

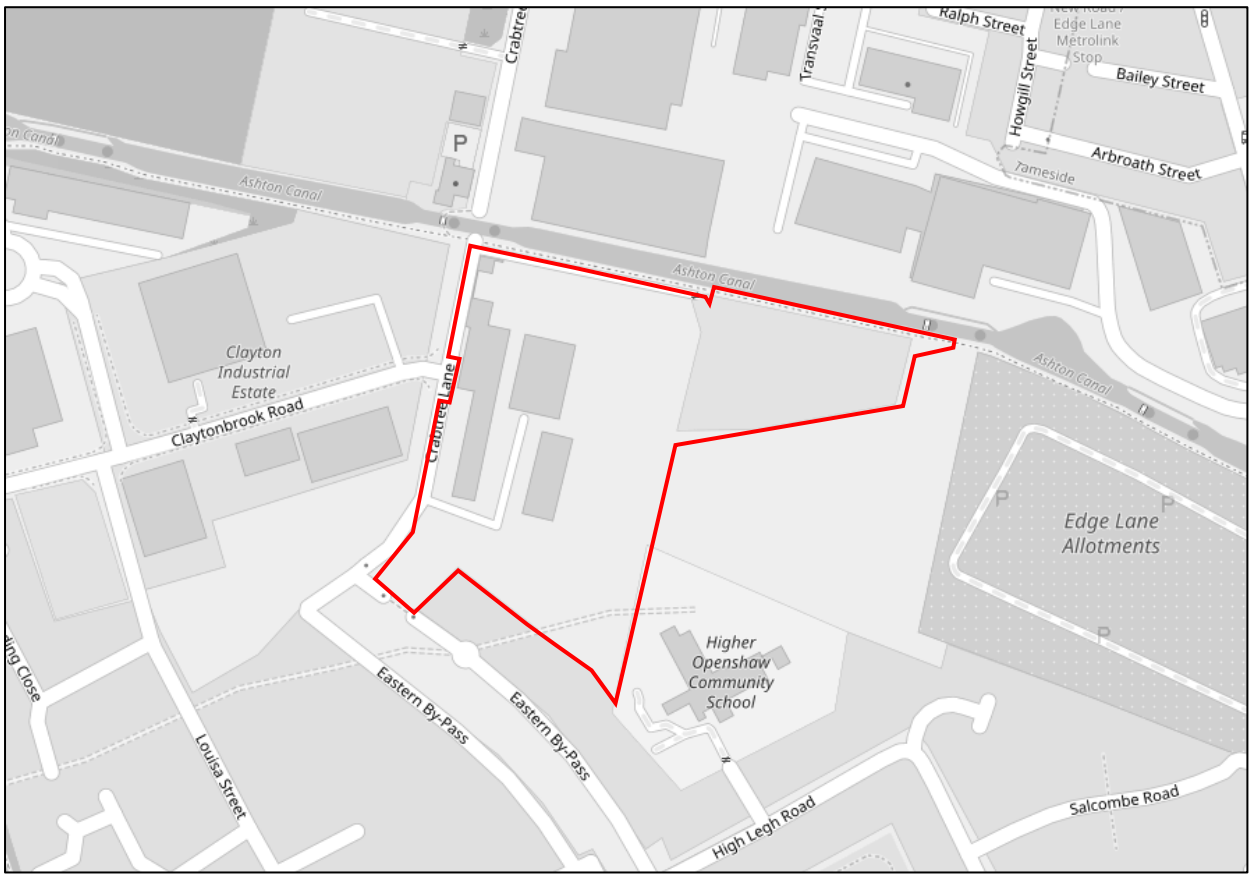
BRIMSTONE

DETAILED UXO RISK ASSESSMENT

STAGE 2 DETAILED UXO RISK ASSESSMENT

Client:	Keepmoat Homes
Project Ref:	KEEP06R
Site Name:	Crabtree Lane, Manchester
Report Ref:	DRA-24-1690-KEEP06R-CrabtreeLane,Manchester
Revision:	2
Status:	Final
Date:	30th April 2026

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EXECUTIVE SUMMARY

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

THE SITE: The Site (centred on the National Grid Ref: SJ 88784 98091) is located in Clayton, within Manchester, approximately 1.1km north-west of Gorton station. The Site is bound to the north by the Manchester and Ashton under Lyme canal, to the east by mature vegetation, to the south by residential structures on Eastern By-Pass and to the west by Crabtree Lane. A majority of the Site comprises areas of open, brownfield land, with four disused warehouse structures present. The north-east appears to be utilised for the storage of raw building materials, and multiple shipping containers are visible in the north. Mature vegetation is present in the south.

THE PROPOSED WORKS: Development works on site will be residential. This will comprise a total of 194 units, with the southern and western portions of the Site occupied by a mix of two-storey terraced and semi-detached houses. Four multi storey apartment blocks are proposed in the northern section of the Site, broadly spaced out along the canal. Associated hardstanding car parking / accessways and soft landscaping will be present throughout. At the time of writing, Brimstone was not aware of any planned SI works taking place on Site.

This UXO Risk Assessment has been prepared in response to Planning Condition 15, which requires the submission of a UXO mitigation strategy and a report outlining any measures necessary to remediate the land. This assessment evaluates the potential for UXO at the site and, informed by the identified level of risk, sets out appropriate mitigation measures, where required, to ensure the site can be safely developed in accordance with the condition.

UXO RISK ASSESSMENT:

German UXO:

- Greater Manchester was the 11th most heavily bombed British conurbation during WWII. Like today, the Site occupied an area on the periphery of the city centre during the Blitz. Analysis of Luftwaffe target mapping indicates that Gorton Locomotive Works, approximately 600m south of the Site, and North Street Works, approximately 600m west of the Site, were identified as primary targets. However, the industrial structures present on Site and in the immediate surrounds may have been identified as targets of opportunity.
- Indeed, one 'fire bomb' is recorded within the Site boundary on a bomb plot and damage map for Manchester, with a further four within an approximate 500m radius. One of the large industrial structures on Site is hatched in red in this source, indicating that it experienced moderate bomb damage during WWII. At some point during WWII, however, this building appears to have been cleared, as evidenced by post-WWII aerial photography dated 1948. It is unlikely that the single fire bomb recorded would have caused significant enough damage for the structure to be cleared. It must be noted that the consulted record sets are not comprehensive, and it is possible that additional, unrecorded, bomb strikes occurred in the vicinity to which this damage could be attributed. This is evidenced by the ruins visible approximately 30m north of the Site in post-WWII OS mapping and aerial photography; this significant damage cannot be attributed to any recorded bomb strikes.

- As briefly discussed above, analysis of post-WWII aerial photography indicates that the Site experienced significant bomb damage during WWII; this is somewhat corroborative of the bomb damage mapping, although the extent of the damage differs. The single large pre-WWII industrial structure is no longer present, with two smaller structures and an area of open ground present in its place. A structure in the north-east of the Site in particular looks newly built in the photography; this change in the Site's composition indicates that the original pre-WWII structure sustained substantial bomb damage during WWII. The structure in the east of the Site does not show any immediately obvious signs of bomb damage, however, is likely also newly built. It is not possible to confirm the exact date that the composition of the Site changed; however, given the recorded bomb strike on Site, it is thought likely this occurred as a response to bomb damage during WWII. Further damage is visible 30m north of the Site, where multiple structures have been severely damaged, leaving ruins in their place.
- Following this damage, the ground conditions are likely to have been largely unconducive to the visual detection of UXBs, and entry holes could easily be obscured in rubble / debris. Furthermore, the area would likely have been cordoned off / abandoned for a period, potentially until the end of the war. Had access levels decreased in the manner anticipated, this marked drop in access could have created a situation wherein a subsequent UXB strike could easily go unnoticed and unrecorded. Such an occurrence is also possible within the areas of open, undeveloped land on / adjacent to the Site, which does not appear to have had an obvious use and appear poorly maintained in consulted aerial photography. These areas are anticipated to have experienced infrequent levels of access, and a UXB strike could easily occur unobserved, its entry hole obscured by vegetation and infilling over time.
- A UXB strike to these open areas, or the ruins on Site, could feasibly have come to rest beneath any undamaged structures on Site due to the J-curve effect, whereby an item of ordnance may travel laterally beneath the surface from its point of entry. Had the structures or roadways on Site survived the war externally structurally intact, a UXB could also have come to rest underneath these owing to the lateral offset (J-curve) effect. In addition, via this method, a UXB strike to the canal immediately north of the Site could also come to rest within the Site boundary, and would leave little evidence of its occurrence as the entry hole could be beneath the water line.
- In summary, given the evidence of bomb damage on Site visible in WWII-era aerial photography and OS mapping, alongside the subsequent anticipated infrequent levels of access, and ground cover unconducive to the visual detection of UXBs, the risk of encountering UXBs on Site has been assessed as **Moderate**.

British / Allied UXO:

- Numerous (>30) permanent HAA batteries were active within range of the Site during WWII. Luftwaffe activity was relatively frequent and intense over the wider area and therefore these guns would have expended a significant quantity of ammunition. Consequently, it is possible that an unexploded AA shell struck the Site and became obscured in any rubble / debris.
- No evidence of historic military activity within the Site boundary has been found and it is highly unlikely that any has occurred historically. Consequently, the risk from associated UXO is **Low**.

Likelihood of UXO Remaining and UXO Encounter:

- The risk associated with any deep buried German UXBs will likely not have been mitigated at all across the Site. The risk associated with any very shallow or shallow buried HAA shells will have been mitigated with the clearing of pre-WWII structures and the subsequent construction/clearance of the post-war industrial structures.
- Please note, the risk of a UXO encounter can be considered mitigated in the exact locations and down to the exact depths of any post-WWII intrusive works.

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

Risk Mitigation Measure	Recommendation
UXO Safety Awareness Briefings	Prior to all intrusive works commencing.
Intrusive Magnetometer Probe Survey	Of all pile positions.
EOD Engineer - On Site Supervision	Watching brief of all open excavations and magnetometer survey of all borehole locations.

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FIGURE 4: Historical OS Mapping

FIGURE 5: Historical Aerial Photography

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APPENDIX 1: Recent UXO Incidents and Historical Analysis

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QUALITY POLICY

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

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

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

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

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

[redacted]

Aaron Florence
Founder and Managing Director
Brimstone Site Investigation Ltd.

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1 INTRODUCTION

1.1 Background

Keepmoat Homes (the Client) has commissioned Brimstone to carry out a Stage 2 Detailed Unexploded Ordnance Risk Assessment (DRA) of the proposed redevelopment works at the Crabtree Lane, Manchester site (the Site).

1.2 Legislation

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

1.2.1 Construction Design and Management Regulations (CDM) 2015

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

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

1.2.2 The Health and Safety at Work Act 1974

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

1.3 Commercial Contractor and the Authorities

1.3.1 Commercial Contractors

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

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

Our UXO Engineers can assess suspicious items on site when they are found. This will avoid unnecessary site evacuations. If our engineer(s) decide the item is UXO, they will coordinate with the authorities, manage disruptions, and advise on control measures, such as evacuations and a cordon.

1.3.2 UK Authorities

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

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

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

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

1.4 UXO Risk in the UK

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

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

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

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

1.5 UXO Detonations

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

The blast wave effect and the shrapnel effect can cause significant damage. Calculating safety distances is a complex process. As a rule of thumb, in open ground, a 250kg explosive charge (as would be found inside a typical 500kg bomb) would require an omnidirectional safety distance of at least 1.6km.

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

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

2 ASSESSMENT METHODOLOGY

2.1 Introduction

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

2.2 SPRC Risk Model

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

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

2.3 Assessment Structure

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

- The likelihood that the site was contaminated with UXO.
- The type of UXO that could have contaminated the site, and their associated hazards.
- The likelihood that UXO remains on the site.

- Theoretical bomb penetration depths.
- The likelihood that UXO will be uncovered during the proposed works.
- Risk rating and risk mapping (as appropriate).
- Risk mitigation recommendations.

2.4 Information Sources

To complete this risk assessment, Brimstone has gathered information from a wide range of sources. Brimstone's research team has completed detailed historical research, including access of original archived records. The following is a general list of information sources that are consulted during the research process:

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

2.5 ALARP Principle

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

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

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

2.6 Risk Tolerances

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

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

2.7 Reliance and Limitations

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

3 THE PROJECT

3.1 The Site

The Site (centred on the National Grid Ref: SJ 88784 98091) is located in Clayton, within Manchester, approximately 1.1km north-west of Gorton station. The Site is bound to the north by the Manchester and Ashton under Lyme canal, to the east by mature vegetation, to the south by residential structures on Eastern By-Pass and to the west by Crabtree Lane.

A majority of the Site comprises areas of open, brownfield land, with four disused warehouse structures present. The north-east appears to be utilised for the storage of raw building materials, and multiple shipping containers are visible in the north. Mature vegetation is present in the south.

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

3.2 The Proposed Works

Development works on site will be residential. This will comprise a total of 194 units, with the southern and western portions of the Site occupied by a mix of two-storey terraced and semi-detached houses. Four multi storey apartment blocks are proposed in the northern section of the Site, broadly spaced out along the canal. Associated hardstanding car parking / accessways and soft landscaping will be present throughout. At the time of writing, Brimstone was not aware of any planned SI works taking place on Site.

This UXO Risk Assessment has been prepared in response to Planning Condition 15, which requires the submission of a UXO mitigation strategy and a report outlining any measures necessary to remediate the land. This assessment evaluates the potential for UXO at the site and, informed by the identified level of risk, sets out appropriate mitigation measures, where required, to ensure the site can be safely developed in accordance with the condition.

FIGURE 3: Existing Site Plan

4 SITE HISTORY

4.1 Site Introduction

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

4.2 Mapping

Period	Map Date	Map Scale	Review
Pre-WWI	1893	1:2,500	The majority of the Site comprises open, undeveloped ground. A small cluster of structures is present in the east of the Site, labelled as an Iron Foundry. An unnamed roadway intersects the north of the Site, connecting the iron foundry and Crabtree Lane. Clayton Brook also intersects the south of the Site. The Manchester & Ashton under Lyne Canal is present directly north of the Site, with open undeveloped ground to the east and south, and Crabtree Lane to the west.
	1908	1:2,500	The iron works has been extended and now encompasses large sections of the north and north-east of the Site. Additional small structures have been developed in the centre and south of the Site.
WWI	1922	1:2,500	No significant changes appear to have taken place on Site. The iron works directly west of the Site has been extended, and is now labelled 'Crabtree Forge'.
Pre-WWII	1932-1933	1:2,500	**FIGURE 4.1:** The works in the north-east Site is now labelled 'Acre Works (Packing Materials), and the works in the north-west is now labelled 'Crabtree Forge'. The structures in the south of the Site have also been cleared. The open ground in the south-east of the Site is now occupied by allotment gardens. Edge Lane Chemical Works is now present adjacent to the Site across the canal to the north.
Post-WWII	1949-1950	1:1,250	**FIGURE 4.2:** The large structure in the north-east of the Site is no longer present, and two smaller structures are in its place. The small structures within Crabtree Forge have been cleared, and replaced with two larger structures. Two ruins are labelled approximately 30m north of the Site on the adjacent side of the canal. Residential structures on Eastern By Pass have been contacted directly south of the Site.
	1994	1:1,250	The two structures in the north-west of the Site are now labelled as 'Works', and the small structures in the centre of the Site have been cleared.
	2003	1:1,250	All of the structures in the north-east of the Site have now been cleared, leaving an area of open, brownfield land.

4.3 Photography/Aerial Photography

Period	Photo Date	Review
Post-WWII	16th May 1948	**FIGURE 5:** This vertical image displays the Site approximately three years after the end of WWII. Some of the structures within the Acre Works in the north-east of the Site do not match the layout displayed in pre-WWII OS mapping; however, the westerly structure does not show any immediately obvious evidence of bomb damage such as light-coloured roofing, indicating repairs. Such evidence is visible to the structure in the centre of the works, however. An area of open ground is present in the north-eastern extent of the Site; this is possibly an area of structural clearance given the change in Site composition between this image and pre-WWII OS mapping. Ruins are visible approximately 30m north of the Site, while the Crabtree Foundry directly west of the Site appears to have survived the war largely externally structurally intact, although a small area of clearance appears to be visible in the south of the foundry. An area of ground disturbance is visible in the south, and immediately south-east of the Site. Whilst it is not possible to confirm their exact cause, these are potentially indicative of bomb damage.

4.4 Additional Site-Specific History

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

5 UXO RISK - GERMAN BOMBING

5.1 WWII Bombing History of the Site

5.1.1 Greater Manchester

Greater Manchester was home to a number of vital wartime industries during WWII, many of which were located in Trafford Park. Infrastructure of strategic importance was also present in the form of Manchester Docks and the Manchester Ship Canal.

Between 29th July 1940 and 30th July 1942, Greater Manchester experienced 41 air raids, most of which were small in scale, often executed by a solitary bomber. At least nine relatively insignificant raids were carried out during the autumn of 1940, with the first medium scale raid affecting a wide area, occurring on 28th August, then on 1st October, a medium to heavy raid was executed.

The Luftwaffe mounted consecutive major attacks on the nights of 22nd-24th December 1940 (the 'Christmas Blitz'). These left large areas of Manchester, Salford and Stretford devastated. NB: a major attack was a Luftwaffe designation for a raid delivering >100 tonnes of HE (in addition to incendiaries) to a target area.

In total, these two attacks involved 441 German bombers dropping 272 tonnes of HE on the first night and 195 tonnes of HE on the second night. Seven conflagrations and 600 smaller fires were reported, the result of tens of thousands of small incendiary bombs (IBs). The Christmas Blitz caused the total destruction of >4,000 houses as well as serious damage to a further 12,000. 805 HE bombs were reported across Manchester, Salford, Stretford and Manchester Docks, including 134 UXBs.

During 1941, two additional major* raids was launched on 9th January and 1st June. Although each involved half as many aircraft as 22nd December 1940 raid, they still delivered a further 208 tonnes of HE bombs and numerous IBs onto the city and surrounding area. Three medium scale raids were also mounted in 1941, during the spring.

*The fourth and final major raid actually only delivered 97 tonnes of HE. However, it is close enough to 100 tonnes to be considered 'major.

5.1.2 Site Specific

Luftwaffe target photography indicates that Gorton Locomotive Works, approximately 600m south of the Site, and North Street Works, approximately 600m west of the Site, were identified as primary targets. The industrial structures on Site, and immediately west, may have provided targets of opportunity.

5.1.3 Bombing Decoy Sites

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

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

792 static decoy sites were built at 593 locations in Britain. They were estimated to have drawn at least 5% of the total weight of bombs away from their intended targets. No decoys were operational within a significant radius of the Site during WWII. The closest was approximately 4.6km to the south-east.

5.2 WWII Bombing Records

5.2.1 Introduction

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

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

Relevant records held at the National Archives and the Greater Manchester County Record Office were obtained for this risk assessment.

5.2.2 Bombing Density Statistics

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

Admin Area	Manchester
Area Acreage	27,255
High Explosive Bombs (all types/weights)	712
High Explosive Parachute Mines	18
Flam (Oil) Bombs	7
40kg Phosphorus Incendiary Bombs (IBs)	0
40kg 'Fire Pot' IBs	0
V1 Flying Bomb	1
V2 Long Range Rocket	0
Total (excluding V-Weapons and 1kg / 2kg IBs)	737
Bombs Per 1,000 Acres	**27.0**

1kg / 2kg incendiary bombs (IBs) and 2kg anti-personnel (AP) bombs were often too numerous to record accurately and therefore are not included in the above figures.

5.2.3 Manchester Bomb Plot & Damage Map: 1940 - 1941

Brimstone has reviewed an original bomb plot and damage map for the wider study area. This map was produced by Manchester City Council's Architect's Department (Building Surveyor's Division) during the war and was updated throughout the conflict to reflect all raids on the city. No original legend / key accompanies this map; however, a contemporary description does confirm some symbols. No symbol for UXBs was identified and any IB strike symbol with a number written within it represents the number of individual IBs falling at that location. Three categories of damage are illustrated on this map: solid red, hatched red and red outline. These are likely to represent 'total destruction or severe damage' (solid red), 'moderate damage' (hatched red) and 'minor blast damage' (red outline) respectively.

A small section of the map covering the study area is presented at **FIGURE 6** and described below.

- Two 'fire bombs' are recorded within the Site boundary.
- A further three 'fire bombs' are recorded within an approximate 500m radius of the Site.
- The large industrial structure in the north-east of the Site has been hatched red, indicating that it experienced moderate damage. This appears to have been cleared at some point during the war as indicated by post-WWII aerial photography (see **FIGURE 5**).

5.2.4 Manchester Civilian Fatalities Map

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, it only covers the two heaviest air raids on the city. Although a potentially significant source of bombing incident locations, many bombs did not cause a fatality and therefore this map should not be viewed as comprehensive.

No fatalities were recorded on or adjacent to the Site. The nearest plotted incident was plotted at '31 John Street, Droylsden, one fatality' (approximately 880m east of the Site).

5.2.5 Abandoned Bomb Register

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

The abandoned bomb register is a public record document held at the Parliamentary Archives of the House of Commons, from which Brimstone has obtained a copy. The register should not be relied on for completeness or accuracy. No abandoned bombs were recorded within a close vicinity of the Site. The nearest was within Salford Docks, approximately 7.8km west of the Site.

5.2.6 Secondary Source / Anecdotal Evidence

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

5.3 Likelihood of UXB Contamination

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

Density of Bombing	
Number of Air Raids in the Vicinity:	A comparison of the bombing incident records confirms that at least one air raid affected the study area. Note, this number is almost certainly higher, as available records are not comprehensive, and evidence of additional raids in the area is visible. The damage sustained by the Site is not consistent with the one fire bomb recorded on Site, and no recorded bomb strikes can be attributed to the ruins approximately 30m north of the Site.
Intensity of these Air Raids:	The majority of bombs dropped in the local area appear to have been part of small-scale raids, although it is also feasible that the Site area was affected by the large-scale raids targeting Manchester.
Bomb Strike Positions	
Closest Bomb Strikes	HE bombs: None recorded within the wider Site area (approx. 500m radius). 1kg / 2kg IBs: On Site.
Alignment of recorded Bomb Strikes:	It has not been possible to identify any potential bomb sticks (individual aircraft bombloads) in the local area due to the limitations of available record sets. For most small IB spreads (covering a wide area) it is impossible to correctly identify the aircraft's flightpath and thus bomb-stick alignment. Furthermore, such bombs were significantly affected by the wind, further hampering analysis.
Bomb Failure Rate	
Evidence to suggest that the generally accepted failure rate of 10% differs in the vicinity of the Site:	Records of exploded and unexploded HE bombs dropped on Manchester, Salford and Stretford during the Christmas Blitz give a failure rate of 16.6% (Smith. P, J, C, 2003). This is higher than the national average of 10%.

UXBs recorded in close proximity to the Site:	None recorded within a significant distance of the Site.

5.4 Likelihood of Subsequent UXB Detection

A range of circumstances determine whether a UXB strike location would have been identified, during and after the war. This is discussed in the following table.

Historic Access
A UXB falling on a site which was frequently accessed would have had a better chance of being found. ARP Wardens actively searched for UXBs in heavily bombed residential areas. The importance of a site or nearby buildings and infrastructure was also a factor. Many industrial facilities had fire watchers tasked with extinguishing incendiary bombs and reporting UXBs.
As the majority of air raids in the immediate vicinity appear to have occurred during the hours of darkness, there is a greater probability that any UXB strike to the Site could have occurred unobserved as residents / employees were inside. However, at the outbreak of WWII, the developed areas of the Site will have experienced a frequent level of access, as the works was in use and any UXB strike would not have been overlooked by returning employees. However, following the substantial bomb damage some of the structures on Site and structural clearance in the north-east, these areas would likely have been abandoned / cordoned off for a significant period. Note, a newly constructed structure is visible on Site in 1948 aerial imagery; it is not known if this construction occurred during the latter years of WWII or immediately post-war. It is therefore feasible that a UXB strike to the ruins of the damaged structure went unnoticed. Furthermore, the areas of open/undeveloped ground on Site do not appear to have had an obvious use, and so would likely not have been frequently accessed during any periods where the structure on Site was vacant. The same can be said for the accessway in the west of the Site.

Bomb Damage
As the bombing campaign continued, damaged areas became vulnerable to unreported UXBs. Bomb site wreckage or soil disturbance at a bomb crater could obscure evidence of a subsequent UXB strike.
A structure in the north-east of the Site appears to have sustained significant bomb damage during WWII. A newly built structure is visible in its place in 1948 aerial photography, alongside an area of open ground in the west, in an area which is developed in pre-WWII OS mapping. Subsequently, structural clearance appears to have occurred in this location. Multiple ruins are visible approximately 30m north of the Site, these are also recorded as ruins in post-WWII OS mapping. This is indicative of substantial bomb damage.

Ground Cover Type
A UXB which falls on open field could easily go unnoticed, whereas a UXB dropped on a hard-surfaced car park would have been easily observed.
Any UXB strike to the undamaged structures on Site would have caused incontrovertible evidence of its incidence as it passed the structures and into the ground beneath. The same can be said for neighbouring structures to the south, where (assuming no cratering) a HE UXB entry hole would have been persistent and easily recognisable. However, a subsequent UXB strike to the ruins of the damaged structure on Site may have gone unnoticed, its entry hole obscured by rubble / debris. Any such UXB strike could have come to rest away from its entry hole via the J-curve effect. It is conceivable that the undeveloped areas on / adjacent to the Site may have been overgrown/unmaintained at some point during WWII. A small UXB entry hole could easily have been obscured within such ground cover. Over time, changing environmental conditions could have caused this hole to infill, erasing any evidence of a UXB. NB: the diameter of the smallest German HE bomb (50kg, which was also the most commonly deployed over Britain) was 20cm, creating a small easily obscured entry hole.

5.5 Bombing During WWI

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

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

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

6 WWII GERMAN BOMBS

6.1 Bombs Dropped on the UK

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

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

- **HE bombs – moderate NEQ (net explosive quantity):** the most common types of HE bombs dropped were the SC (general purpose - GP) and SD (semi-armour piercing - SAP) series of bombs. The NEQ is between 30-50%. SAP bombs are engineered to attack light fortifications, whereas GP bombs are used in a mixed destructive blast and anti-personnel fragmentation role. 70% of bombs dropped on the UK were the 50kg type.
- **HE bombs – high NEQ:** blast bombs and parachute mines have bodies made of thin steel, allowing for larger HE charges. These were designed to detonate above ground, maximising the blast effect.

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

Parachute mines were weapons slowed by parachutes and designed to detonate without penetrating the ground. Although, in some marshland areas, partially buried parachute mines have been observed. Consequently, it is highly unlikely that any unexploded blast bombs remain buried in the UK today.

- **HE bombs – low NEQ:** The PC series were armour piercing bombs used against heavy fortifications and reinforced bunkers. They were not commonly used over the UK.
- **Small incendiary bombs:** The 1kg and 2kg incendiaries were the most dropped bomb. Up to 620 x 1kg incendiaries could be packed into the largest container unit, which opened at a pre-determined height scattering its payload over a wide area. These small bombs could fully penetrate soft ground due to their small diameter. Variants of the 1kg and 2kg incendiary bombs contained a small HE charge designed for an anti-personnel role, and to increase its incendiary effect.
- **Large incendiary bombs - Thick skinned:** The C50 has a thick body and contained a mixture of incendiary liquids and white phosphorus. Another version of the C50 had a white phosphorus fill. The C50 'firepot' contained thermite incendiary containers (aka firepots) and a small HE charge.
- **Large incendiary bombs - Thin skinned:** The Flam 250 and Flam 500 models had thin steel bodies designed to break up on impact, spreading their oil-incendiary mixture, which was ignited by a small HE charge. Consequently, it is highly unlikely that any unexploded Flam bombs remain buried in the UK today. Their unreliability meant withdrawal from frontline use by January 1941.
- **Submunitions:** The SD2 'butterfly' bomb was a 2kg submunition dropped on several British cities and towns. It contained a 225gram HE charge. SD2s had no ground penetration ability so the vast majority were recovered at the time. However, SD2s are still found across Britain today.
- **V1 flying bombs and V2 rockets:** In the final year of WWII Germany began using pilotless weapons against England. Both V Weapons had 1,000kg HE warheads. Due to their light-body construction, they had no penetration ability, and any impact left a noticeable debris field. As such, there is negligible risk from unexploded V Weapons today.

6.2 Bomb Failures

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

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

Failures can happen for different reasons, including:

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

6.3 Bomb Ground Penetration

6.3.1 Introduction

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

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

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

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

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

6.3.2 The J-Curve Effect

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

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

6.3.3 Site Specific Geology

BGS Mapping	**Superficial Deposits:** n/a	**Bedrock Deposits:** Manchester Marls Formation (Mudstone)
SI Data	No recent SI data was provided by the Client. However, local BGS borehole logs were available. The closest BGS SI through the same mapped geology as the Site is located approximately 160m south of the Site (BGS ID: 13468717). This SI (October 1984) encountered the following ground conditions: - 2.50m of made ground (bricks, clay and stones) - 1.40m of made ground (loose ash and shale) - 0.40m of very soft brown clay - 1.40m of very loose brown sand with pieces of brick and clay - 2.80m of loose to compact brown sand with small coal pieces - 0.50m of brown sand with thin bands of clay - 0.80m of soft laminated clay - 0.60m of loose brown layered silt with thin bands of soft clay - 2.70m of very stiff brown clay	

6.3.4 Site Specific Maximum Bomb Penetration Depth

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

In order to calculate the most likely maximum depth to which a bomb would penetrate, Brimstone has taken the average of the average and maximum figures for the predominant Site-specific geology (clay and sand) in the table above. This gives a likely maximum bomb penetration depth of 12.95m below WWII ground level for a 500kg bomb.

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

However, any UXB striking the structures on Site will have first passed through multiple stories. This will have caused the bomb to lose kinetic energy prior to ground penetration. This factor indicates that sections of the Site will have had a maximum bomb penetration depth significantly shallower than 14.25m. However, this makes calculating an accurate depth impossible.

7 UXO RISK - BRITISH/ALLIED ACTIVITY

7.1 Introduction

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

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

7.2 Potential Sources of UXO

7.2.1 Introduction

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

7.2.2 WWII Anti-Aircraft Fire

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

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

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

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

  The 40mm Bofors gun could fire 120 x HE shells / minute to a ceiling of 1,800m. Each shell was designed to self-destruct if it didn't strike an aircraft, however, inevitably some failed and fell back to earth.

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

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

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

Numerous (>30) permanent HAA batteries were active within range of the Site during WWII. LAA guns likely defended vulnerable points within the borough. Luftwaffe activity was relatively frequent and intense over the wider area and therefore these guns would have expended a sizeable quantity of ammunition. Consequently, there is an elevated likelihood of unexploded AA shells striking the Site and penetrating to a shallow depth, potentially becoming obscured in any rubble / debris.

8 UXO RISK MITIGATING CIRCUMSTANCES

8.1 Introduction

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

8.2 Explosive Ordnance Clearance Tasks

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

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

UXO encounters on civilian land are often reported in the media and therefore a web search of local media outlets was also carried out. No recent incidents within close proximity to the Site were identified.

8.3 Ground Works

It is not thought likely that any of the post conflict ground works occurring on Site have disturbed ground to a deep (>2m bgl) depth. The construction of the post-WWII industrial structures on Site likely disturbed ground to a shallow (1-2m bgl) depths; the same can be said for the subsequent clearance of these structures, and the grubbing out of any foundations. General maintenance of the Site, and the potential re-laying of any hardstanding, may have disturbed ground to a very shallow (<1m) depth.

8.4 Deductions

The risk associated with any deep buried German UXBs will likely not have been mitigated at all across the Site. The risk associated with any very shallow or shallow buried HAA shells will have been mitigated with the clearing of pre-WWII structures and the subsequent construction/clearance of the post-war structures.

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

9 CONCLUSION

9.1 Accuracy of Historical Records

Occasionally, the accuracy of some historical records can prove to be poor when compared with other sources of information. One significant consequence of this can be the possibility of unrecorded German bomb strikes in the study area. No comprehensive record set for the County Borough of Manchester exists, and as such there are vast disparities between the damage recorded in available record sets and what is visible in WWII-era aerial photography. For example, there are no bomb strikes recorded to account for the ruins visible approximately 30m north of the Site. These ruins are also not recorded as having sustained any damage in the bomb plot and damage mapping, although these sources are known to not be comprehensive.

9.2 The Risk of UXO Contamination on Site

9.2.1 Key Findings – German UXO Risk

- Greater Manchester was the 11th most heavily bombed British conurbation during WWII. Like today, the Site occupied an area on the periphery of the city centre during the Blitz. Analysis of Luftwaffe target mapping indicates that Gorton Locomotive Works, approximately 600m south of the Site, and North Street Works, approximately 600m west of the Site, were identified as primary targets. However, the industrial structures present on Site and in the immediate surrounds may have been identified as targets of opportunity.
- Indeed, one 'fire bomb' is recorded within the Site boundary on a bomb plot and damage map for Manchester, with a further four within an approximate 500m radius. One of the large industrial structures on Site is hatched in red in this source, indicating that it experienced moderate bomb damage during WWII. At some point during WWII, however, this building appears to have been cleared, as evidenced by post-WWII aerial photography dated 1948. It is unlikely that the single fire bomb recorded would have caused significant enough damage for the structure to be cleared. It must be noted that the consulted record sets are not comprehensive, and it is possible that additional, unrecorded, bomb strikes occurred in the vicinity to which this damage could be attributed. This is evidenced by the ruins visible approximately 30m north of the Site in post-WWII OS mapping and aerial photography; this significant damage cannot be attributed to any recorded bomb strikes.
- As briefly discussed above, analysis of post-WWII aerial photography indicates that the Site experienced significant bomb damage during WWII; this is somewhat corroborative of the bomb damage mapping, although the extent of the damage differs. The single large pre-WWII industrial structure is no longer present, with two smaller structures and an area of open ground present in its place. A structure in the north-east of the Site in particular looks newly built in the photography; this change in the Site's composition indicates that the original pre-WWII structure sustained substantial bomb damage during WWII. The structure in the east of the Site does not show any immediately obvious signs of bomb damage, however, is likely also newly built. It is not possible to confirm the exact date that the composition of the Site changed; however, given the recorded bomb strike on Site, it is thought likely this occurred as a response to bomb damage during WWII. Further damage is visible 30m north of the Site, where multiple structures have been severely damaged, leaving ruins in their place.
- Following this damage, the ground conditions are likely to have been largely unconducive to the visual detection of UXBs, and entry holes could easily be obscured in rubble / debris. Furthermore, the area would likely have been cordoned off / abandoned for a period, potentially until the end of the war. Had access levels decreased in the manner anticipated, this marked drop in access could have created a situation wherein a subsequent UXB strike could easily go unnoticed and unrecorded. Such an occurrence is also possible within the areas of open, undeveloped land on / adjacent to the Site, which does not appear to have had an obvious use and appear poorly maintained in consulted aerial photography. These areas are anticipated to have experienced infrequent levels of access, and a UXB strike could easily occur unobserved, its entry hole obscured by vegetation and infilling over time.
- A UXB strike to these open areas, or the ruins on Site, could feasibly have come to rest beneath any undamaged structures on Site due to the J-curve effect, whereby an item of ordnance may travel laterally beneath the surface from its point of entry. Had the structures or roadways on Site survived the war externally structurally intact, a UXB could also have come to rest underneath these owing to the lateral offset (J-curve) effect. In addition, via this method, a UXB strike to the canal immediately north of the Site could also come to rest within the Site boundary, and would leave little evidence of its occurrence as the entry hole could be beneath the water line.

- In summary, given the evidence of bomb damage on Site visible in WWII-era aerial photography and OS mapping, alongside the subsequent anticipated infrequent levels of access, and ground cover unconducive to the visual detection of UXBs, the risk of encountering UXBs on Site has been assessed as **Moderate**.

9.2.2 Key Findings - British UXO Risk

- Numerous (>30) permanent HAA batteries were active within range of the Site during WWII. Luftwaffe activity was relatively frequent and intense over the wider area and therefore these guns would have expended a significant quantity of ammunition. Consequently, it is possible that an unexploded AA shell struck the Site and became obscured in any rubble / debris.
- No evidence of historic military activity within the Site boundary has been found and it is highly unlikely that any has occurred historically. Consequently, the risk from associated UXO is **Low.**

9.3 Site-Specific UXO Hazards

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

UXO Type	NEQ (NEQ Range)	Likely Burial Depth	Hazard Posed
WWII German General Purpose HE Bombs	25kg - 220kg (most commonly deployed bomb weights)	Likely deep burial (>2m)	**HIGH RISK**
WWII British Heavy Anti-Aircraft Shells (HAA Shells)	1.1kg - 1.7kg	Shallow burial (1-2m)	**MODERATE-HIGH RISK**
WWII British Land Service Ammunition (LSA)	<2kg	Shallow burial (1-2m)	
WWII German 2kg Incendiary / HE Bombs (IBs)	680g incendiary hazard + ~500g explosive hazard	Shallow burial (1-2m)	
WWII German 1kg IBs	680g (incendiary, not explosive hazard)	Shallow burial (1-2m)	**MODERATE RISK**
WWII British Light Anti-Aircraft Shells (LAA Shells)	4g - 70g	Very shallow burial (<1m)	**LOW-MODERATE RISK**
Small Arms Ammunition (SAA)	<1g	Very shallow burial (<1m)	**LOW RISK**
Inert/Practice Item	0g	Very shallow burial (<1m)	

9.4 The Likelihood of UXO Encounter

9.4.1 Introduction

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

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

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

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

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

9.4.2 German UXBs

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

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

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

9.4.3 British / Allied UXO

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

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

9.4.4 Deductions

An elevated likelihood of UXO contamination (German) and likelihood of that UXO remaining up to the present day has been identified across the entire Site. Therefore, all the proposed works are considered to be exposed to a UXO encounter.

10 OVERALL RISK RATING

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

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

11 RISK MITIGATION RECOMMENDATIONS

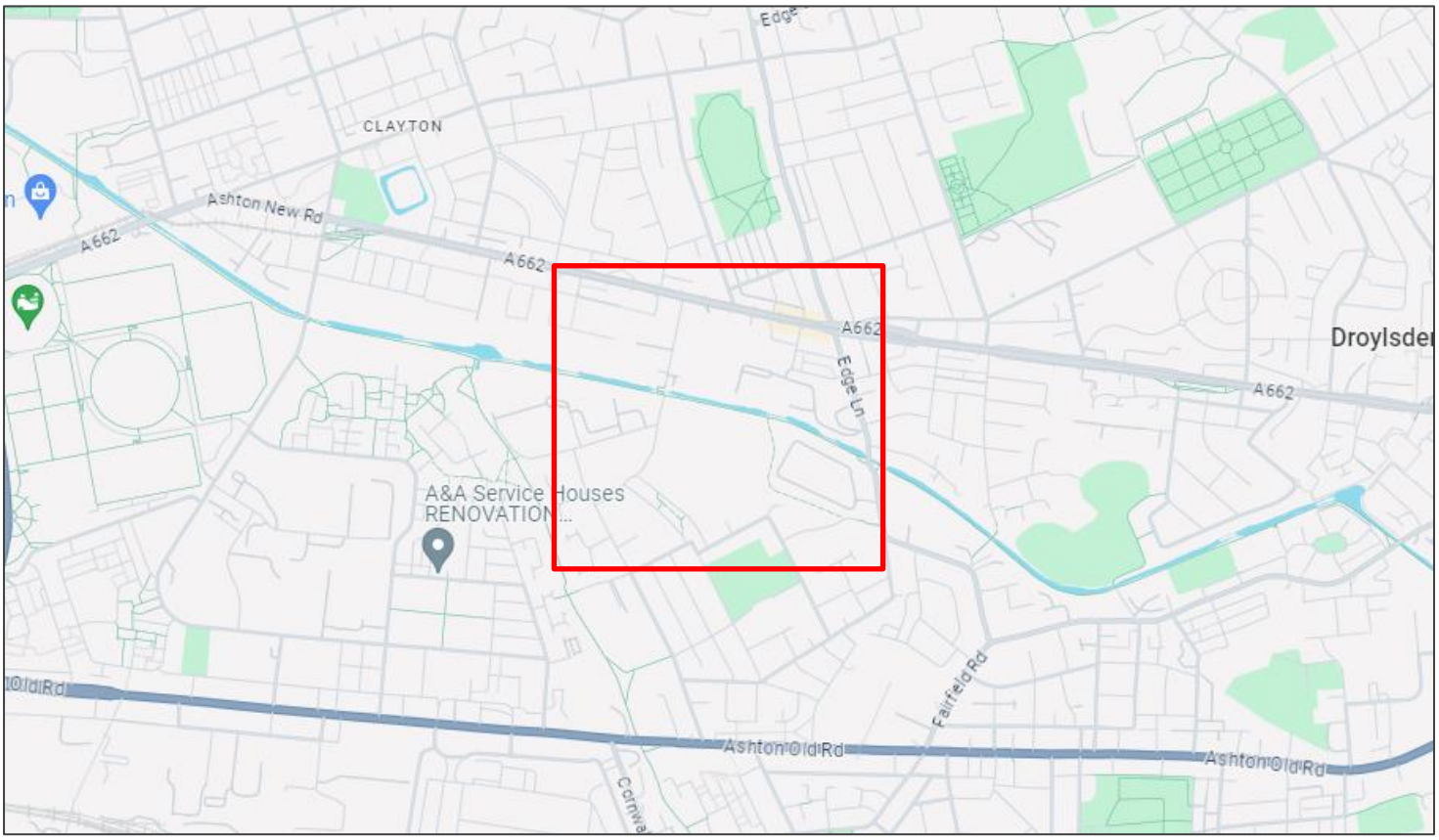
Brimstone has identified an elevated UXO risk to the proposed works. The measures detailed below are recommended to mitigate the risk to ALARP level.

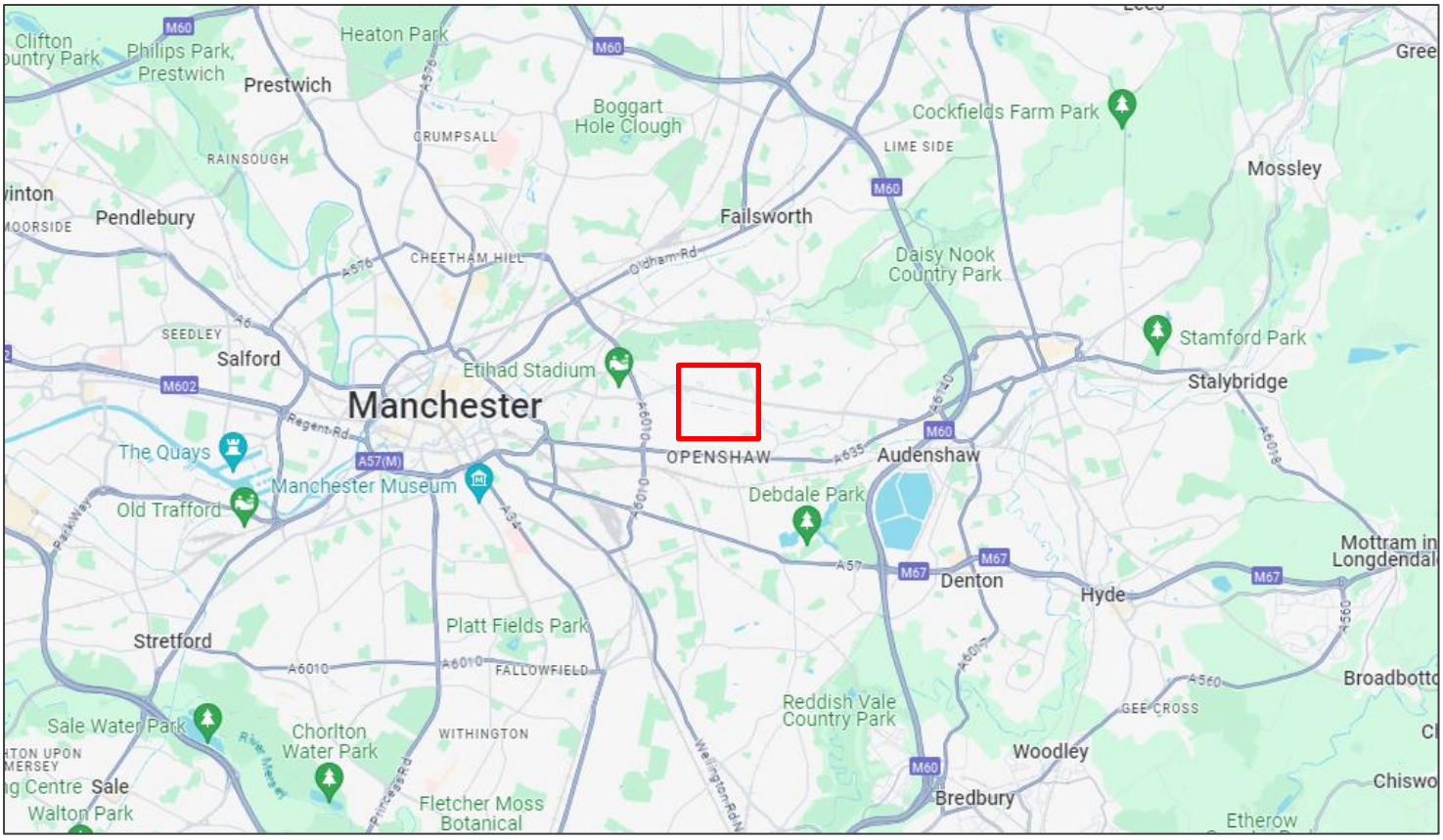
Risk Mitigation Measure	Recommendation
UXO Safety Awareness Briefings: To all personnel conducting intrusive works on Site. An essential part of the Health & Safety Plan for a site. Conforms to the requirements of CDM2015.	Prior to all intrusive works commencing.
EOD Engineer - On Site Supervision: Watching brief for open excavations below WWII ground level. Portable magnetometer instruments for clearing ground ahead of borehole positions and shallow excavations (where / when appropriate). Positive identification of suspicious (non UXO) objects. Liaison during confirmed UXO incidents. Provision of additional UXO Safety Awareness Briefings.	Watching brief of all open excavations and magnetometer survey of borehole locations.
Intrusive Magnetometer Probe Survey: A range of intrusive magnetometer methodologies can be deployed to survey the ground (down to the maximum bomb penetration depth) prior to deep intrusive works; pile foundations. The appropriate technique is governed by a number of factors, the most important being the site-specific ground conditions.	Of all/any pile positions.

FIGURES: 1 - 6

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N	Title:	Site Location Maps	FIGURE: 1





Project:	**Crabtree Lane, Manchester**
Client:	**Keepmoat Homes**
Report Ref:	**DRA-24-1690**
General Site Location:	Info Source: Google (open-source)

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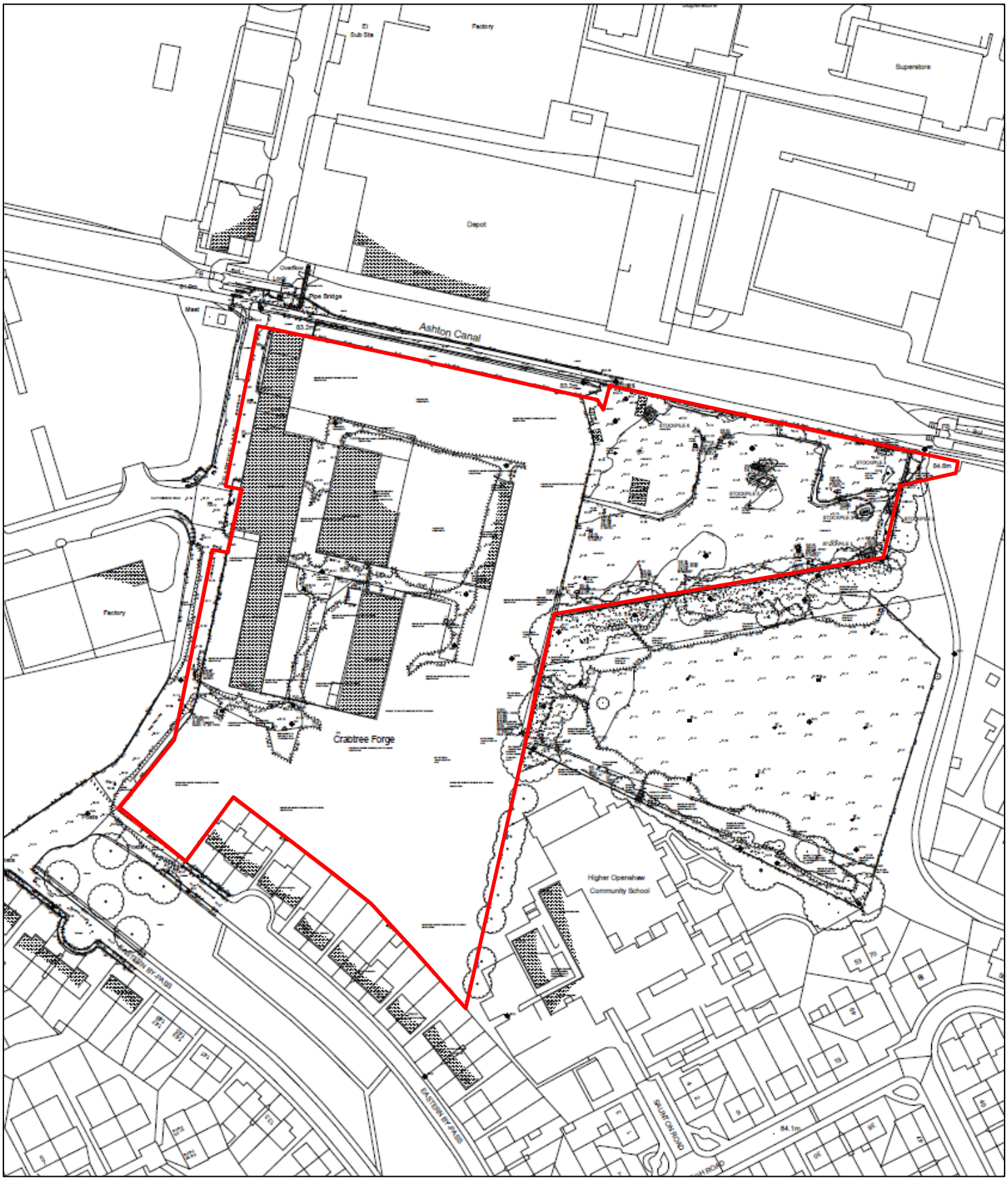
N	Title:	Recent Aerial Photograph	FIGURE: 2



Project:	Crabtree Lane, Manchester
Client:	Keepmoat Homes
Report Ref:	DRA-24-1690
Approx. Site Boundary:	Info Source: Google (open-source)

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N	Title:	Existing Site Plan	FIGURE: 3



Project:	Crabtree Lane, Manchester
Client:	Keepmoat Homes
Report Ref:	DRA-24-1690
Site Boundary:	Info Source: Keepmoat Homes

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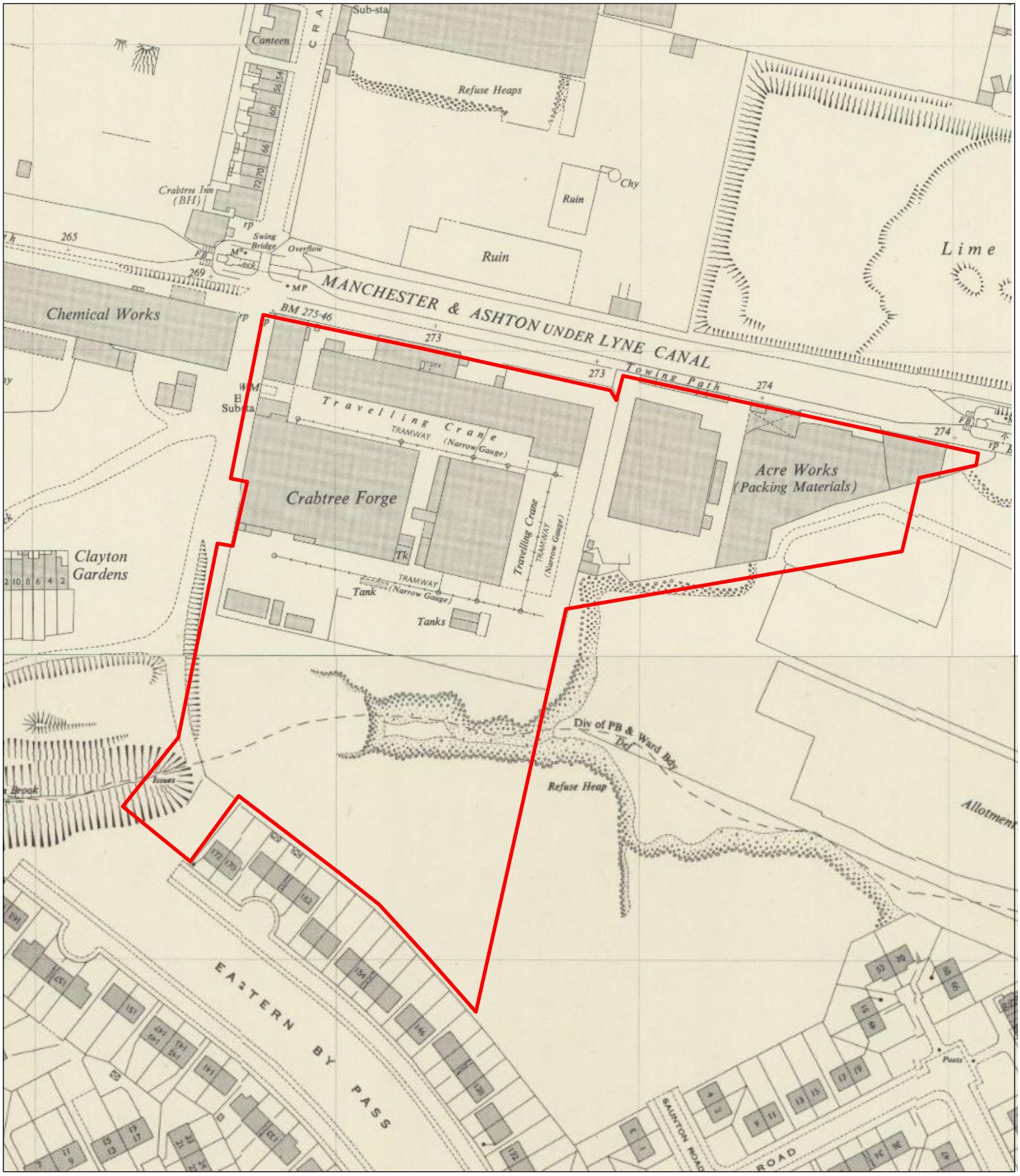
N	Title:	Historical OS Mapping – 1932 - 1933	FIGURE: 4.1



Project:	Crabtree Lane, Manchester
Client:	Keepmoat Homes
Report Ref:	DRA-24-1690
Approx. Site Boundary:	Info Source: NLS

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N	Title:	Historical OS Mapping - 1949	FIGURE: 4.2



Project:	Crabtree Lane, Manchester
Client:	Keepmoat Homes
Report Ref:	DRA-24-1690
Approx. Site Boundary:	Info Source: NLS

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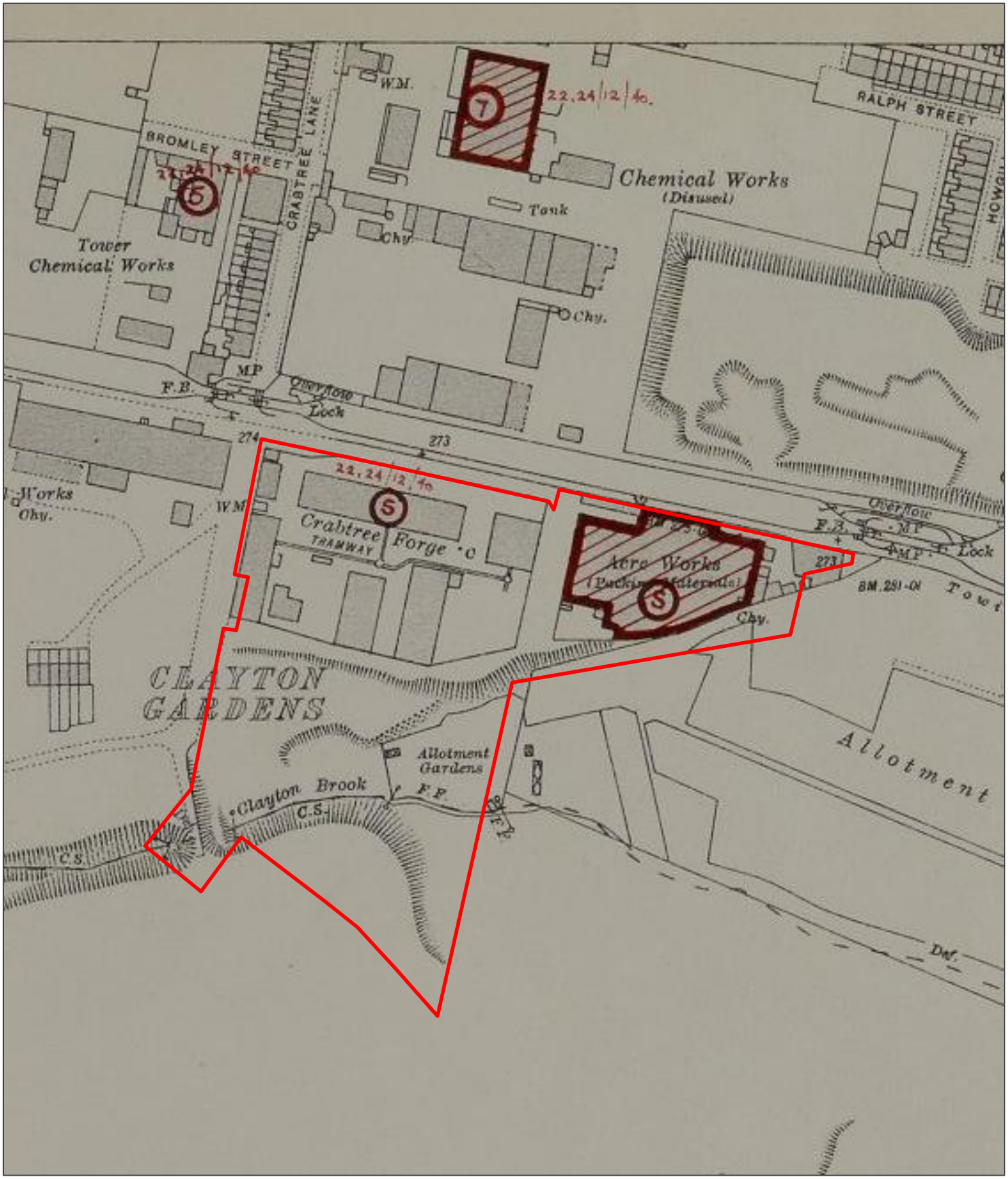
Title:	Historical Aerial Photography – 16th May 1948	FIGURE: 5



Project:	Crabtree Lane, Manchester
Client:	Keepmoat Homes
Report Ref:	DRA-24-1690
Approx. Site Boundary:	Info Source: Historic England

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N	**Title:** Manchester Bomb Plot & Damage Map: 1940 - 1941	**FIGURE: 6**



Project:	**Crabtree Lane, Manchester**
Client:	**Keepmoat Homes**
Report Ref:	**DRA-24-1690**
Approx. Site Boundary:	Info Source: **Greater Manchester County Record Office**

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APPENDICES: 1 - 5

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Recent German UXB Finds in the UK + Historical Analysis

- ***23rd May 2019*** - An SC250 (standard 250kg HE bomb) was found during shallow excavations at a building site in Kingston upon Thames, London. *Historical Analysis: The UXB landed in a small residential back garden belonging to an undamaged terraced house. It came to rest approximately 3 to 4m bgl.*
- ***15th May 2017 -*** An SC250 (standard 250kg HE bomb) was found during shallow excavations at a building site in Aston, Birmingham. *Historical Analysis: The UXB landed in a small back garden belonging to a terraced house, part of a row. It J-Curved under a neighbouring garden and came to rest at just 1.4m bgl. NB: These houses had not sustained bomb damage.*
- ***2nd March 2017 -*** A 250kg HE bomb was found during deep excavations at a building site in Brondesbury Park, London. *Historical Analysis: UXB landed in a large residential back garden. A single storey building was built on top of the UXB post-WWII.*
- ***19th January 2017 -*** An SD50 (semi-armour piercing 50kg HE bomb) was dredged from the Thames during barge dredging works near Westminster Bridge, London.
- ***12th May 2016 -*** A 500kg HE bomb was found buried just 1m below the playground of the former Royal High Junior School in Bath. *Historical Analysis: The UXB landed in a plot of neglected, unmaintained vegetation in between the school gym and main school building.*
- ***23rd September 2015 -*** A 1,000kg HE bomb was encountered by a mechanical excavator on a building site in Paradise Street, Coventry. *Historical Analysis: the UXB landed in a large residential back garden occupied by dense vegetation. A two storey building was built on top of the UXB post-WWII.*
- ***10th August 2015 -*** A 250kg HE bomb was found immediately beneath a basement floor during refurbishment works in Temple Street, Bethnal Green (London). *Historical Analysis: The UXB struck a house that had been damaged beyond repair during a previous air raid. The existing house was then built on top of UXB post-WWII.*
- ***21st May 2015 -*** An SC50 (general purpose 50kg HE bomb) was found during deep excavations at a construction site in Wembley, London. *Historical Analysis: UXB landed in a large residential back garden.*
- ***23rd March 2015 -*** A 250kg HE bomb was found during deep excavations at a building site in Grange Walk, Bermondsey (London). *Historical Analysis: inconclusive - reported UXB position is likely inaccurate.*

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

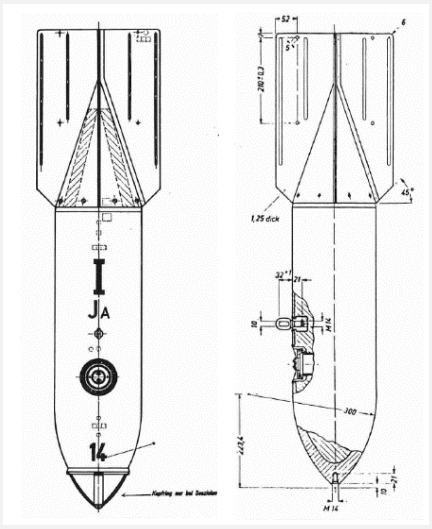
Initiation of WWII Allied Bombs

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

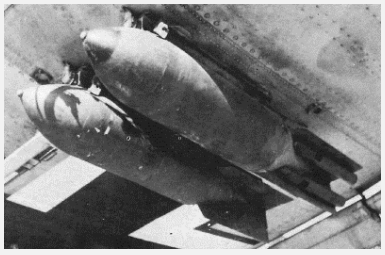
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SC 50

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

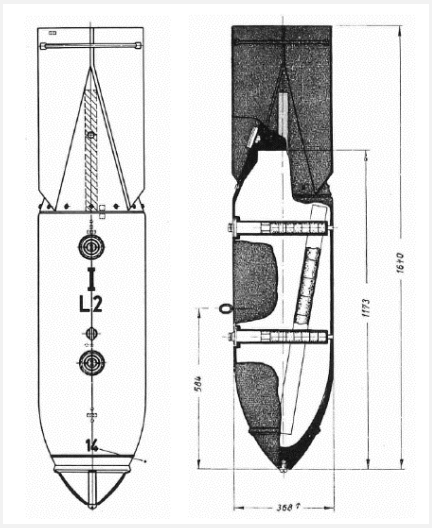






SC 250

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

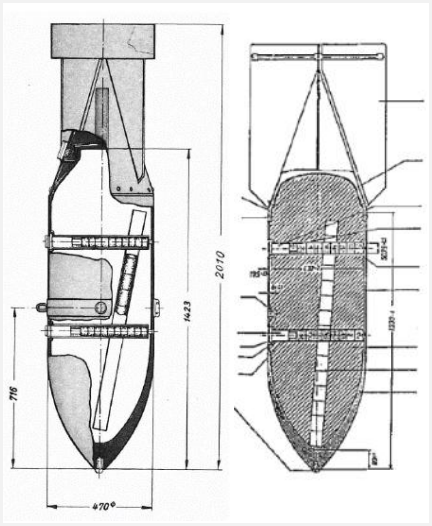






SC 500

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



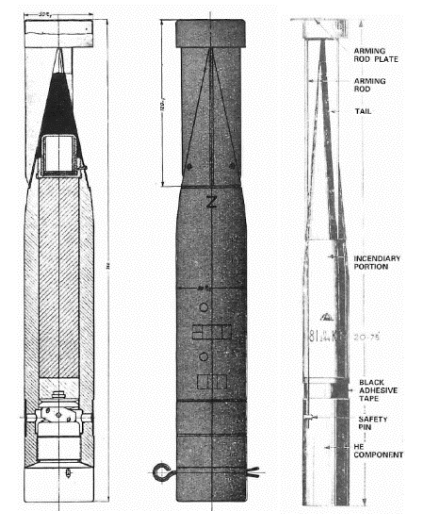




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B-1E Sub-Munition

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

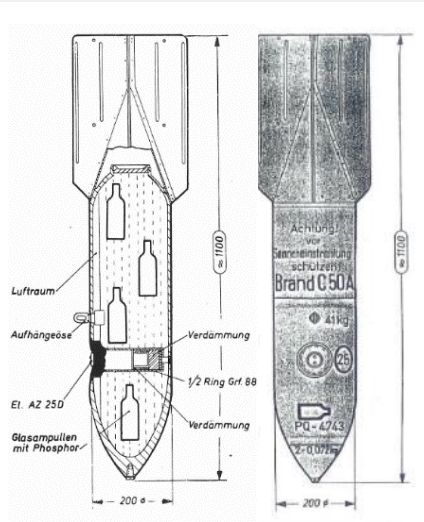






Brand C50

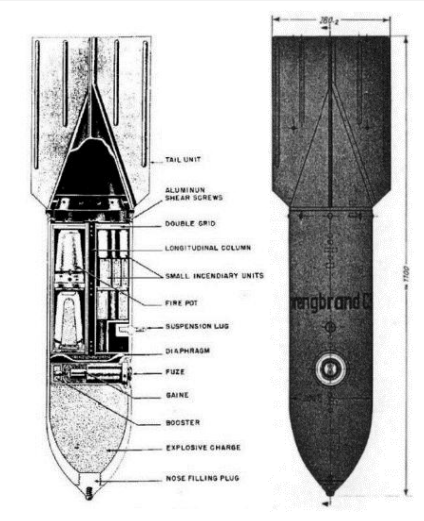
Bomb Weight:	41kg (90.4lb)
Incendiary Weight:	13kg (30lb)
Filling:	Main fill (86% Benzine, 10% Rubber) plus 4% Phosphorus in glass bottles
Fuse Type:	1 x electrical impact fuse
Bomb Dimensions:	762mm length x 203mm diameter
Appearance:	bomb body and tail painted grey or green with the rear of the bomb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

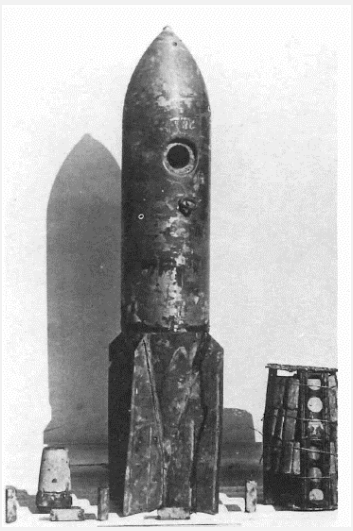




Spreng-Brand C50 - *Fire Pot*

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



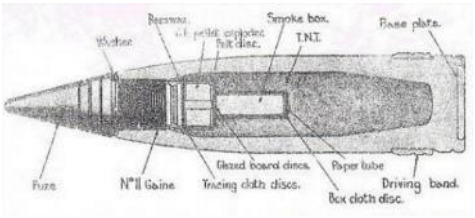


Project:	**Crabtree Lane, Manchester**
Client:	**Keepmoat Homes**
Report Ref:	**DRA-24-1690**
Info Source:	*W, Ramsey.1988 / various news sources*

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HAA Battery - 3.7" QF Shell

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

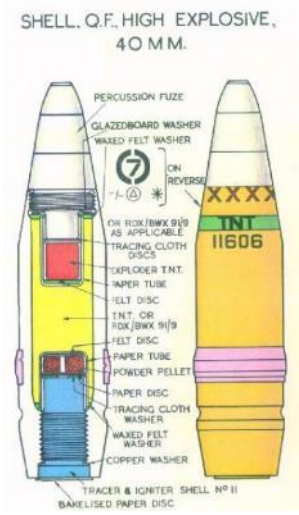






LAA Battery - 40mm Bofors Shell

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



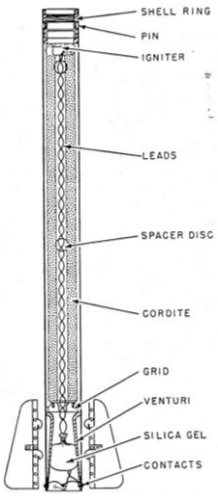






Z Battery - 3" U.P Rocket

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





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

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