys can be calibrated to ignore magnetic anomalies that model under a certain mass.

A standard notice accompanying British Army EOC documentation states that 'the presence of EO can never be completely discounted. Although considered unlikely, there still remains the possibility of buried or stray [EO] items.' EOC tasks are not conducted on all MOD land prior to disposal / sale. An EOC task will only be carried out on land where there is a known risk of EO contamination, e.g. a former firing range.

IAL has access to a database of historic EOC tasks carried out by the British Army's 33 Engineer Regiment EOD (now part of 29 EOD&S Group). However, this database is only complete up until the early 2000s and only provides basic details on each task. Freedom of Information requests lodged by IAL confirm that the MOD will almost always withhold any historic EOC task documentation for civilian sites in the UK.

10.3.3 Site-Specific Conclusion

Ground Works: Post-WW2 / Post Military Use	Site-Specific Comment
EOC Activity: evidence of EOC task(s) affecting the Site. Or, is there an increased chance that the Site has experienced partial or complete EOC?	No.
Phases of Development / Redevelopment: How many phases of ground work have affected the Site?	One.
Greenfield Land: Does the Site contain any significant areas of undisturbed greenfield land?	Possibly - the southwest and northeast extents.
Very Shallow Buried EO: Have any parts of the Site experienced very shallow level soil / made ground disturbance? e.g. demolition works, soil stripping, site enabling works, minor grading works, agricultural ploughing, etc.	Yes. Agricultural ploughing affecting almost the entire Site area and subsequent development works affecting most of the Site area.
Shallow Buried EO: Have any parts of the Site experienced shallow level soil disturbance? e.g. grading works, strip / pad foundations, buried services installation (drainage), etc.	Yes. The footprint of post-war (since demolished) buildings.
Deep Buried German 'Iron' UXBs: Have any parts of the Site experienced deep level soil disturbance? e.g. bulk excavations (basement levels), dense pile layout, installation of large subsurface tanks, cut and fill, etc.	Unlikely (unknown).

Conclusion
Any very shallow buried EO contamination (British SAA, LSA, LAA shells or German 1kg / 2kg IBs) will probably have been unearthed, observed and removed from Site during years of post-war agricultural ploughing, if not, during the subsequent construction works. Any British UX HAA shell contamination beneath existing greenfield land or ground laid to hardstanding post-war is more likely to remain in-situ today, at an approximate depth range of 0.5m to 1.5m bgl. Although unlikely, it is conceivable that such EO could also remain under the footprint of post-war low-rise buildings (since demolished), occupying small volumes of undisturbed WW2-era soil in between strip foundation trenches. Any deep buried EO (chiefly German HE bombs weighing ≥50kg) is highly likely to remain in-situ today, as the likelihood that such EO contaminated the Site in the first instance, is low.

TABLE 10: The Degree of Risk Mitigation: Site-Specific Comments

10.4 The Likelihood of Encounter

10.4.1 Introduction

The likelihood of an EO encounter at a given site will vary depending on the hazard items, the EO burial depth and the type(s) of intrusive methodology employed. The greater the volume of soil disturbed within the Zone of Potential EO Contamination (ZPC), the greater the likelihood of an EO encounter.

Most domestic AXO and UXO (LSA and SAA), British UXAA projectiles and small (1kg and 2kg) German IBs will typically be encountered at very shallow or shallow burial levels (<1.0m and <2.0m). Whereas heavy German 'iron' bombs will typically be encountered at deeper levels.

The ZPC is defined as the site-specific volume of soil which could contain EO. The size of a ZPC will depend on the history of the site. At a site where the hazard items are German UXBs only, the ZPC will exist between just below WW2 ground level and the maximum BPD. Alternatively, at an active military site where the threat items are known to be British AXO only, the ZPC will exist between just below present-day ground level and approx. 1.0m bgl.

The smaller the mass of the individual EO threat item, the shallower the likely 'as found' depth, generally speaking. There are however some noteworthy exceptions regarding German 'iron' UXBs. In extreme cases, heavy UXBs can be encountered at shallow depths (see **Subheading 4.2.5**).

10.4.2 Bomb Penetration Depth Calculations

To calculate BPDs for a given site, one must make assumptions based on the most likely bomb impact scenario:

- **Impact Velocity:** The majority of German HE bombs dropped on the UK resulted from large-scale carpet-bombing raids. These attacks were carried out at altitudes exceeding 5,000m which would have resulted in a 500kg HE UXB impacting the ground at approximately 260m/s.
- **Impact Angle:** Luftwaffe high altitude bombing resulted in bomb impact angles of 10 to 15 degrees from the vertical. Note, it will be assumed that the bomb was stable at the point of impact.
- **Bomb Design:** Some larger German bombs had metal 'Kopfrings' fitted around the nose of the bomb to limit ground penetration. It must be assumed that no such retarder units were fitted.

10.4.3 Site-Specific Maximum Bomb Penetration Depth

The likelihood of German 'iron' UXB contamination of the Site is not significantly elevated. Therefore, a Site-specific calculation of the maximum BPD unnecessary.

Note, BGS data states that the Site is underlain by approximately 4.0m of glacial Diamicton (gravelly sand and gravelly sandy clay) above >4.0m of mudstone bedrock. Any UX HAA shell striking the Site during WW2 would probably have fully penetrated the (presumably) thin band of topsoil, coming to rest within the Diamicton layer.

10.4.4 Site-Specific Conclusion

- The EO contamination risk is uniform across the Site area, although the likelihood that EO remains in-situ today is greater within the southwest and northeast areas of existing green space. As proposed building footprints are planned for these areas, risk pathways will be created during associated ground works, exposing them to a potential EO encounter (chiefly a British HAA shell within natural soil at a depth within 1.5m of the current ground level). Note, the possibility of such a EO encounter cannot however be completely discounted within the brownfield areas of the Site also.
- The anticipated SI will disturb a much smaller volume of soil / geology within the ZPC than the subsequent development works. As such, there is a much lower likelihood of encountering anything buried (e.g. EO) during this initial phase of works.
- Boreholes and piling may be required. These works raise the possibility of encountering the most severe EO hazard, a very heavy (deep buried) German UXB. However, the likelihood of such EO remaining on Site today is low.
- There is a very low likelihood of encountering EO within the post-WW2 created made ground on Site.

10.5 The Likelihood of Initiation

10.5.1 Introduction

The likelihood of initiating EO depends on the type of EO and how aggressively it is encountered. Various types of EO buried in the UK require an impact, vibration or heat to initiate. Most EO contains a fuze and most fuzes contain a small quantity of shock-sensitive primary explosive. An impact to a fuze can therefore cause it to initiate, in turn detonating the main explosive charge.

German UXBs buried in the UK do not spontaneously self-detonate. The vast majority of German WW2 'iron' bombs contained an electrical fuze. Decades of burial (exposure to environmental conditions) will have caused these fuzes to corrode and lose their electrical charge. Consequently, during any such UXO encounter, it would be almost impossible for the fuze to initiate via its original (electrical) explosive train.

In theory, German UXBs could still initiate if the bomb were impacted with enough force. Percussive piling and bore-holing are engineering works that could impart enough force to detonate the main explosive charge of an EO, without requiring the fuze to function. Furthermore, the 'blind' nature of these intrusions elevates the likelihood of an EO impact.

Excavators and loaders impart less energy via their buckets and site workers might be able to notice a partially unearthed EO and halt works prior to an impact. For these reasons, IAL conducts separate risk rating calculations for different intrusive methodologies.

During WW2, the Allied air forces used mechanical (not electrical) fuzes, which pose a greater long-term UXB hazard on the continent. Furthermore, in Germany, 1No. buried Allied WW2 HE bomb per year (on average) self-detonates due to degradation of the chemical detonator in its time-delay fuze.

Sensitive types of EO include German 2kg (mechanically fuzed) 'Butterfly' bombs, types of British (mechanically fuzed) unexploded LSA ('blind' / 'dud' items), and bombs with chemical time-delay fuzes.

10.5.2 Site-Specific Conclusion

- There is no reason to believe that the Site-specific hazard items are more sensitive to an initiation when compared to similar EO contamination elsewhere in the UK.
- As 'blind' and potentially percussive intrusive methodologies, borehole and piling works would be at a greater risk of initiating EO (chiefly a German HE UXB), when compared to 'open' mechanical excavations.
- A borehole / pile drill head striking a relatively small, unexploded AA shell occupying shallow depth relatively soft / uncompacted soil is more likely to result in a glancing blow that pushes the EO device to one side, dissipating much of the force. Such a strike on a large / heavy German bomb occupying stiffer (deeper) geology would presumably not have the same effect. This perhaps limits the likelihood of initiating the primary Site-specific hazard item (a HAA shell) during the borehole and (any subsequent) piling works.

11 The Historical Record: Extent and Accuracy

11.1 Introduction

The availability of key documents and data will affect the completeness and accuracy of the Site-specific risk assessment. Furthermore, historical records can sometimes be proven inaccurate, when compared with other records. Some inaccuracies could significantly affect the outcome of a risk assessment and therefore a Site-specific review must be conducted.

11.2 Site-Specific

No significant inconsistencies between the records have been identified. The lack of a complete record identifying bombing incident locations within Cheadle & Gatley Urban District is not considered to be significant. Analysis of the other available records suggests a low likelihood that additional bombs (not highlighted as part of this risk assessment) fell within 500m of the Site's eastern boundary. Consequently, IAL is confident that an accurate risk assessment can be conducted.

12 Site-Specific Risk Calculation

12.1 Introduction

The first stage of the semi-quantitative risk model considers potential sources of buried EO on Site. The next stage evaluates the possible linkages, identifying whether significant harm could occur (as a result of the proposed Site works) and the impact of such harm. To provide a numerical evaluation of risk, the two key considerations must be assigned a score and then multiplied together to provide a final risk rating / risk level:

- The likelihood of an EO linkage becoming complete: **FACTOR 3** (= Factors 1 x 2)
- The severity of the consequence(s) resulting from this linkage completion: **FACTOR 6** (= Factors 4 x 5)

12.2 Factor 1 (F1): Explosive Ordnance Presence

The Likelihood of EO contamination of the Site combined with the degree of subsequent risk mitigation. This factor is described and scored in the table below.

Classification	Example Descriptions	F1 Rating
Impossible	No EO contamination due to complete subsequent excavation / removal of the ZPC.	**0**
Highly Unlikely	EO contamination is highly unlikely to have occurred. Most of the ZPC subsequently excavated or EOC task(s) have been conducted.	**1**
Unlikely	EO contamination is unlikely to have occurred. Part of the ZPC subsequently excavated or EOC task(s) have been conducted.	**2**
Possible	EO contamination could have occurred. Part or none of the ZPC subsequently excavated.	**3**
Likely	EO contamination is likely to have occurred. Only a fraction or none of the ZPC subsequently excavated.	**4**
Almost Certain	Confirmed evidence of local EO contamination. Greenfield land / ZPC remains undisturbed.	**5**

TABLE 11: Factor 1 Scoring

12.3 Factor 2 (F2): Explosive Ordnance Initiation

The likelihood of encountering EO during the proposed works combined with the likelihood of initiating EO during the proposed works. This factor is described and scored in the table below.

Classification	Example Descriptions	F2 Rating
Impossible	The ZPC will not be disturbed during the proposed ground works.	**0**
Highly Unlikely	Fraction of the ZPC will be intruded / excavated. Hand-dug trial pits. Vegetation clearance / soil stripping. Hazard items include relatively insensitive EO.	**1**
Unlikely	Part of the ZPC will be intruded / excavated. Mechanically excavated trial pits. Shallow excavations for traditional foundations. Piling or boreholes. Hazard items include relatively insensitive EO.	**2**
Possible	Moderate to high intrusion / excavation of the ZPC. Large-scale shallow excavations for traditional foundations. Single basement level construction. Piling or boreholes. Hazard items include relatively insensitive and possibly sensitive EO.	**3**
Likely	Almost the entire ZPC will be excavated. Multi-level basement construction. Large scale piling works (including percussive piling). Hazard items include sensitive EO.	**4**
Almost Certain	The entire ZPC will be excavated. Multi-level basement construction. Large scale piling works (including percussive piling). Hazard items include highly sensitive EO.	**5**

TABLE 12: Factor 2 Scoring

12.4 Factor 3 (F3): Calculating the Likelihood of an Explosive Ordnance Initiation Event

The table below includes the calculations of 'Likelihood' and descriptions of the resulting scores.

F1 x F2 = F3	Classification	Example Descriptions	F3 Rating
F3 = 0	**Impossible**	Confirmed evidence that no EO is present or no pathway to sensitive receptors present.	**0**
F3 = 1 to 4	**Highly Unlikely**	EO is highly unlikely to be present. No pathway to sensitive receptors present. Initiation of EO is highly unlikely.	**1**
F3 = 5 to 8	**Unlikely**	EO is unlikely to be present. There is an established pathway to sensitive receptors. Initiation of EO unlikely.	**2**
F3 = 9 to 13	**Possible**	EO could be present. There is an established pathway to sensitive receptors. Initiation of EO is unlikely but possible.	**3**
F3 = 14 to 20	**Likely**	EO is likely to be present. There is an established pathway to sensitive receptors. Initiation of EO could occur.	**4**
F3 = 21 to 25	**Almost Certain**	Confirmed evidence of EO contamination. There is an established pathway to sensitive receptors. Initiation of EO is likely.	**5**

TABLE 13: Factor 3 Scoring

12.5 Factor 4 (F4): Explosive Ordnance Event Magnitude

The potential hazard associated with each hazard item combined with the likely depth of EO initiation. This factor is described and scored in the table below.

Classification	Example Descriptions	F4 Rating
None	British military training device (inert).	**0**
Very Small	British SAA at depth. 1kg German bomb at depth.	**1**
Small	British LSA or HAA projectile at depth. British LAA projectile near the surface. 2kg German bomb at depth. 1kg German bomb near the surface. British SAA near the surface.	**2**
Medium	British LSA or HAA projectile near the surface. 2kg German bomb near the surface. Medium German 'iron' bombs at depth.	**3**
Large	Large German 'iron' bombs at depth. Medium German 'iron' bombs near the surface.	**4**
Very Large	Large German 'iron' bombs near the surface.	**5**

TABLE 14: Factor 4 Scoring

12.6 Factor 5 (F5): Sensitive Receptors

The presence and sensitivity of receptors in the vicinity at the time of the proposed works. This factor is described and scored in the table below.

Classification	Example Descriptions	F5 Rating
Single	Plant / equipment.	**1**
Few	Human, plant / equipment.	**2**
Medium	Human, plant / equipment, buried services.	**3**

Most	Human, plant / equipment, buried services, buildings.	**4**
All	Human, plant / equipment, buried services, buildings, listed buildings, scheduled ancient monuments, protected environment (e.g. TPO).	**5**

TABLE 15: Factor 5 Scoring

12.7 Factor 6 (F6): Calculating the Consequence of an Explosive Ordnance Initiation Event

The table below includes the calculations of 'Consequence' and descriptions of the resulting scores.

F4 x F5 = F6	Classification	Example Descriptions	F6 Rating
F6 = 0	**None**	Contact with inert military device. No initiation event. No risk to human health or damage sustained.	**0**
F6 = 1 to 4	**Insignificant**	Very small magnitude inadvertent initiation at depth. Possible cosmetic damage to plant. No risk to human health or buildings damaged.	**1**
F6 = 5 to 8	**Mild**	Small magnitude inadvertent initiation. Possible damage to plant. Possible risk to human health (minor first aid injury).	**2**
F6 = 9 to 13	**Moderate**	Medium magnitude inadvertent initiation. Damage to plant. Possible damage to buried services. Possible cosmetic damage to buildings. Possible risk to human health (minor injury).	**3**
F6 = 14 to 20	**Severe**	Large magnitude inadvertent initiation. Severe damage to plant, buried services and buildings. Fatality and / or severe injuries.	**4**
F6 = 21 to 25	**Catastrophic**	Large magnitude inadvertent initiation. Catastrophic damage to plant, buried services and buildings (including listed buildings, scheduled ancient monuments, etc). Multiple fatalities and severe injuries.	**5**

TABLE 16: Factor 6 Scoring

12.8 Calculating the Final Risk Level(s)

The 'Likelihood' and 'Consequence' factors are combined in the risk matrix below to produce a final risk score.

		Consequence (F6)						
		0	**1**	**2**	**3**	**4**	**5**	
Likelihood (F3)	**5**	**0**	**5**	**10**	**15**	**20**	**25**	Final Risk Score
	4	**0**	**4**	**8**	**12**	**16**	**20**	
	3	**0**	**3**	**6**	**9**	**12**	**15**	
	2	**0**	**2**	**4**	**6**	**8**	**10**	
	1	**0**	**1**	**2**	**3**	**4**	**5**	
	0	**0**	**0**	**0**	**0**	**0**	**0**	

Final Risk Rating (score)						
0 - 1	**2 - 5**	**6 - 9**	**10 - 12**	**15 - 16**	**20**	**25**
Very Low	**Low**	**Low-to-Moderate**	**Moderate**	**Moderate-to-High**	**High**	**Very High**
Risk Levels						

TABLE 17: Risk Matrix

12.9 Conceptual Site Model

Site-specific risk model calculations have identified one risk zone. The conceptual model is displayed below. Note, in lieu of detailed information regarding the scope of the proposed ground works, average / standard values have been used.

	Low-to-Moderate Risk Table						
	Hazard Item	Pathway	Receptor	Likelihood (F3)	Consequence (F6)	Final Risk Rating	Risk Level
German	**WW2 'iron' HE Bombs**	SI works. Blast + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:2)	**4** (F4:4 x F5:4)	**4** (1 x 4)	**Low**
		Piling. Blast + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:3)	**4** (F4:4 x F5:4)	**4** (1 x 4)	
		Mech excavations. Blast + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:3)	**4** (F4:4 x F5:4)	**4** (1 x 4)	
	WW2 'iron' Incendiary Bombs	SI works. Blast + frag + heat.	Human, Plant, Structures.	**1** (F1:1 x F2:2)	**4** (F4:4 x F5:4)	**4** (1 x 4)	**Low**
		Piling. Blast + frag + heat.	Human, Plant, Structures.	**1** (F1:1 x F2:3)	**4** (F4:4 x F5:4)	**4** (1 x 4)	
		Mech excavations. Blast + frag + heat.	Human, Plant, Structures.	**1** (F1:1 x F2:3)	**4** (F4:4 x F5:4)	**4** (1 x 4)	
	WW2 1kg and 2kg Incendiary + HE Bombs	SI works. Blast + heat.	Human, Plant	**1** (F1:1 x F2:2)	**3** (F4:3 x F5:3)	**3** (1 x 3)	**Low**
		Piling. Blast + heat.	Human, Plant	**1** (F1:1 x F2:2)	**3** (F4:3 x F5:3)	**3** (1 x 3)	
		Mech excavations. Blast + Heat.	Human, Plant.	**1** (F1:1 x F2:3)	**3** (F4:3 x F5:3)	**3** (1 x 3)	
British	**WW2 Anti-Aircraft Projectiles**	SI works. Blast + frag.	Human, Plant, Structures.	**2** (F1:3 x F2:2)	**3** (F4:3 x F5:3)	**6** (2 x 3)	**Low-to-Moderate**
		Piling. Blast + frag.	Human, Plant, Structures.	**2** (F1:3 x F2:2)	**3** (F4:3 x F5:3)	**6** (2 x 3)	
		Mech excavations. Blast + frag.	Human, Plant, Structures.	**3** (F1:3 x F2:3)	**3** (F4:3 x F5:3)	**9** (3 x 3)	
	Land Service Ammunition	SI works. Blast + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:2)	**3** (F4:3 x F5:3)	**3** (1 x 3)	**Low**
		Piling. Blast + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:3)	**3** (F4:3 x F5:3)	**3** (1 x 3)	
		Mech excavations. Blast + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:3)	**3** (F4:3 x F5:3)	**3** (1 x 3)	
	Small Arms Ammunition	SI works.	Human.	**1** (F1:1 x F2:1)	**1** (F4:1 x F5:1)	**1** (1 x 1)	**Very Low**
		Piling.	Human.	**1** (F1:1 x F2:1)	**1** (F4:1 x F5:1)	**1** (1 x 1)	
		Mech excavations.	Human.	**1** (F1:1 x F2:2)	**1** (F4:1 x F5:1)	**1** (1 x 1)	

TABLE 18: Low-to-Moderate Risk Table

13 Risk Mitigation

13.1 ALARP Principle

ALARP is a risk principle associated with the Health and Safety at Work Act 1974. It is used in the regulation and management of construction industry risks and states that risk must be averted unless there is a gross disproportion between the costs and benefits of doing so.

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

13.2 Risk Levels and Risk Tolerance

The table below outlines the relationship between final risk scores / levels (the output of the IAL semi-quantitative risk model), risk tolerance and the available industry standard risk mitigation measures. An elevated UXO risk should always be reduced to ALARP level.

Risk Level	IAL Recommendation	Risk Tolerance	Mitigation Measures
Very High	**Proactive** mitigation measures considered essential	Intolerable risk level in all but extreme circumstances.	► EOD Engineer supervision of ground works ► Magnetometer surveying prior to ground works ► Explosive Ordnance Safety & Awareness Briefing(s) ► Explosive Ordnance Site Safety Instructions
High			
Moderate-to-High	**Proactive** mitigation measures recommended	Intolerable level of risk where risk mitigation to ALARP is cost effective. A client may consider the risk tolerable due to impracticability of the available risk mitigation measures or disproportionately high cost of mitigation.	
Moderate		Tolerable risk level providing the recommended mitigation measures have been adopted.	
Low-to-Moderate	**Reactive** mitigation measures recommended	Possibly tolerable risk level, however **reactive** risk mitigation measures would be the prudent course of action. For sensitive, high value sites, a zero-tolerance policy may exist, mandating **proactive** risk mitigation measures.	► Explosive Ordnance Safety & Awareness Briefing(s) ► Explosive Ordnance Site Safety Instructions
Low	**Reactive** mitigation measures considered prudent (not recommended)	Likely to be a tolerable risk level for most clients. However, adoption of the basic precautionary mitigation measure would be the prudent (and very cost effective) course of action, especially for greenfield sites.	► Explosive Ordnance Safety & Awareness Briefing(s) considered prudent. ► Explosive Ordnance Site Safety Instructions considered prudent.
Very Low	No mitigation measures	N/A	N/A

TABLE 19: Risk Levels and Risk Tolerance

13.3 Site-Specific Recommendation(s)

The following table describes the available industry standard risk mitigation measures and identifies those (if any) that are recommended to reduce an elevated risk to ALARP level.

Mitigation Measure	Appropriate For	Site-Specific
Explosive Ordnance Site Safety Instructions: EO Safety Instructions (compiled by an EO specialist) provide a written record of the key points that make up an EO Safety & Awareness Briefing. Including instructions on making a preliminary suspicious object threat assessment, a visual catalogue of commonly found EO types, and the steps to take in the event of a potential EO find. The instructions should be included within the site-specific Health & Safety Manual.	► Provided to Site personnel prior to commencement of excavations. ► Not appropriate for 'blind' intrusions (e.g. boreholes)	**Recommended** In support of development phase grounds works only.
Explosive Ordnance Safety & Awareness Briefings: All personnel conducting ground works on Site should receive this briefing. It should feature as a key element of the CDM Regulations 2015 Health & Safety training package for the site. The briefing should be conducted by a trained EO specialist. Such briefings instruct recipients in the identification of EO hazards and actions to be taken in the event of an EO incident.		**Recommended** In support of SI phase and development phase grounds works.
Explosive Ordnance Disposal (EOD) Engineer Supervision: An EOD engineer (banksman) providing a 'watching brief' of mechanical excavations. Any suspicious objects will be quickly identified, allowing works to continue if the object is not EO. This reduces the risk of delays to the project. EOD engineers can use portable / handheld magnetometer instruments to scan ground ahead of boreholes.	► SI (including some boreholes) ► Small volume earthworks on greenfield land ► Excavations within made ground	**Not Recommended**
Intrusive Magnetometer Probe Survey: A range of intrusive magnetometer methodologies can be deployed. Which equipment is most appropriate will depend upon the ground conditions and site access. This survey will scan the ground down to the maximum bomb penetration depth and therefore is the most appropriate option for clearing pile locations ahead of 'blind' piling works. Multiple overlapping surveys can be conducted, providing matrix clearance of made ground, e.g basement dig.	► Pile locations ► Boreholes ► Large volume earthworks on brownfield land	**Not Recommended**
Non-Intrusive Magnetometer Survey: A range of non-intrusive magnetometer survey methodologies can be deployed to survey ground to a limited depth. Such surveys can typically detect a 50kg 'iron' bombs at a depth of 4.5m bgl, providing the ground is 'magnetically clean'. Such surveys are not appropriate for brownfield land where 'magnetic noise' will result in unusable data.	► Large volume earthworks on magnetically clean land	**Not Recommended**

TABLE 20: Recommendations for Risk Mitigation

Figures: 1 - 5



Figure: 01.0

Figure Title:
Recent Aerial Photograph

Legend:

Approx. Site boundary

Notes:

Source: Google

N

Project: Atlas Park Development, Wythenshawe

Client: Aviva Life and Pensions UK Limited

Doc Ref: DRA.10073.22 **Version: 3**

IMPARTIAL ASSESSMENTS

Explosive Ordnance Risk Assessments

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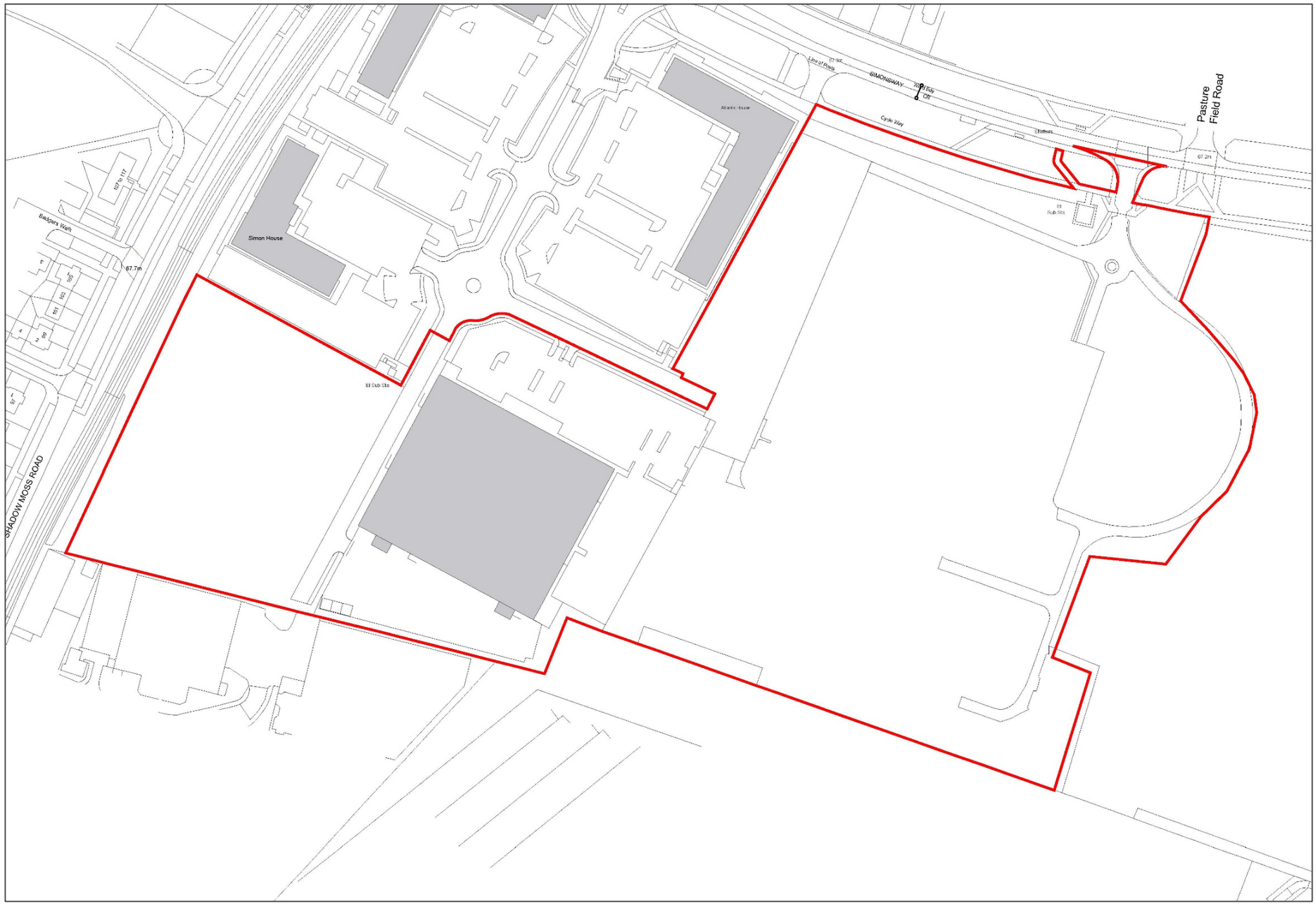


Figure: 02.0

Figure Title:
Existing Site Plan

Legend:

Site boundary

Notes:

Source: Aviva Life and Pensions UK Limited

N

Project: Atlas Park Development, Wythenshawe

Client: Aviva Life and Pensions UK Limited

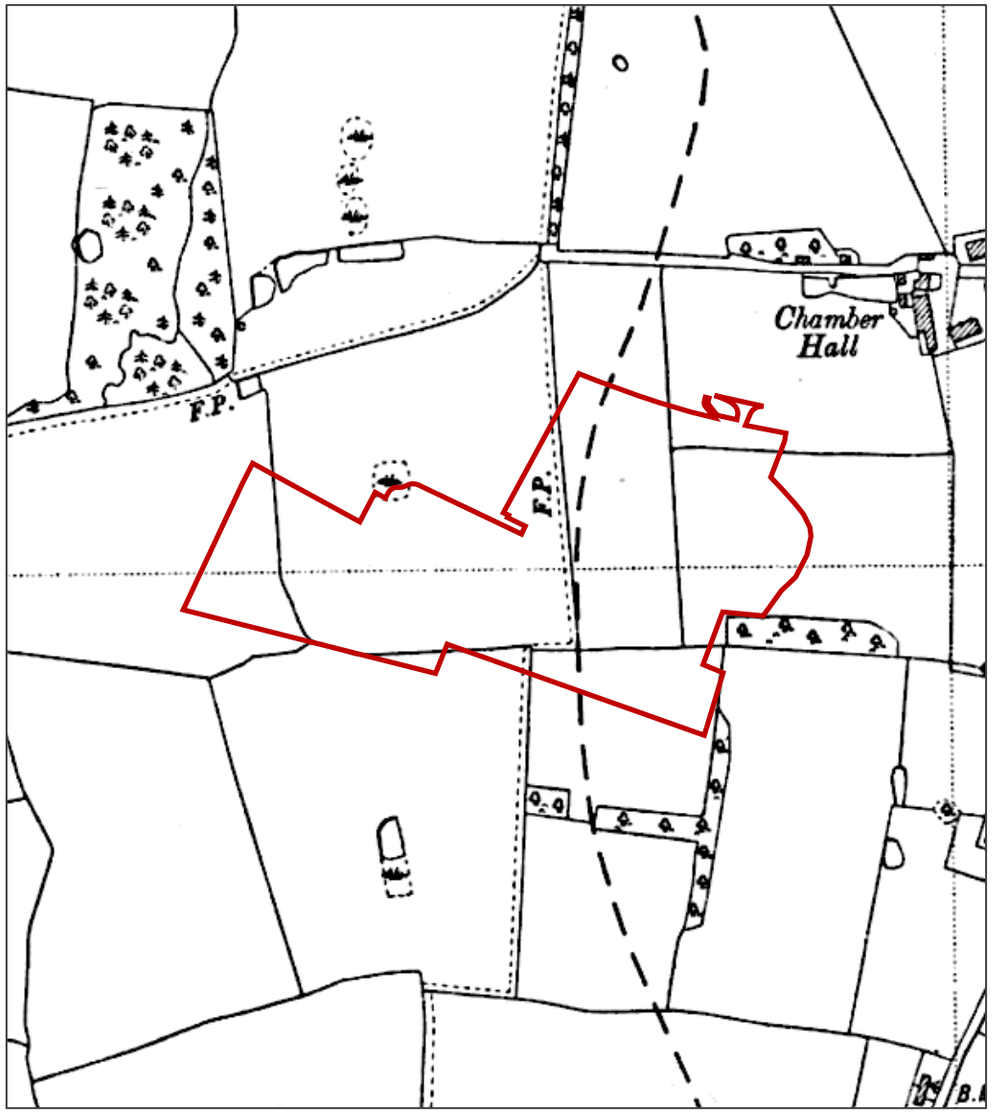
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1938



1954

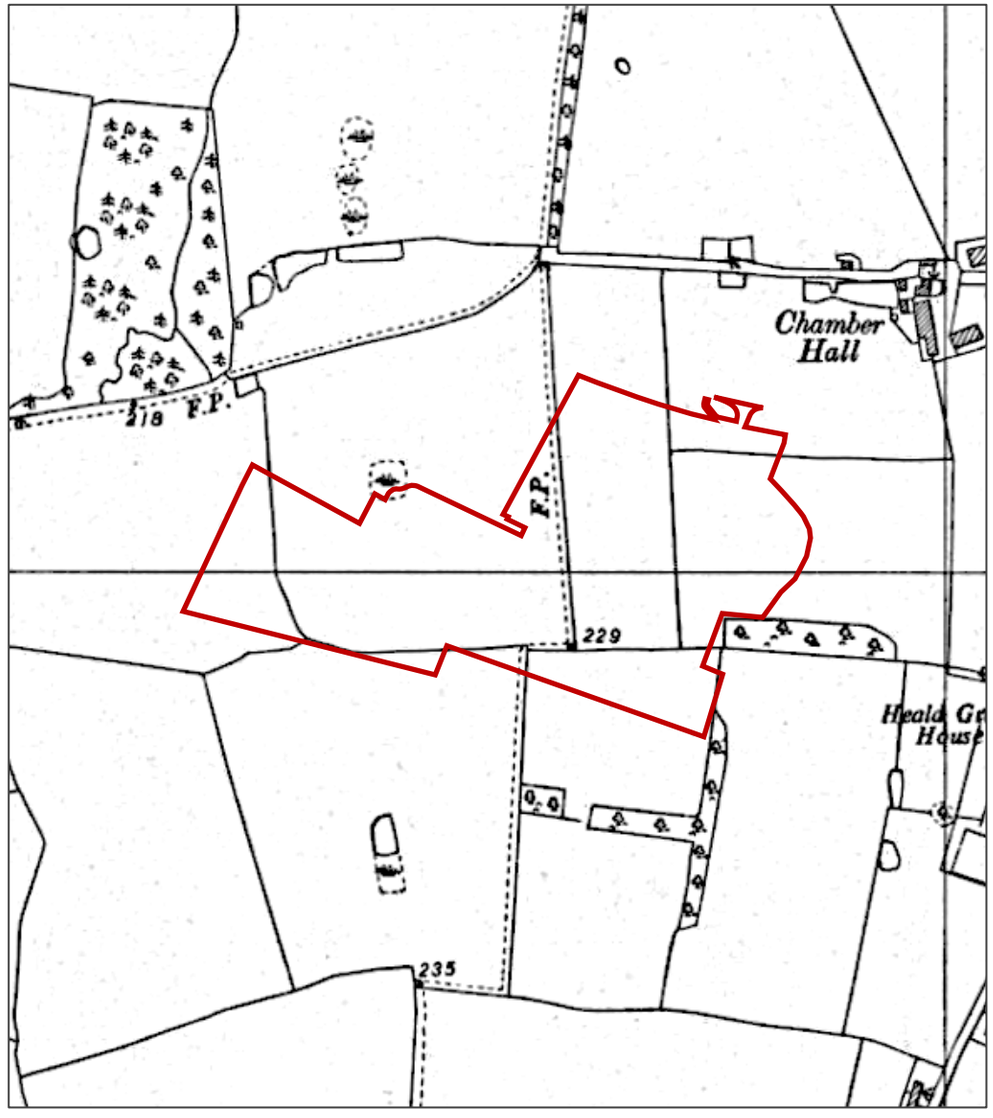


Figure: 03.0

Figure Title:
Historic OS Mapping

Legend:

Approx. Site boundary

Notes:

Latest pre-WW2 and earliest post-WW2 OS maps comparison.

Source: Groundsure

N

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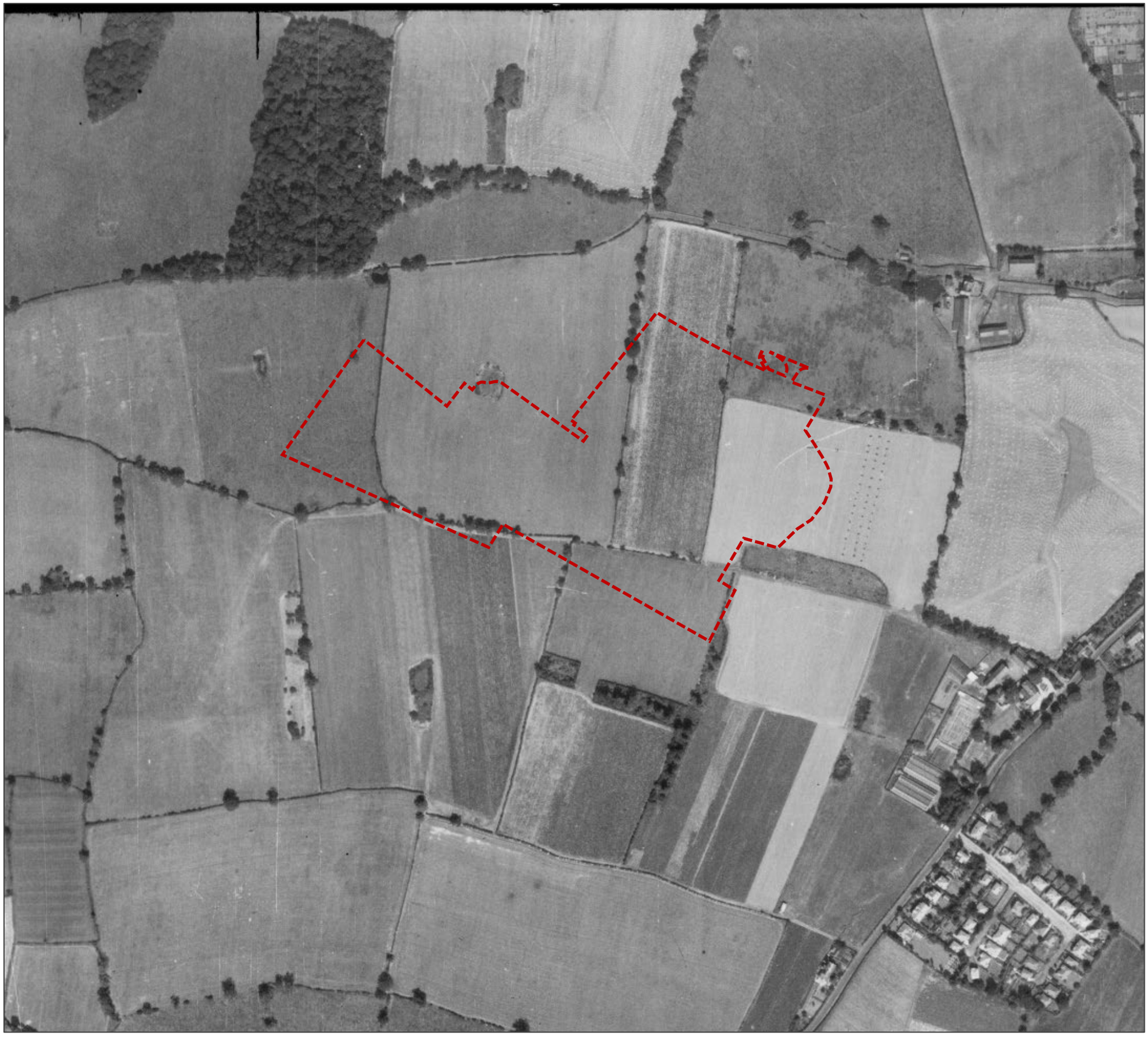


Figure: 04.0

Figure Title:
Historic Aerial Photography: August 1945

Legend:

Approx. Site boundary

Notes:

Source: Historic England

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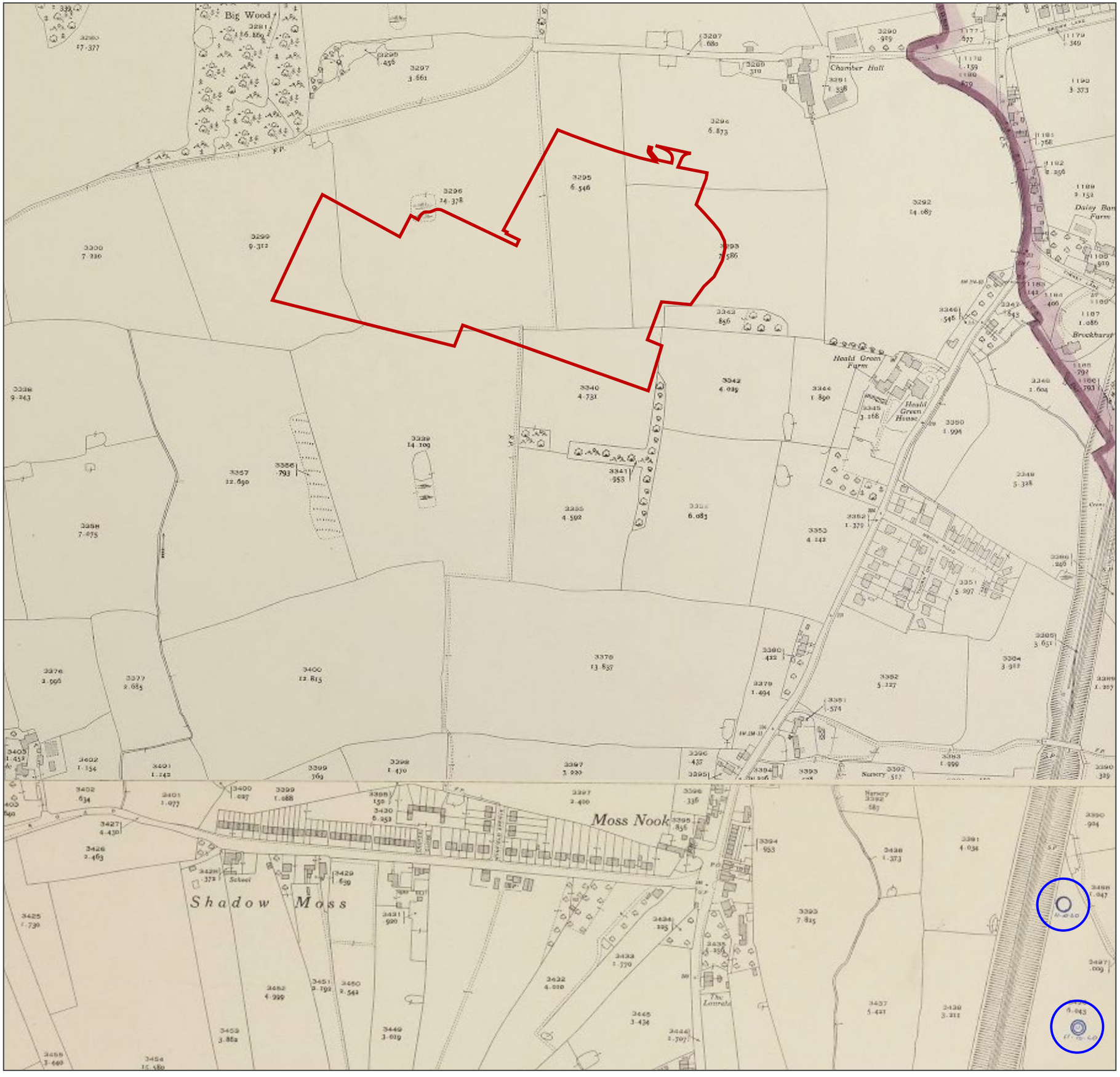


Figure: 05.0

Figure Title:
Manchester Bomb and Damage Plot Map

Legend:

- Approx. Site Boundary
- HE bomb strike

Notes:

Source: University of Manchester

N

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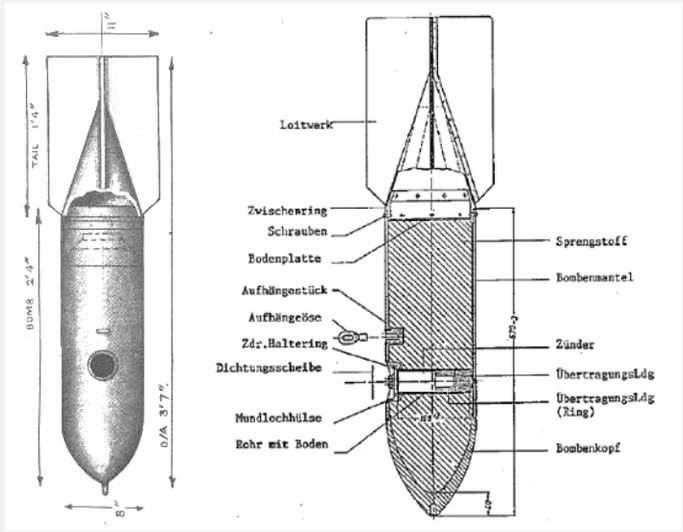
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Appendices: 1 - 4

German WW2 High Explosive ‘Iron Bombs’ - most likely to be encountered

SC 50

Bomb Weight:	54kg (119lb)
Explosive Weight:	25kg (55lb)
Filling:	TNT, Amatol or Trialen
Charge/Weight Ratio:	46%
Fuze Type:	Side fuzed. Electrical impact or mechanical delay
Body Dimensions:	670 to 762mm x 203mm
Material:	Steel
Appearance:	Grey/green with yellow stripe on the tail unit
Variants:	Grades I, II and III. Body length / construction

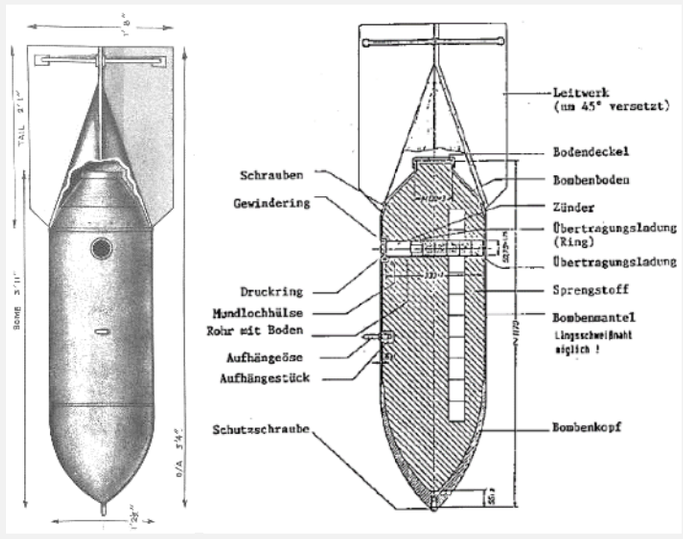






SC 250

Bomb Weight:	256kg (564lb)
Explosive Weight:	125 to 130kg (276 to 287lb)
Filling:	TNT, Amatol or Trialen
Charge/Weight Ratio:	44%
Fuze Type:	Side fuzed. Electrical impact or mechanical delay
Body Dimensions:	1,173 to 1,193mm x 368mm
Material:	Steel
Appearance:	Grey/green with yellow stripe on the tail unit
Variants:	Grades I and II. Body length and doubled fuzed type

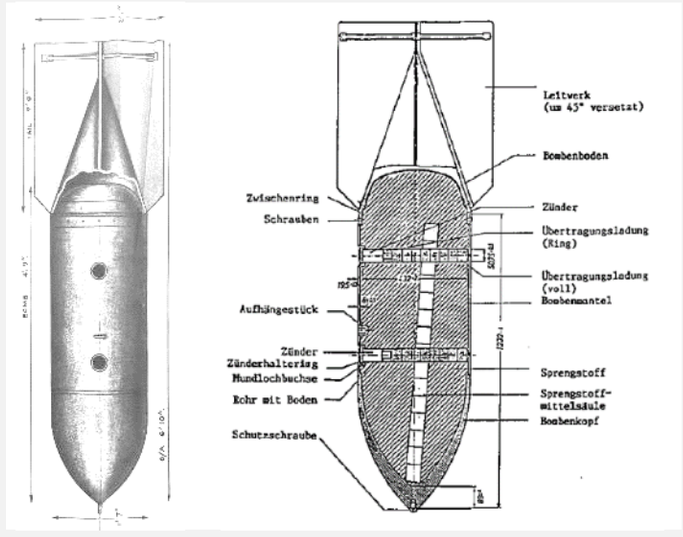






SC 500

Bomb Weight:	480 to 520kg (1,058 to 1,146lb)
Explosive Weight:	220kg (485lb)
Filling:	TNT, Amatol or Trialen
Charge/Weight Ratio:	44%
Fuze Type:	Side fuzed. Electrical impact or mechanical delay
Body Dimensions:	1,414 to 1,486mm x 470mm
Material:	Steel
Appearance:	Grey/green or buff with yellow stripe on the tail unit
Variants:	Grades I, II and III. Body length / construction







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Appendix: 01.1

Appendix Title:
Data Sheets - Commonly Deployed German WW2 Bombs

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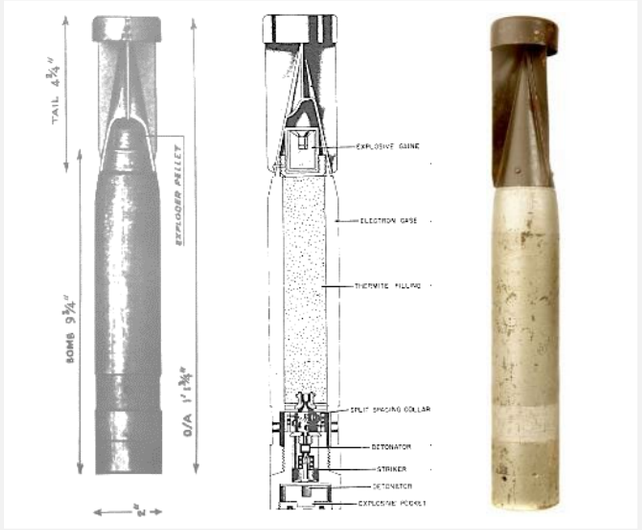
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German WW2 Incendiary Bombs - most likely to be encountered

B1 Series Sub-Munition

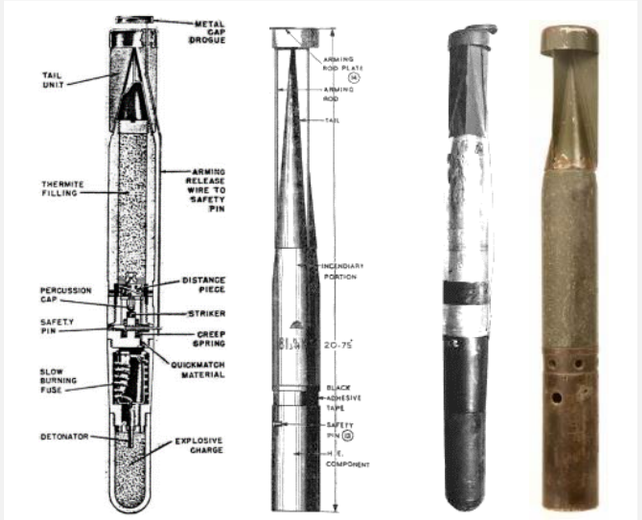
Bomb Weight:	1.0 to 1.3kg (2.20 to 2.87lb)
Incendiary Weight:	680g
Filling:	Thermite
Fuze Type:	Nose fuzed, impact
Body Dimensions:	247mm x 50mm
Material:	Magnesium alloy body, steel tail
Appearance:	Grey body, dark green tail unit
Variants:	Four types. Two delayed action and one steel nosed
Bomb Container:	Various sizes holding between 36No. and 620No. B1s

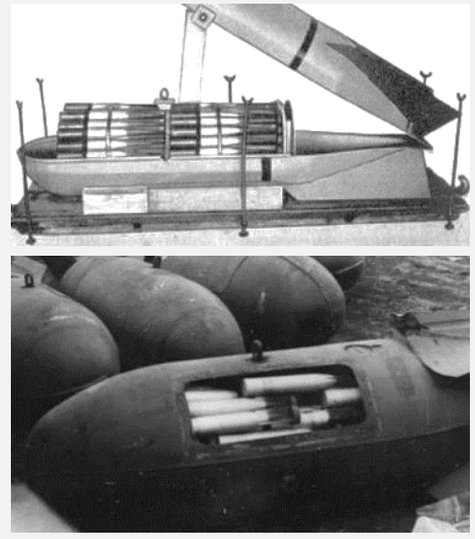




B2 Series Sub-Munition

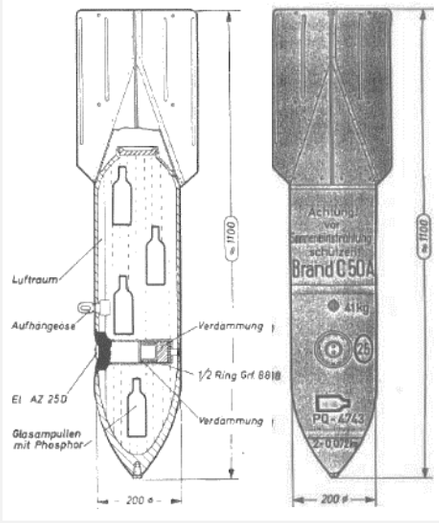
Bomb Weight:	2.0 to 2.2kg (4.40 to 4.85lb)
Fill Weight:	680g incendiary plus 100g HE
Filling:	Thermite and Penthrite or TNT
Fuze Type:	Nose fuzed, impact
Body Dimensions:	311mm x 50mm
Material:	Magnesium alloy and steel body, steel tail
Appearance:	Green body and tail, explosive black, red or unpainted
Variants:	Two types; round nose or flat nose plus longer tail unit
Bomb Container:	Various sizes holding up to 372No. B2s. Usually mixed with B1s.





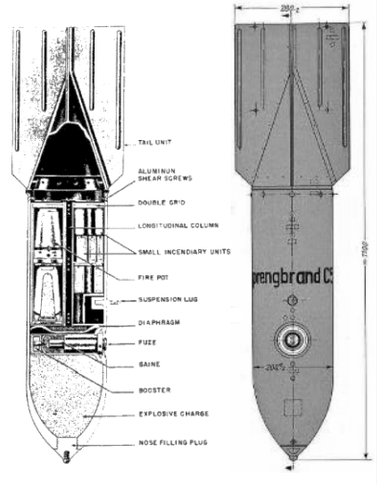
Brand C50 A

Bomb Weight:	41kg (75lb)
Incendiary Weight:	13kg (30lb)
Filling:	15 litres (86% Benzine, 10% Rubber, 4% Phosphorus)
Fuze Type:	Side fuzed. Electrical impact
Body Dimensions:	762mm x 203mm
Material:	Steel
Appearance:	Grey or green body, red base, red band around the centre of the body
Variants:	C50 B (77% Phosphorus fill)



Sprengbrand C50 'Fire Pot'

Bomb Weight:	50kg (110lb)
Fill Weight:	10kg (22lb)
Filling:	7kg TNT and 3kg Thermite in multiple small containers
Fuze Type:	Side fuzed. Electrical impact
Body Dimensions:	711mm x 203mm
Material:	Steel
Appearance:	Grey or green body, red or brown stencilling on body
Variants:	None



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Appendix: 01.2

Appendix Title:
Data Sheets - Commonly Deployed German WW2 Bombs

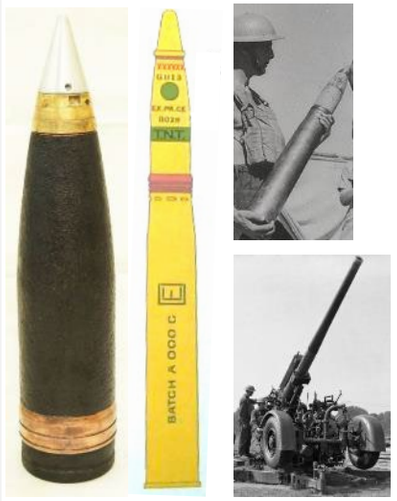
Project:	Atlas Park Development, Wythenshawe
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British WW1 and WW2 Anti-Aircraft Projectiles

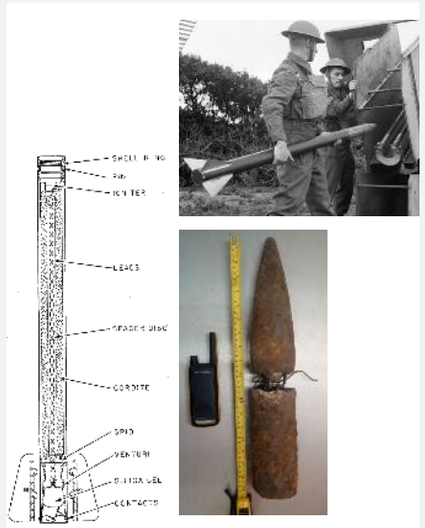
3.7-inch QF Heavy AA Gun (WW2)

Shell Weight:	12.7kg
Fill Weight:	1.1kg
Filling:	Amatol, TNT or RDX and TNT
Fuze Type:	Nose mechanical time delay fuze
Shell Dimensions:	94mm x 360 or 438mm
Shell Appearance:	Yellow or Grey body, copper driving bands, brass neck, grey nose fuze
Max Range:	12,000m
Rate of Fire:	10 to 20rpm



3-inch UP Rocket - Z Battery (WW2)

Rocket Weight:	24.5kg
Warhead Weight:	3.4kg
Fill Weight:	0.96kg
Filling:	TNT warhead. Black Powder solid fuel rocket motor
Fuze Type:	Nose mechanical time delay fuze
Rocket Dimensions:	1,930mm x 82mm
Shell Appearance:	Pointed bronze or black nose
Max Range:	6,770m



20mm Light AA Gun (WW2)

Shell Weight:	123g or 116g or 130g
Fill Weight:	6.0 to 11.0g
Filling:	Incendiary comp and/or TNT or Tetryl
Fuze Type:	Nose impact fuze
Shell Dimensions:	20mm x 110mm or 128mm
Shell Appearance:	Blue, orange, red or green bodies indicate TNT fill
Max Range:	4,389m
Rate of Fire:	250 to 450rpm



40mm Light AA Gun (WW2)

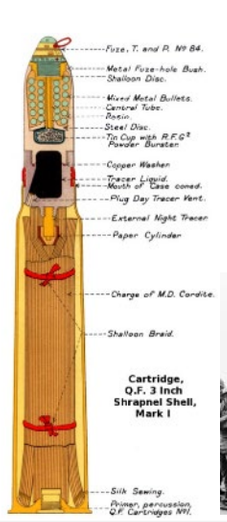
Shell Weight:	0.84kg
Fill Weight:	68g
Filling:	TNT
Fuze Type:	Nose impact fuze
Shell Dimensions:	40mm x 180mm
Shell Appearance:	Yellow or orange body, copper driving band, grey nose fuze
Max Range:	7,160m
Rate of Fire:	120rpm





3 inch QF Heavy AA Gun (WW1)

Shell Weight:	5.7kg or 7.3kg
Fill Weight:	<0.6kg (explosive)
Filling:	TNT or TNT plus ball bearings
Fuze Type:	Nose mechanical time delay fuze
Shell Dimensions:	76.2mm x 384mm or 420mm
Shell Appearance:	Black body, copper driving bands, brass nose fuze
Max Range:	6,700m
Rate of Fire:	16 to 18rpm

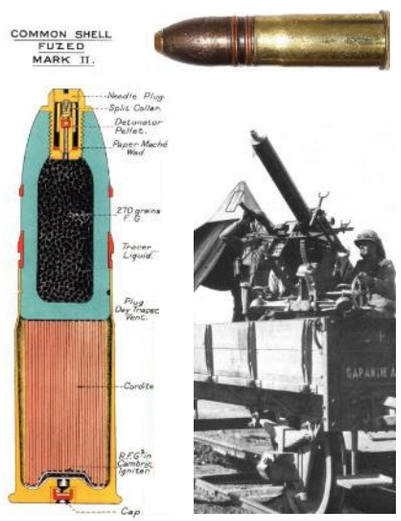






37mm Light AA Gun (WW1)

Shell Weight:	0.45kg
Fill Weight:	17.0g
Filling:	Gunpowder / black powder
Fuze Type:	Nose impact fuze
Shell Dimensions:	93mm x 37mm
Shell Appearance:	Brown body, copper driving bands and brass fuze.
Max Range:	4,110m
Rate of Fire:	300rpm



Appendix: 02.0

Appendix Title:
Data Sheets - Commonly Deployed British Anti-Aircraft Projectiles

Project:	Atlas Park Development, Wythenshawe
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British Army WW2-era Land Service Ammunition

2-inch SBML Mortar (HE)

Shell Weight:	1.02kg
Fill Weight:	200g
Filling:	RDX or TNT (high explosive)
Dimensions:	51mm x 290mm
Material:	Steel
Appearance:	Cylindrical shape. Brown body, green and red bands, five finned.
Variants	Smoke, signal multi-star, parachute illumination, white phosphorus.

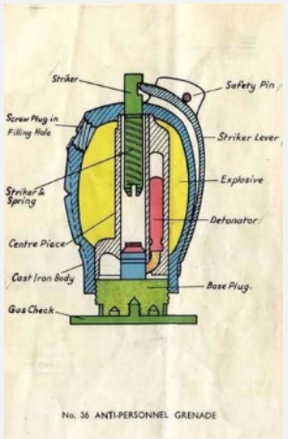




No.36 Hand Grenade - Frag

Weight:	760g
Fill Weight:	71g
Filling:	Baratol (high explosive)
Dimensions:	95mm x 61mm
Material:	Cast iron
Appearance:	Black grooved lemon shaped body. Fragmentation 'pineapple' design.
Fuze:	4 second time delay fuze.





3-inch ML Mortar (HE)

Shell Weight:	4.5kg
Fill Weight:	882g
Filling:	RDX or TNT (high explosive)
Dimensions:	81mm x 490mm
Material:	Steel
Appearance:	Pear-drop shape. Brown body, green and red bands, five finned tail.
Variants	Smoke, signal multi-star, parachute illumination, white phosphorus.

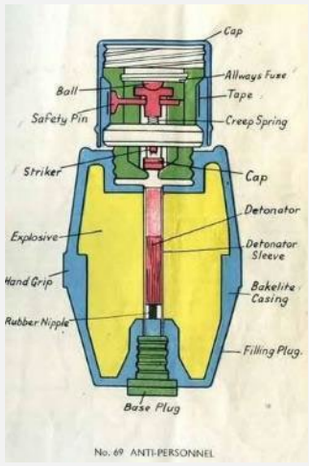




No.69 Hand Grenade - Blast

Weight:	383g
Fill Weight:	92g
Filling:	Baratol, Amatol or Lyddite (high explosive)
Dimensions:	114mm x 60mm
Material:	Bakelite (plastic)
Appearance:	Smooth black lemon shaped body. Green band.
Fuze:	4 second time delay fuze.





Ordnance QF 2-pounder Gun - HE

HE Round Weight:	1.86kg (full cartridge)
Fill Weight:	85g (plus propellant)
Filling:	RDX or TNT (high explosive)
Dimensions:	40mm x 304mm
Material:	Steel projectile. Brass case.
Appearance:	Brass body. Buff nose with red and green bands.
Remark	Note, the HE round was brough into service in 1942.



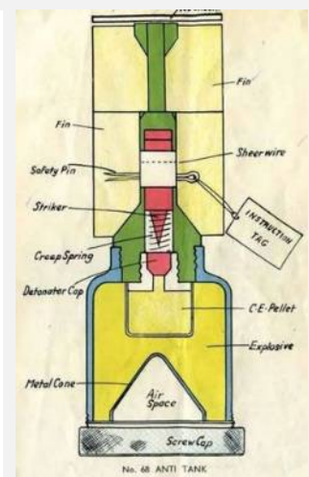


Anti-tank solid shot variant pictured

No.68 Anti-Tank Rifle Grenade

Weight:	893g
Fill Weight:	425g
Filling:	DX, Lyddite or Pentolite (high explosive)
Dimensions:	178mm x 64mm
Material:	Steel
Appearance:	Bell-shaped buff coloured body. Tail unit. Red and green bands.
Remark	These grenades were fired from a rifle using a special 'cup' attachment.





Appendix: 03.0

Appendix Title:
Data Sheets - Commonly Deployed WW2-era British Army Land Service Ammunition

Project: Atlas Park Development, Wythenshawe

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Appendix: 04.0

Appendix Title:
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