

5. UK Regulatory Environment

5.1. General

There is no formal obligation requiring a UXO risk assessment to be undertaken for construction projects in the UK, nor is there any specific legislation stipulating the management or mitigation of UXO risk. However, it is implicit in the legislation outlined below that those responsible for intrusive works (archaeology, site investigation, drilling, piling, excavation etc.) should undertake a comprehensive and robust assessment of the potential risks to employees and that mitigation measures are implemented to address any identified hazards.

5.2. CDM Regulations 2015

The Construction (Design and Management) Regulations 2015 (CDM 2015) define the responsibilities of parties involved in the construction of temporary or permanent structures.

The CDM 2015 establishes a duty of care extending from clients, principle co-ordinators, designers, and contractors to those working on, or affected by, a project. Those responsible for construction projects may therefore be accountable for the personal or proprietary loss of third parties, if correct health and safety procedure has not been applied.

Although the CDM does not specifically reference UXO, the risk presented by such items is both within the scope and purpose of the legislation. It is therefore implied that there is an obligation on parties to:

- Provide an appropriate assessment of potential UXO risks at the site (or ensure such an assessment is completed by others).
- Put in place appropriate risk mitigation measures if necessary.
- Supply all parties with information relevant to the risks presented by the project.
- Ensure the preparation of a suitably robust emergency response plan.

5.3. The 1974 Health and Safety at Work etc. Act

All employers have a responsibility under the Health and Safety at Work etc. Act 1974 and the Management of Health and Safety at Work Regulations 1999, to ensure the health and safety of their employees and third parties, so far as is reasonably practicable and conduct suitable and sufficient risk assessments.

5.4. Additional Legislation

In the event of a casualty resulting from the failure of an employer/client to address the risks relating to UXO, the organisation may be criminally liable under the Corporate Manslaughter and Corporate Homicide Act 2007.

6. Role of Commercial UXO Contractors and The Authorities

6.1. Commercial UXO Contractors

In the event that a risk of UXO contamination is detected at the proposed site, the support of a UXO specialist may be recommended. A UXO specialist may be able to avoid unnecessary call-outs to the authorities through the disposal or removal of low risk items. In addition a specialist will assist in the swift recognition of high risk items, and will thereafter co-ordinate with the local authority with the objective of causing minimal levels of disruption to site operations, whilst putting in place safe and appropriate measures.

For more information on the role of commercial UXO specialists, see *CIRIA C681*.

6.2. The Authorities

The police have a responsibility to co-ordinate the emergency services in the event of an ordnance-related incident at a construction site. Upon inspection they may impose a safety cordon, order an evacuation, and call the military authorities Joint Services Explosive Ordnance Disposal (JSEOD) to arrange for investigation and/or disposal. In the absence of a UXO specialist, police officers will usually employ such precautionary safety measures, thereby causing works to cease, and possibly requiring the evacuation of neighbouring businesses and properties.

The priority given to the police request will depend on JSEOD's judgement of the nature of the UXO risk, the location, people and assets at risk, as well as the availability of resources. The speed of response varies; authorities may respond immediately or in some cases it may take several days for the item of ordnance to be dealt with.

Depending on the on-site risk assessment the item of ordnance may be removed from the site and/or destroyed by a controlled explosion. The latter process is lengthy and may necessitate the establishment of addition cordons and evacuations.

Following the removal of an item of UXO, the military authorities will only undertake further investigations or clearances in high risk situations. If there are regular UXO finds on a site the JSEOD may not treat each occurrence as an emergency and will recommend the construction company puts in place alternative procedures, such as the appointment of a commercial contractor to manage the situation.

7. The Site

7.1. Site Location

The site is currently located in the area of Holburn, in the London Borough of Camden, between the roads of Vine Hill to the west and Eyre Street Hill to the east. Warner Street and Clerkenwell Road are the two closest streets to the north and south respectively.

The site is approximately centred on the OS grid reference: **TQ 3117282122**

Site location maps are presented in **Annex A**.

7.2. Site Description

The site is currently occupied by a mix of multi-storey buildings, mostly in the west of the site, and hard-standing land in use as car parking in the east of the site.

A recent aerial photograph and site plan are presented in **Annex B** and **Annex C** respectively.

8. Scope of the Proposed Works

8.1. General

It is proposed to refurbish the existing Former Ragged School building (18 Vine Hill) and to construct a new hotel with a single or two-storey basement in the car park / garage area (15-29 Eyre St Hill). Ground investigation works are believed to be taking place on site prior to any construction.

9. Ground Conditions

9.1. General Geology

The British Geological Survey (BGS) map shows the bedrock geology of the site to be underlain by the London Clay Formation – clay, silt and sand, of the Palaeogene Period. The superficial deposits are comprised of Sand and Gravel of the Quaternary Period.

9.2. Site Specific Geology

Site specific geotechnical data was not available during the production of this report.

10. Site History

10.1. Introduction

The purpose of this section is to identify the composition of the site pre and post-WWII. It is important to establish the historical use of the site, as this may indicate the site's relation to potential sources of UXO as well as help with determining factors such as the land use, groundcover, likely frequency of access and signs of bomb damage.

10.2. Ordnance Survey Historical Maps

Relevant historical maps were obtained for this report and are presented in **Annex D**. See below for a summary of the site history shown on acquired mapping.

WWI Period		
Date	Scale	Description
1916	1:2,500	This map shows that an institute occupied the western part of the site, while the eastern part of the site was occupied with structures and part of a road.

Post-WWII		
Date	Scale	Description
1952 – 1953	1:1,250	This map shows that while the western part of the site was still occupied with structures, the eastern part of the site looks to have been cleared, apart from three new buildings in the south of the site. The road has moved eastwards, and now does not appear as part of the site.
1965 – 1968	1:2,500	The site does not appear to have significantly changed since the previous map edition. Some construction may have occurred in the eastern part of the site.
1976	1:1,250	The site does not appear to have significantly changed since the previous map edition. Some construction appears to have occurred in the eastern part of the site.

10.3. Goad Fire Insurance Mapping

Available pre and post-WWII fire insurance plans for the site were obtained by 1st Line Defence. These are comprehensive street plans detailing the structure and uses of individual buildings. The plans were originally designed to assist the fire insurance industry. See **Annex E** for the mapping with the site boundary outlined accordingly.

During WWII	
Date	Description
1942	The western part of the site is occupied by buildings, while the eastern part of the site is currently vacant. This map does not appear to show wartime damage.

Post-WWII	
Date	Description
1951	The buildings within the west of the site do not appear to have significantly changed since the previous map edition. Three new temporary structures have been constructed in the east of the site. The area immediately west of the site is labelled as 'cleared due to enemy action'.
1967	The majority of structures within the site do not appear to have changed since the previous map edition.

10.4. Historical Aerial Photographs of the Site

Historical aerial photographs have been consulted from the Aerofilms collection available from Britain From Above. These photographs provide a view of the site in 1934 & 1947 (see **Annex F**). See below for a description of each photograph.

Title of Photograph	Comments
General Post Office Mount Pleasant complex and environs, Clerkenwell, 1934	This oblique aerial image shows the site to appear similar to the 1916 historic OS mapping edition. The large building in the west of the site can be seen, along with the majority of the smaller structures in the east of the site. These structures do not appear to be in a good condition.
The Bourne Estate and environs, Holborn, 1947	This oblique image shows the site post-war. The structures in the east of the site have been fully cleared, matching up with the 1942 Goad Mapping. Clearance also appears to have taken place to the west of the site, along with a large area of clearance to the north-east of the site, on the other side of Eyre Street Hill.

11. Aerial Bombing Introduction

11.1. General

During WWI and WWII, many towns and cities across the UK were subjected to bombing which often resulted in extensive damage to city centres, docks, rail infrastructure and industrial areas. The poor accuracy of WWII targeting technology and the nature of bombing techniques often resulted in neighbouring areas to targets sustaining collateral damage.

In addition to raids which concentrated on specific targets, indiscriminate bombing of large areas also took place, this occurred most prominently in the London 'Blitz', though affected many other towns and cities. As discussed in the following sections, a proportion of the bombs dropped on the UK did not detonate as designed. Although extensive efforts were made to locate and deal with these UXBs at the time, many still remain buried and can present a potential risk to construction projects.

The main focus of research for this report will concern German aerial delivered weapons dropped during WWII, although WWI bombing will also be considered.

11.2. Generic Types of WWII German Aerial-delivered Ordnance

An understanding of the type and characteristics of the ordnance used by the Luftwaffe during WWII allows an informed assessment of the hazards posed by any unexploded items that may remain in situ on a site.

Generic Types of WWII German Aerial Delivered Ordnance		
Type	Frequency	Likelihood of detection
High Explosive (HE) bombs	In terms of weight of ordnance dropped, HE bombs were the most frequently deployed by the Luftwaffe during WWII.	Although efforts were made to identify the presence of unexploded ordnance following an air raid, often the damage and destruction caused by detonated bombs made observation of UXB entry holes impossible. The entry hole of an unexploded bomb can be as little as 20cm in diameter and was easily overlooked in certain ground conditions (see Annex H). Furthermore, ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded 50kg bomb. UXBs therefore present the greatest risk to present-day intrusive works.
Aerial or Parachute mines (PM)	There were deployed less frequently than HE and IBs due to size, cost and the difficulty of deployment.	If functioning correctly, PMs generally would have had a slow rate of descent and were very unlikely to have penetrated the ground. Where the parachute failed, mines would have simply shattered on impact if the main charge failed to explode. There have been extreme cases when these items have been found unexploded. However, in these scenarios, the ground was either extremely soft or the munition fell into water.
1kg Incendiary bombs (IB)	In terms of the number of weapons dropped, small IBs were the most numerous. Millions of these were dropped throughout WWII.	IBs had very limited penetration capability and in urban areas would often have been located in post-raid surveys. If they failed to initiate and fell in water, on soft vegetated ground, or bombed rubble, they could have gone unnoticed.
Large Incendiary bombs (IB)	These were not as common as the 1kg IBs, although they were more frequently deployed than PMs and AP bomblets.	If large IBs did penetrate the ground, complete combustion did not always occur and in such cases they could remain a risk to intrusive works.
Anti-personnel (AP) bomblets	These were not commonly used and are generally considered to pose a low risk to most works in the UK.	SD2 bomblets were packed into containers holding between 6 and 108 submunitions. They had little ground penetration ability and should have been located by the post-raid survey unless they fell into water, dense vegetation or bomb rubble.

Images and brief summaries of the characteristics of the above listed German aerial delivered ordnance are presented in **Annex G**.

11.3. Failure Rate of German Aerial-delivered Ordnance

It has been estimated that 10% of WWII German aerial delivered HE bombs failed to explode as designed. Reasons for why such weapons might have failed to function as designed include:

- Malfunction of the fuze or gain mechanism (manufacturing fault, sabotage by forced labour or faulty installation).
- Many were fitted with a clockwork mechanism that could become immobilised on impact.
- Failure of the bomber aircraft to arm the bombs due to human error or an equipment defect.
- Jettisoning the bomb before it was armed or from a very low altitude. This most likely occurred if the bomber aircraft was under attack or crashing.

From 1940 to 1945 bomb disposal teams dealt with a total of 50,000 explosive items of 50kg, over, 7,000 anti-aircraft projectiles and 300,000 beach mines. Unexploded ordnance is still regularly encountered across the UK, see press articles in **Annex I**.

11.4. V-Weapons

Hitler's 'V-weapon' campaign began from mid-1944. It used newly developed unmanned cruise missiles and rockets. The V-1 known as the *flying bomb* or *pilotless aircraft* and the V-2, a long range rocket, were launched from bases in Germany and occupied Europe. A total of 2,419 V-1s and 517 V-2s were recorded in the London Civil Defence region alone.

Although these weapons caused considerable damage their relatively low numbers allowed accurate records of strikes to be maintained. These records have mostly survived. There is a negligible risk from unexploded V-weapons on land today since even if the 1,000kg warhead failed to explode, the weapons are so large that they would have been observed and the risk dealt with at the time. Therefore, V-weapons are referenced in this report not as a viable risk factor, but primarily in order to help account for evidence of damage and clearance reported.

12. UXB Ground Penetration

12.1. General

An important consideration when assessing the risk from a UXB is the likely maximum depth of burial. There are several factors which determine the depth that an unexploded bomb will penetrate:

- Mass and shape of bomb.
- Height of release.
- Velocity and angle of bomb.
- Nature of the ground cover.
- Underlying geology.

Geology is perhaps the most important variable. If the ground is soft, there is a greater potential of deeper penetration. For example, peat and alluvium are easier to penetrate than gravel and sand, whereas layers of hard strata will significantly retard and may stop the trajectory of a UXB.

12.2. The J-Curve Effect

J-curve is the term used to describe the characteristic curve commonly followed by an aerial delivered bomb dropped from height after it penetrates the ground. Typically, as the bomb is slowed by its passage through underlying soils, its trajectory curves towards the surface. Many UXBs are found with their nose cone pointing upwards as a result of this effect. More importantly however is the resulting horizontal offset from the point of entry. This is typically a distance of about one third of the bomb's penetration depth, but can be up to 15m.

12.3. WWII UXB Penetration Studies

During WWII the Ministry of Home Security undertook a major study on actual bomb penetration depths, carrying out statistical analysis on the measured depths of 1,328 bombs as reported by bomb disposal (BD) teams. Conclusions were made as to the likely average and maximum depths of penetration of different sized bombs in different geological strata.

For example, the largest common German bomb (500kg) had a likely concluded penetration depth of 6m in sand or gravel but 11m in clay. The maximum observed depth for a 500kg bomb was 11.4m and for a 1,000kg bomb 12.8m. Theoretical calculations suggested that significantly greater penetration depths were probable.

12.4. Site Specific Bomb Penetration Considerations

When considering an assessment of the bomb penetration at the site of proposed works the following parameters have been used:

- WWII geology – London Clay Formation.
- Impact angle and velocity – 10-15° from vertical and 270 metres per second.
- Bomb mass and configuration – The 500kg SC HE bomb, without retarder units or armour piercing nose (this was the largest of the common bombs used against Britain).

It has not been possible to determine maximum bomb penetration capabilities at this stage due to the lack or limitations of site specific borehole geotechnical information. An assessment can be made once such information becomes available or by an UXO Specialist on-site.

13. Initiation of Unexploded Ordnance

13.1. General

Unexploded ordnance does not spontaneously explode. All high explosive filling requires significant energy to create the conditions for detonation to occur. In the case of unexploded German bombs discovered within the construction site environment, there are a number of potential initiation mechanisms.

13.2. UXB Initiation Mechanisms

UXB Initiation	
Direct Impact	Unless the fuze or fuze pocket is struck, there needs to be a significant impact e.g. from piling or large and violent mechanical excavation, onto the main body of the weapon to initiate a buried iron bomb. Such violent action can cause the bomb to detonate.
Re-starting the Clockwork Fuze	A small proportion of German WWII bombs employed clockwork fuzes. It is probable that significant corrosion would have taken place within the fuze mechanism over the last 70+ years that would prevent clockwork mechanisms from functioning. Nevertheless, it was reported that the clockwork fuze in a UXB dealt with by 33 EOD Regiment in Surrey in 2002 did re-start.
Friction Impact	The most likely scenario resulting in the detonation of a UXB is friction impact initiating the shock-sensitive fuze explosive. The combined effects of seasonal changes in temperature and general degradation over time can cause explosive compounds to crystallise and extrude out from the main body of the bomb. It may only require a limited amount of energy to initiate the extruded explosive which could detonate the main charge.

Annex I details incidents where intrusive works have caused items of UXO to detonate, resulting in death or injury and damage to plant.

13.3. Effects of Detonation

When considering the potential consequences of a detonation, it is necessary to identify the significant receptors that may be affected. The receptors that may potentially be at risk from a UXO detonation on a construction site will vary depending on the site specific conditions but can be summarised as follows:

- People – site workers, local residents and general public.
- Plant and equipment – construction plant on site.
- Services – subsurface gas, electricity, telecommunications.
- Structures – not only visible damage to above ground buildings, but potentially damage to foundations and the weakening of support structures.
- Environment – introduction of potentially contaminating materials.

14. The Risk from German Air Delivered UXBs

14.1. World War I

During WWI London was targeted and bombed by Zeppelin Airships as well as Gotha and Giant fixed-wing aircraft. An estimated 250 tons of ordnance (high explosive and incendiary bombs) was dropped on Greater London, more than half of which fell on the City of London (see **Annex J** for a WWI bomb plot map of London).

Two significant WWI raids are shown to affect areas close to the site. A Zeppelin raid on the 8th/9th September 1915 dropped bombs over an area of central London, including Bedford Row to the north of the site. Another Zeppelin raid, on the 13th/14th October 1915 involved bombing incidents close to the site, at Gray's Inn. Whilst this shows bombing in areas close to the site, no WWI bombing is shown to have taken place within the site area or in an immediate proximity.

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

14.2. World War II Bombing of Holborn

The Luftwaffe's main objective for the attacks on London was to inhibit the capital's commercial output. To achieve this they targeted the docks, warehouses, wharves, railway lines, factories and power stations. As the war progressed this strategy gradually changed to the indiscriminate bombing of civilian areas in an attempt to subvert public morale.

During WWII the site was located within the Metropolitan Borough of Holborn, which sustained a very high density of bombing as represented by bomb density data figures and maps, see **Annex K**. The density of bombing in Holborn can be attributed largely to its position in central London meaning that it was at the centre of the Luftwaffe's targeted campaign against the capital. Holborn is home to many historic buildings and commercial institutions that made obvious targets.

Records of bombing incidents in the civilian areas of London/the region were collected by the Air Raid Precautions wardens and collated by the Civil Defence Office. Some other organisations, such as the London Port Authority and railways, maintained separate records. Records would be in the form of typed or hand written incident notes, maps and statistics. Bombing data was carefully analysed, not only due to the requirement to identify those parts of the country most needing assistance, but also in an attempt to find patterns in the Germans' bombing strategy in order to predict where future raids might take place.

Records of bombing incidents for Holburn are presented in the following sections.

14.3. WWII Home Office Bombing Statistics

The following table summarises the quantity of German bombs (excluding 1kg incendiaries and anti-personnel bombs) falling on the Metropolitan Borough of Holborn between 1940 and 1945.

Record of German Ordnance Dropped on the Metropolitan Borough of Holborn		
Area Acreage	406	
Weapons	High Explosive Bombs (all types)	354
	Parachute Mines	7
	Oil Bombs	8
	Phosphorus Bombs	0
	Fire Pot	0
	Pilotless Aircraft (V1)	4
	Long Range Rockets (V2)	1
Total	374	
Number of Items per 1,000 acres	921.2	

Source: Home Office Statistics

This table does not include UXO found during or after WWII.

Detailed records of the quantity and locations of the 1kg incendiary and anti-personnel bombs were not routinely maintained by the authorities as they were frequently too numerous to record. Although the risk relating to IBs is lesser than that relating to larger HE bombs, they were designed to inflict damage and injury and should therefore not be dismissed. Therefore, they should not be overlooked in assessing the general risk to personnel and equipment. Anti-personnel bombs were used in much smaller quantities and are rarely found today but are potentially more dangerous.

14.4. London Civil Defence Region ARP Bomb Census Maps

During WWII, the ARP Department within the Research and Experiments Branch of the Ministry of Home Security produced consolidated, weekly and V-1 pilotless aircraft bomb census maps for the London Civil Defence Region. These maps collectively shows the approximate locations of bombs, mines and rockets. The site area was checked on each available map sheet, those showing bomb incidents on and in the immediate vicinity of the site are discussed below and are presented in Annexes L & M.

London Consolidated Bomb Census Maps	
Date Range	Comments
Night Bombing up to 7 th October 1940	No bomb strikes are recorded within the site and the immediate proximity of the site.
7 th October 1940 to 6 th June 1941	One bomb is recorded on the site's south-western border.

London Weekly Bomb Census Maps	
Date Range	Comments
7 th to 14 th October 1940	An Incendiary bomb 'shower' can be seen to the south-west of the site, along with a HE bomb to the south-east.
21 st to 28 th October 1940	One bomb strike can be seen to the north-east and south-east of the site respectively.
4 th to 11 th November 1940	One UXB and several bomb strikes can be seen to the south of the site.
30 th December 1940 to 6 th January 1941	An incendiary bomb shower can be seen to the north of the site.
5 th to 12 th May 1941	One bomb is recorded on the site's south-western border. Two further strikes are recorded to the north of the site.

V-1 Pilotless Aircraft Bomb Census Map	
Date Range	Comments
1944-45	No V1 strikes can be seen to be affecting the site and the site's proximity.

14.5. Holborn Record of Air Raid Incidents

Bomb incident records were obtained from the Camden Local Studies And Archives Centre. A transcript of the associated written records for bombs which fell in the site area is presented in the table below.

Holborn Record Of Air Raid Incidents	
Date Range	Comments
8 th September 1940	One Incendiary bomb on Rosebery Avenue, in the roadway. Extinguished by wardens. A 50kg HE bomb fell on waste ground on Summer Street between Eyre Street Hill & Back Hill. No apparent damage.
16 th September 1940	Incendiary bombing on Rosebery Avenue. No damage recorded.
27 th September 1940	Incident recorded on Eyre Street Hill, but later recorded as 'nil'. The 'bomb strike' was found to be machine gun bullets.
11 th October 1940	Incendiary bombing on Rosebery Square, Rosebery Avenue, Vine Hill & Eyre Street Hill. All bombs put out.
15 th October 1940	Incendiary bombing on Rosebery Avenue, Vine Hill & Eyre Street Hill. Fire Brigade reported as dealing with the incidents. No casualties reported.
5 th January 1941	Incendiary bombing on Rosebery Avenue & Eyre Street Hill. Fires put out.
8 th March 1941	Incendiary bombing on Rosebery Square buildings, Rosebery Avenue. Fire put out.
10 th May 1941	One 250kg bomb on Vine Hill Buildings near Rosebery Square / Avenue. Severe damage to rear of buildings and adjoining premises. Incendiary bombs & fire recorded in the front of the buildings. Two recorded as dead.
22 nd March 1944	Damage was recorded as having been sustained from two HE bombs on Rosebery Square, Rosebery Avenue & Vine Hill. A large number of properties were registered as damaged in this incident. It is plausible that the cause of this was a parachute mine that exploded in the air.
6 th July 1944	A V1 Flying bomb was recorded as having damaged number 37 Eyre Street Hill. The flying bomb actually landed in the Metropolitan Borough of Finsbury.

14.6. London County Council Bomb Damage Map

A map created by London County Council (LCC) showing the extent of bomb damage in the city was compiled during/after WWII. The section showing the area of the site is described in the table below and presented in Annex N.

LCC Bomb Damage Map	
Date Range	Comments
1940-1945	This mapping records damage requiring demolition' to the structures immediately west of the site during the war. The area in the east of the site is marked as 'cleared by the War Debris & Disposal Service'. This means that this area was likely cleared before any damage could be attributed to it, meaning that it was either damaged by bombing or in such a poor condition that it was cleared regardless.

14.7. WWII-Era Aerial Photography

A high resolution scan of WWII-era aerial photography for the site area was obtained from the National Monuments Record Office (Historic England). This photograph provides a record of the potential composition of the site during the war, as well as its condition immediately following the war (see Annex O).

WWII-Era Aerial Photography	
Date	Description
12 th August 1945	This photography shows the site in 1945, immediately after the end of the war. The main building in the western part of the site can be seen. The eastern part of the site appears to be cleared. What appears to damage can be seen to the west of the site boundary. A large area of clearance can be seen on the eastern side of Eyre Street Hill.

14.8. Abandoned Bombs

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

Given the inaccuracy of WWII records and the fact that these bombs were 'abandoned', their locations cannot be considered definitive or the lists exhaustive. The MoD states that 'action to make the devices safe would be taken only if it was thought they were unstable'. It should be noted that other than the 'officially' abandoned bombs, there will inevitably be UXBs that were never recorded.

1st Line Defence holds no records of officially registered abandoned bombs at or near the site of the proposed works.

14.9. Bomb Disposal Tasks

The information service from the Explosive Ordnance Disposal (EOD) Archive Information Office at 33 Engineer Regiment (EOD) is currently facing considerable delay. It has therefore not been possible to include any updated official information regarding bomb disposal/clearance tasks with regards to this site. A database of known disposal/clearance tasks has been referred to which does not make reference to such instances occurring within the site of proposed works. If any relevant information is received at a later date GEA Ltd will be advised.

14.10. Evaluation of German Air Delivered UXB Risk

Factors	Conclusion
Density of Bombing <i>It is important to consider the bombing density when assessing the possibility that UXBs remain in an area. High levels of bombing density could allow for error in record keeping due to extreme damage caused to the area.</i>	<p>The site was situated in the Metropolitan Borough of Holborn during WWII. According to Home Office statistics, this borough received 921.2 items per 1,000 acres, the highest bomb density within London and the country.</p> <p>London bomb census mapping, both consolidated and weekly, record one bomb strike on the site's south-western border.</p> <p>The Holborn Record Of Air Raid Incidents, obtained from Camden Archives, records this strike in roughly the same place in May 1941.</p>
Damage <i>If buildings or structures on a site sustained bomb or fire damage any resulting rubble and debris could have obscured the entry holes of unexploded bombs dropped during the same, or later, raids. Similarly, a High Explosive bomb strike in an area of open agricultural land will have caused soil disturbance, increasing the risk that a UXB entry hole would be overlooked.</i>	<p>LCC Bomb damage mapping records 'damage requiring demolition' to the structures immediately west of the site during the war. The area in the east of the site is marked as 'cleared by the War Debris & Disposal Service'. This means that this area was likely cleared before any damage could be attributed to it, meaning that it was either damaged by bombing or in such a poor condition that it was cleared regardless.</p>
Access Frequency <i>UXO in locations where access was irregular would have a greater chance of passing unnoticed than at those that were regularly occupied. The importance of a site to the war effort is also an important consideration as such sites are likely to have been both frequently visited and subject to post-raid checks for evidence of UXO.</i>	<p>The western part of the site, which was occupied by a large multi-storey structure, was likely accessed frequently throughout the war. The eastern part of the site was likely accessed less frequently, as it does not appear to have been occupied with structures throughout the war and was cleared at some point.</p>
Ground Cover <i>The nature of the ground cover present during WWII would have a substantial influence on any visual indication that may indicate UXO being present.</i>	<p>The western part of the site was occupied by buildings during the war. The eastern part of the site appears to have been cleared by 1942, and appears on 1945 photography to be undeveloped hard-standing land, post-clearance. While the groundcover in the west of the site would have been conducive to the evidence of UXO, this would not have been the case in the east of the site.</p>
Bomb Failure Rate	<p>There is no evidence to suggest that the bomb failure rate in the locality of the site would have been dissimilar to the 10% normally used.</p>
Abandoned Bombs	<p>1st Line Defence holds no records of abandoned bombs at or within the site vicinity.</p>
Bombing Decoy sites	<p>1st Line Defence could find no evidence of bombing decoy sites within the site vicinity.</p>
Bomb Disposal Tasks	<p>1st Line Defence could find no evidence of bomb disposal tasks within the site boundary and immediate area.</p>

15. The Risk from Allied Ordnance

15.1. General

The potential risk of encountering Allied ordnance on construction sites is particularly elevated in areas previously associated with military activity. This includes munitions deposited by military training exercises, dumped as a result of poor working practices, or deliberately placed to prevent adversary occupation and from other home defence activities. For example, contamination from items of Land Service (LSA) and Small Arms Ammunition (SAA) may result from historical occupation of an area or its use for military training.

It should be highlighted that there is no evidence that the site formerly had any military occupation or usage that could have led to contamination with such items of Allied ordnance. Despite this, urban areas such as the location of the site, can however be at risk from buried unexploded Anti-Aircraft projectiles fired during WWII – as addressed below.

15.2. Defending the UK From Aerial Attack

During WWII the Ministry of Defence employed a number of defence tactics against the Luftwaffe from bombing major towns, cities, manufacturing areas, ports and airfields. These can be divided into passive and active defences (examples are provided in the table below).

Active Defences	Passive Defences
<ul style="list-style-type: none"> Anti-aircraft gun emplacements to engage enemy aircraft. Fighter aircraft to act as interceptors. Rockets and missiles were used later during WWII. 	<ul style="list-style-type: none"> Blackouts and camouflaging to hinder the identification of Luftwaffe targets. Decoy sites were located away from targets and used dummy buildings and lighting to replicate urban, military, or industrial areas. Barrage balloons forced enemy aircraft to greater altitudes. Searchlights were often used to track and divert adversary bomber crews during night raids.

Active defences such as anti-aircraft artillery present a greater risk of UXO contamination than passive defences. Unexploded ordnance resulting from dogfights and fighter interceptors is rarely encountered and difficult to accurately qualify.

15.3. Anti-Aircraft Artillery (AAA)

During WWII three main types of gun sites existed: heavy anti-aircraft (HAA), light anti-aircraft (LAA) and 'Z' batteries (ZAA). If the projectiles and rockets fired from these guns failed to explode or strike an aircraft they would descend back to land. The table below provides further information on the operation and ordnance associated with these type of weapons.

Anti-Aircraft Artillery				
Item	Description			
HAA	These large calibre guns such as the 3.7" QF (Quick Firing) were used to engage high flying enemy bombers., They often fired large HE projectiles, which were usually initiated by integral fuzes triggered by impact, area, time delay or a combination of aforementioned mechanisms The closest HAA was located approximately 3.7km south-west of the site, however the range of a projectile can be up to 15km.			
LAA	These mobile guns were intended to engage fast, low flying aircraft. They were typically rotated between locations on the perimeters of towns and strategically important industrial works. As they could be moved to new positions with relative ease when required, records of their locations are limited. The most numerous of these were the 40mm Bofors gun which could fire up to 120 x 40mm HE projectiles per minute to over 1,800m.			
Variations in HAA and LSA Ammunition	Gun type	Calibre	Shell Weight	Shell Dimensions
	3.0 Inch	76mm	7.3kg	76mm x 356mm
	3.7 Inch	94mm	12.7kg	94mm x 438mm
	4.5 Inch	114mm	24.7kg	114mm x 578mm
Z-AA	The three inch unrotated rocket/projectile known as the UP-3 had initially been developed for the Royal Navy. The UP-3 was also used in ground-based single and 128-round launchers known as "Z" batteries. The rocket, containing a high explosive warhead was often propelled by cordite.			
29mm Spigot Mortars (Blacker Bombarbs)	This was an infantry anti-tank weapon. A heavy steel rod (spigot) would be driven into the hollow tail of a projectile to ignite the explosive charge located in the rear of the projectile, and lead to it being propelled toward a target. It was not an effective method of air defence and was mainly used in defensive positions at key locations. If encountered, a spigot mortar projectile will resemble a mortar round, but with an elongated metal tail rod.			
Quick Firing (QF) 1 and 2 Pounder	QF 1 and 2 Pounders, or 'pom poms' were a light battery most often used by the navy. During the beginning of WWII they were used to defend targets in the absence of more effective LAA or HAA.			
Machine Gun Posts	These were established at some significant military and industrial positions. Machine guns were a largely ineffective form of AAA. Machine guns usually fired the .303 Round.			

The conditions in which an HAA or LAA projectiles may have fallen unnoticed within a site area are analogous to those regarding aerial delivered ordnance. For detailed analysis on the ground conditions and access frequency within the proposed site, see the evaluation of German Bombing Records in [Section 14.10](#)

Unexploded HAA ammunition is likely to be found close to WWII ground level. If encountered, the high explosive fill and fragmentation hazard of these items could present a significant risk to workers and equipment.

40mm projectiles are similar in appearance and effect to SAA. However, they remain dangerous as they were fitted with an impact initiated explosive fuse that may cause harm if detonated.

Spigot mortar rounds do not lose their efficacy over time. If encountered they are likely to be unstable and easily initiated. If initiated a spigot mortar may result in harm and damage to persons and plant.

Z-battery rounds do not lose their effectiveness with age. Z-battery rockets were filled with a TNT based compound. If initiated the projectile may result in harm and damage to persons and plant.

If encountered, a QF pom pom round is comparable to a 40mm projectile.

Illustrations of Anti-Aircraft artillery, projectiles and rockets are presented at **Annex P**.

15.4. Evaluation of Allied Ordnance Risk

1st Line Defence has considered the following potential sources of Allied ordnance contamination:

Sources of Contamination	Conclusion
Military Camps <i>Military camps present an elevated risk from ordnance simply due to the large military presence and likelihood of associated live ordnance training.</i>	1 st Line Defence could find no evidence of a military camp within the site.
Anti-Aircraft Defences <i>Anti-Aircraft defences were employed across the country. Proximity to anti-aircraft defences increases the chance of encountering AA projectiles.</i>	1 st Line Defence could find no evidence of Anti-Aircraft defences such as a HAA or LAA gun emplacement occupying or bordering the site. The closest HAA was located approximately X.Xkm north-east of the site, however the range of a projectile can be up to 15km. The conditions in which HAA or LAA projectiles may have fallen unnoticed within a site footprint are analogous to those regarding German aerial delivered ordnance.
Home Guard Activity <i>The Home Guard regularly undertook training and ordnance practice in open areas, as well as burying ordnance as part of anti-invasion defences.</i>	Evidence of Home Guard training areas and activities is difficult to obtain. 1 st Line Defence has no evidence of any Home Guard activities on the site.
Defensive Positions <i>Defensive positions suggest the presence of military activity, which is often indicative of ordnance storage, usage or disposal.</i>	There is no evidence of any defensive features formerly located on or bordering the site footprint.
Training or firing ranges <i>Areas of ordnance training saw historical ordnance usage in large numbers, often with inadequate disposal of expended and live items. The presence of these ranges significantly impact on the risk of encountering items of ordnance in their vicinity.</i>	There is no evidence of such features affecting the site.

Defensive Minefields <i>Minefields were placed in strategic areas to defend the country in the event of a German invasion. Minefields were not always cleared with an appropriate level of vigilance.</i>	There is no evidence of defensive minefields affecting the site.
Ordnance Manufacture <i>Ordnance manufacture indicates an increased chance that items of ordnance were stored, or disposed of, within a location.</i>	No information of ordnance being stored, produced, or disposed of within the proposed site could be found.
Military Related Airfields <i>Military airfields present an elevated risk from ordnance simply due to the large military presence and likelihood of associated live ordnance training or bombing practice.</i>	The site was not situated within the perimeters or vicinity of a military airfield.

16. Ordnance Clearance and Post-WWII Ground Works

16.1. General

It is important to consider the extent to which any explosive ordnance clearance (EOC) activities or extensive ground works have occurred on site. This may indicate previous ordnance contamination or reduce the risk that ordnance remains undiscovered.

16.2. UXO Clearance

1st Line Defence has no evidence that any official ordnance clearance operations have taken place on site. Note however that we have not received confirmation of this fact from 33 EOD Regiment.

16.3. Post-war Redevelopment

The site does not appear to have been significantly developed post-war. The building in the west of the site does not appear to have changed, while the east of the site is occupied by hard-standing land. The risk from deep-buried unexploded bombs is only considered mitigated at locations where post war piling or deep foundations have taken place. Any smaller developments may have mitigated the risk from shallow-buried items somewhat.

17. 1st Line Defence Risk Assessment

17.1. Risk Assessment Stages

Taking into account the quality of the historical evidence, the assessment of the overall risk from unexploded ordnance is based on the following five considerations:

1. That the site was contaminated with unexploded ordnance.
2. That unexploded ordnance remains on site.
3. That such items will be encountered during the proposed works.
4. That ordnance may be initiated by the works operations.
5. The consequences of encountering or initiating ordnance.

UXO Risk Assessment	
Quality of the Historical Record	The research has located and evaluated pre- and post-WWII Ordnance Survey maps, London WWII ARP bomb plots from 1940 to 1945, Holborn written records, bomb damage mapping, in-house data and pre- and post-WWII aerial imagery of the site. In general, the presence of recorded bombing incidents is consistent with evidence of damage.
The Risk that the Site was Contaminated with UXO	<p>After considering the following facts, 1st Line Defence has assessed that there is a Medium Risk that items of unexploded German aerial delivered and anti-aircraft ordnance could have fallen unrecorded within the site boundary.</p> <ul style="list-style-type: none"> • The site was situated in the Metropolitan Borough of Holborn during WWII. According to Home Office statistics, this borough received 921.2 items per 1,000 acres, the highest bomb density within London and the country. • London bomb census mapping, both consolidated and weekly, record one bomb strike on the site's south-western border. The Holborn Record Of Air Raid Incidents, obtained from Camden Archives, records this strike in roughly the same place in May 1941. • LCC Bomb damage mapping records 'damage requiring demolition' to the structures immediately west of the site during the war. The area in the east of the site is marked as 'cleared by the War Debris & Disposal Service'. This means that this area was likely cleared before any damage could be attributed to it, meaning that it was either damaged by bombing or in such a poor condition that it was cleared regardless. • The western part of the site, which was occupied by a large multi-storey structure, was likely accessed frequently throughout the war. The eastern part of the site was likely accessed less frequently, as it does not appear to have been occupied with structures throughout the war and was cleared by 1942. This section appears on 1945 photography to be undeveloped hard-standing land, post-clearance. While the groundcover in the west of the site, which was occupied by a large multi-storey building, would have been conducive to the evidence of UXO, this would not have been the case in the east of the site. • Evidence from bomb mapping, damage mapping and incident records suggests that at least one strike occurred within the site's immediate proximity, to the west of the site. This caused significant damage. The eastern area of the site was marked as cleared on damage mapping. It is not know what caused this clearance. It is possible that this part of the site was in such a poor condition that it was cleared during the destruction of damaged properties. The combination of both this area and the bombing and damage recorded to the west of the site, means that no area of the site can be considered as 'low risk', due to the 'J-curve effect'. A buffer zone

	<p>has been placed around the damaged/cleared areas to account for the possibility that a UXB can end its trajectory at a lateral offset from point of entry – sometimes ending up beneath structures which survived the war intact.</p> <ul style="list-style-type: none"> • There is no evidence that the site formerly had any military occupation or usage that could have led to contamination with items of Allied ordnance, such as LSA and SAA. The conditions in which HAA or LAA projectiles may have fallen unnoticed within the site boundary are however analogous to those regarding aerial delivered ordnance.
The Risk that UXO Remains on Site	The site does not appear to have been significantly developed post-war. The building in the west of the site does not appear to have changed, while the east of the site is occupied by hard-standing land. The risk from deep-buried unexploded bombs is only considered mitigated at locations where post war piling or deep foundations have taken place. Any smaller developments may have mitigated the risk from shallow-buried items somewhat.
The Risk that UXO may be Encountered during the Works	<p>The most likely scenarios under which items of UXO could be encountered during construction works is during piling, drilling operations or bulk excavations for basement levels. The risk of encountering will depend on the extent of the works, such as the numbers of boreholes/piles (if required) and the volume of the excavations.</p> <p>An aerial delivered bombs may come to rest at any depth between just below ground level and its maximum penetration depth. Consequently there is also a possibility that UXBs could be encountered during shallow excavations (for services or site investigations) into the original WWII ground level.</p> <p>There is not considered to be any significant risk of encountering UXO during works planned within the footprint and down to the depth of any post-war buildings/excavations. Beyond these depths and away from these areas, a risk of encounter could remain.</p>
The Risk that UXO may be Initiated	<p>The risk that UXO could be initiated if encountered will depend on its condition, how it is found, and the energy with which it is struck. Certain construction activities such as piling and percussive drilling pose a greater risk of initiating UXO in comparison to machine excavation, where the force of impact is generally lower and the item is more likely to be observed.</p> <p>If a UXB is struck by piling or percussive drilling equipment, the force of the impact can be sufficient to detonate the main high explosive charge irrespective of the condition of the fuze or other components. Violent vibration might also impart enough energy to a chemical detonator for it to function, and there is a potential risk that clockwork fuzes could restart.</p> <p>If piling works are planned at the Ragged School site, there is a potential risk that a UXB, if present, could be initiated. The risk of initiation is assessed to be lower for any shallow intrusive works planned.</p>
The Consequences of Encountering or Initiating Ordnance	<p>The repercussions of the inadvertent detonation of items of UXO during intrusive ground works are potentially severe, both in terms of human and financial cost. A serious risk to life and limb, damage to plant and total site shutdown during follow-up investigations are potential outcomes.</p> <p>If appropriate risk mitigation measures are undertaken, the chances of initiating an item of UXO during ground works is comparatively low. The primary consequence of encounter of UXO will therefore be economic. This would be particularly notable in the case of sites with a high-profile or where it is necessary to evacuate the public from the surrounding area. A site may be closed from a few hours to a week with potentially significant cost in lost time.</p> <p>It should be noted that even the discovery of suspected or possible items of UXO during intrusive works (if handled solely through the authorities), may also involve loss of</p>

production. Generally, the first action of the police in most cases will be to isolate the locale whilst awaiting military assistance, even if this becomes unnecessary.

17.2. Assessed Risk Level

Taking into consideration the findings of this study, 1st Line Defence has assessed that there is a **Medium Risk** from German and anti-aircraft unexploded ordnance at the site of proposed works.

Medium Risk

Ordnance Type	Risk Level			
	Negligible	Low	Medium	High
German Unexploded HE Bombs			✓	
German 1kg Incendiary Bombs			✓	
Anti-Aircraft Artillery Projectiles			✓	
Allied Military Land Service Ammunition (Grenades, Mortars etc.)	✓			

18. Proposed Risk Mitigation Methodology

18.1. General

The following risk mitigation measures are recommended to support the proposed works at the Ragged School site:

Type of Work	Recommended Mitigation Measure
All Works	<ul style="list-style-type: none"> Site Specific UXO Awareness Briefings to all personnel conducting intrusive works. As a minimum precaution, all personnel working on the site should be briefed on the basic identification of UXO and what to do in the event of encountering a suspect item. This should in the first instance be undertaken by a UXO Specialist. Posters and information on the risk of UXO can be held in the site office for reference.
Shallow Intrusive Works/Open Excavations	<ul style="list-style-type: none"> Unexploded Ordnance (UXO) Specialist Presence on Site to support shallow intrusive works When on site the role of the UXO Specialist would include: <ul style="list-style-type: none"> Monitoring works using visual recognition and instrumentation, including immediate response to reports of suspicious objects or suspected items of ordnance that have been recovered by the ground workers on site. Providing UXO awareness briefings to any uninformed staff and advise staff of the need to modify working practices to take account of the ordnance risk. To aid incident management which would involve liaison with the local authorities and police should ordnance be identified and present an explosive hazard.
Borehole/Piles	<ul style="list-style-type: none"> Intrusive Magnetometer Survey of all borehole and pile locations down to a maximum bomb penetration depth: 1st Line Defence can deploy a range of intrusive magnetometer techniques to clear pile locations. The appropriate technique is influenced by a number of factors, but most importantly the site's ground conditions. The appropriate survey methodology would be confirmed once the enabling works have been completed.

In making this assessment and recommending these risk mitigation measures, if known, the works outlined in the 'Scope of the Proposed Works' section were considered. Should the planned works be modified or additional intrusive engineering works be considered, 1st Line Defence should be consulted to see if a re-assessment of the risk or mitigation recommendations is necessary.

1st Line Defence Limited

26th March 2018

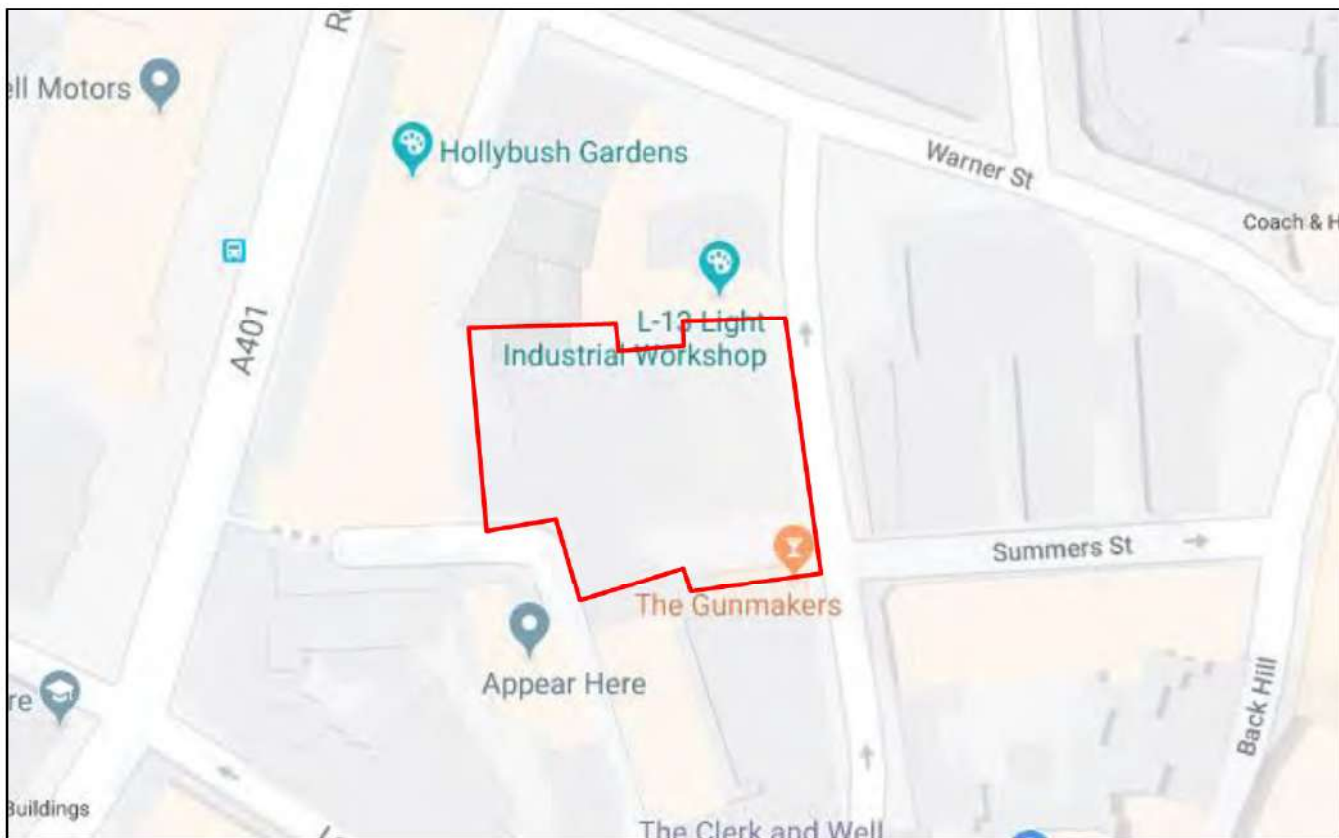
This Report has been produced in compliance with the Construction Industry Research and Information Association (CIRIA) C681 guidelines for the writing of Detailed UXO Risk Assessments.

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Project: **Ragged School**

Ref: **DA6188-00**

Source: Google Maps

Approximate site boundary



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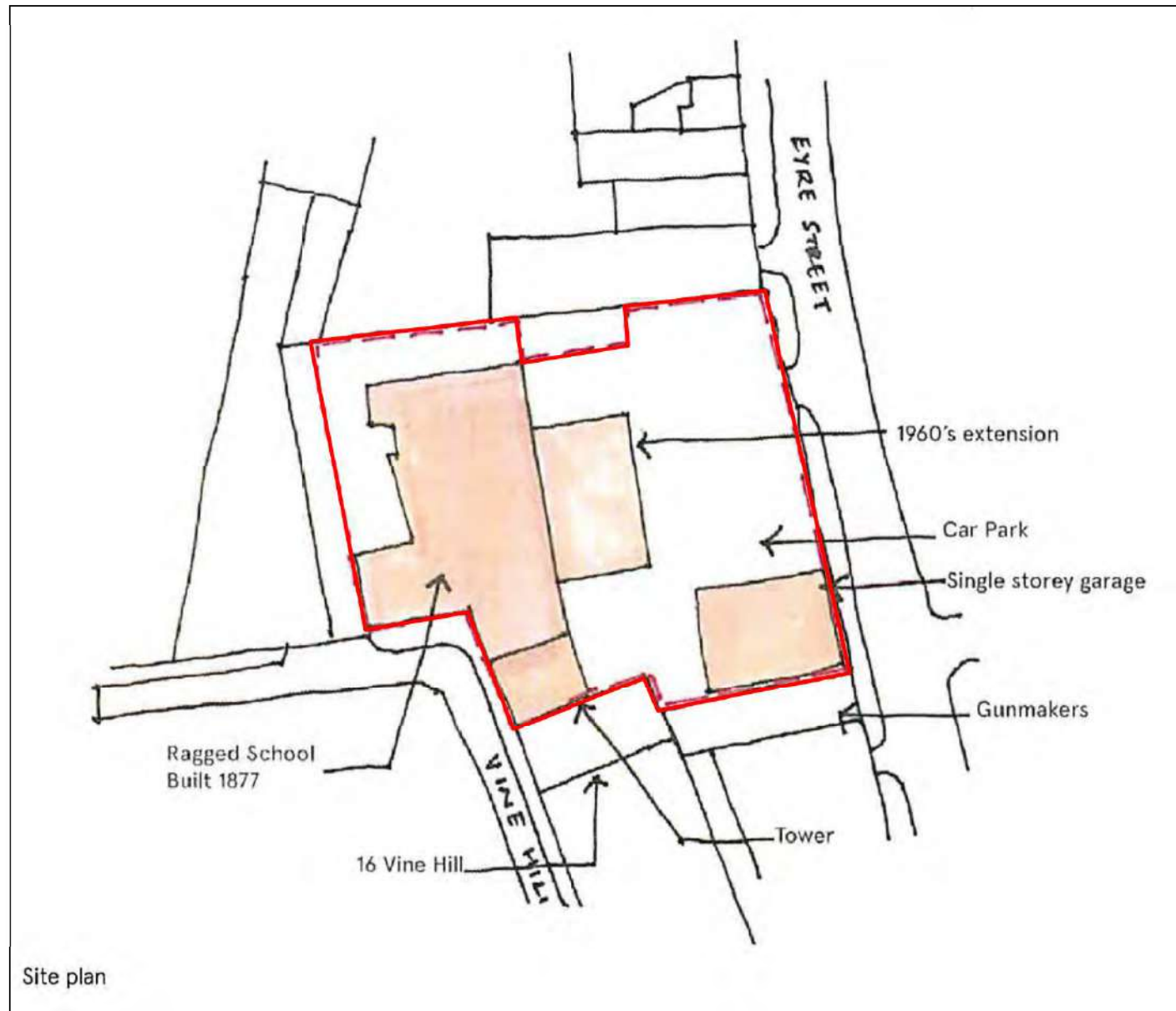
Ref: **DA6188-00**

Source: Google Earth™ Mapping Services

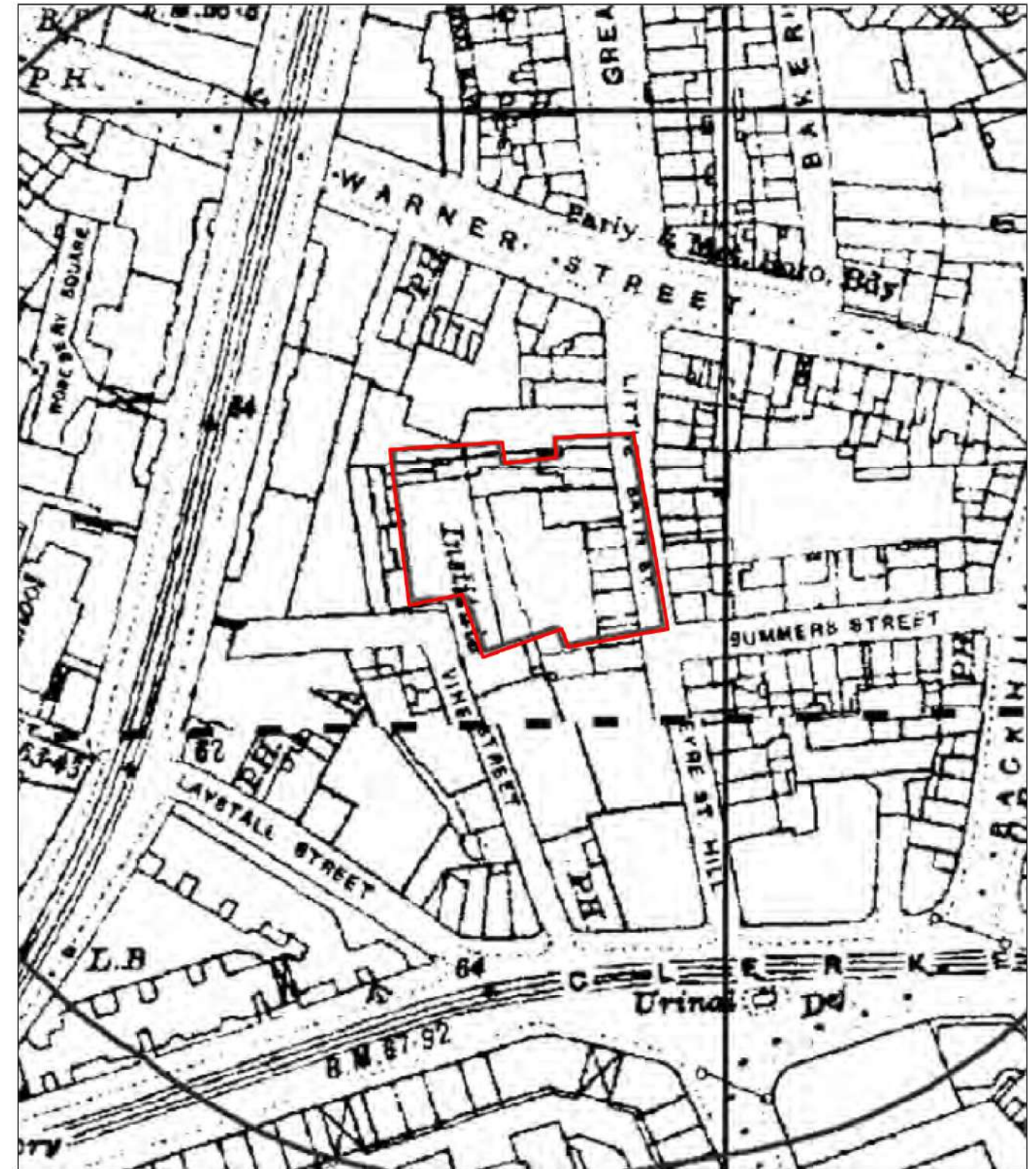
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Site plan



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