BRIMSTONE
SITE INVESTIGATION

DETAILED
UXO RISK ASSESSMENT

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STAGE 2 DETAILED UXO RISK ASSESSMENT

Client:	University of Exeter
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EXECUTIVE SUMMARY

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

THE SITE: The Site comprises two parcels of land located approximately 600m apart; the site areas will be referred to as **Site A** and **Site B** for the purposes of this assessment. Both Site areas are located in Exeter, within Devon. Site A is located approximately 660m north of Exeter St Davids railway station.

Site A (approximately centred on the National Grid Ref: SX 91347 94073) comprises a large part of the University of Exeter campus, including student accommodation blocks and facilities, associated landscaping, areas of undeveloped / open space, hard surfaced roadways, courtyards, pathways, access ways and car parking facilities, as well as pockets of vegetation, largely mature in nature. Peripheral vegetation is also present throughout the Site. It is bound to the north by residential properties on Glenthorne Road, Clydesdale Road and Highcroft Court, to the east by properties and undeveloped ground associated with the University of Exeter, to the south by the Queen's Drive and residential properties and associated garden areas situated on Streatham Drive, Lodge Hill, Birchcote and Elmbridge Gardens, and to the west by Cowley Bridge Road.

Site B (approximately centred on the National Grid Ref: SX 92102 94527) comprises predominantly undeveloped ground consisting of grass and spoil from landscaping activities. A roadway leading off Higher Hoopern Lane is present in the south. It is bound to the north by a footpath and dense mature vegetation, to the east by undeveloped land consisting of grass with some temporary structures, to the south by a multi-storey car park and a ground level car park and to the west by an underground reservoir.

THE PROPOSED WORKS: The proposed development for **Site A** comprises the demolition of existing structures and the subsequent construction of student accommodation and ancillary amenity facilities with associated infrastructure, the provision of solar panels at Holland Hall Car Park, general landscaping and the refurbishment of Birks Grange Blocks A-E including external alterations to the appearance of the building. A demolition plan can be seen in **FIGURE 3.2**.

The proposed development for **Site B** comprises the construction of a new Estate Services Centre, comprising offices, a workshop, glasshouses, polytunnels, a growing area and storage buildings, with associated infrastructure and landscaping.

Part of the development will involve piled foundations with a contiguous piled retaining wall. NB: this is thought to be part of the development planned for Site A. However, the exact depths to which piles / further excavations are planned is currently not available.

UXO RISK ASSESSMENT:

German UXO:

- Exeter experienced 19 air raids during WWII. Most of these were executed by solitary bombers; however, two raids in April and May 1942 were concentrated medium-scale attacks, during which hundreds of high explosive (HE) bombs and thousands of incendiary bombs (IBs) were dropped causing widespread damage. The Site occupied a peripheral area of the city, away from the Luftwaffe's primary target point (the city centre). Consequently, the study area is likely to have experienced a lower localised bombing density than that of the wider borough and city centre. However, despite the lower localised bombing density, according to official records, the Site areas experienced at least two raids (likely more).
- These two raids resulted in 13 incidents within a 400m radius of Site A and eight incidents within a 400m radius of Site B. The majority of these incidents were recorded during the May 1942 raid, as part of the Baedeker raids on the city. The closest recorded incidents were plotted to the immediate north-east of Site A and the immediate west of Site B.
- From these records, it has been possible to identify a number of potential linear bomb-sticks (individual aircraft bombload) in the local area and therefore, the flightpath orientations of aircraft. This analysis identifies at least five (possibly more) potential occasions during which an unexploded bomb (UXB) (unobserved and unplotted) could have been released over and landed on or adjacent to the Site.

- An anecdotal account describing bombing incidents over the University of Exeter was also reviewed. It suggests that the wider study area experienced incendiary bombing, which was not recorded within either bomb mapping set. In addition, the account suggests that the Site experienced far more intense bombing than the official records suggest, with one extract stating that 24 items of ordnance were dropped over the university campus during one raid.
- Furthermore, the account refers to several UXBs being present in the vicinity of the university. Given Site A's close proximity to the main university buildings, it is entirely feasible that such incidents occurred on Site and went unnoticed. This can also be said for Site B, despite being slightly further away from the college, due to its undeveloped nature.
- As all local air raids occurred during the hours of darkness, there is a greater risk associated with unexploded ordnance (UXO) falling within the Site unobserved. Furthermore, no evidence was found to confirm that night-time observers (fire watchers or anti-aircraft (AA) gunners) were active in the vicinity.
- Additionally, in relation to the undeveloped areas of the Site; these are likely to have only experienced intermittent levels of access and are unlikely to have been subject to specific post-raid searches for German UXBs in the wake of raids. Even if the Site had been searched, which is suggested in the anecdotal account, it is conceivable that a UXB entry hole could have been easily obscured in dense vegetation, areas of crop growth or ploughed soil and gone unreported. This can be evidenced by the discovery of a 1,000kg HE bomb to the immediate north of Site A.

British / Allied UXO:

- 11 permanent heavy anti-aircraft (HAA) batteries were active within range of the Site during WWII. Luftwaffe activity was frequent and intense over the wider area and therefore these guns would have expended a vast quantity of ammunition. Consequently, it is quite possible that an unexploded AA (anti-aircraft) shell struck the Site and remained unnoticed as per the reasons cited above
- 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 (unexploded ordnance) is low.

Likelihood of UXO Remaining and UXO Encounter:

- Several properties have been constructed throughout Site A, many of which are multi-storey student accommodation blocks. The excavations for the structures are anticipated to have varied from shallow (1-2m below ground level (bgl) for structures >3 storeys) to deep (<2m bgl for structures =/<3 storeys). WWII-era foundations are assumed to remain beneath the structure in the west of Site A, which has survived until the present day.
- Site B has experienced no significant post-WWII ground works. It has remained in the same configuration since WWII-era, aside from the laying of hard surfaced ground in the south. This will have likely disturbed WWII-era soil to a very shallow depth. The same can be said of the hard surfaced ground present in Site A.
- The risk associated with any buried German UXBs will have only been mitigated at the locations and down to the maximum depths of each post-WWII installation / excavation. A deep buried UXB could conceivably remain under the Site, either in places not subject to post-WWII excavations or in between / below post-WWII excavations.
- It is also conceivable that a UXB could be encountered during any shallow mechanical excavations beneath the existing ground level in this location.

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.
EOD Engineer - On Site Supervision	During all open excavations.
Intrusive Magnetometer Probe Survey	At all pile positions.

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BRIMSTONE SITE INVESTIGATION LTD

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

- **Integrity** in advice, information and the manner in which we conduct ourselves and our operations.
- **Professionalism** in the way we handle our operations, people, and processes.
- **Knowledge** in new skills and information, to ensure we remain at the forefront of innovation and strategy.

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1 INTRODUCTION

1.1 Background

The University of Exeter (the Client) has commissioned BSI to carry out a Stage 2 Detailed Unexploded Ordnance Risk Assessment (DRA) of the proposed redevelopment works at the University of Exeter site (the Site).

1.2 Legislation

There are no regulations that specifically govern the UXO risk mitigation industry in the UK. There are however 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 BSI'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 BSI 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 detonating 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 9000m 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 cause substantial corrosion in WWII German UXBs and therefore an incident such as this is extremely rare.

2 ASSESSMENT METHODOLOGY

2.1 Introduction

This assessment has been produced in accordance with the relevant CIRIA guidelines; *Unexploded Ordnance (UXO) - A Guide for the Construction Industry C681* (published in 2009). CIRIA C681 is 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. Another consequence to consider however 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 BSI has gathered information from a wide range of sources. BSI'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, Bluesky),
- Google open source mapping,
- The British Geological Society,
- Open sources; published book, articles, web resources,
- Site specific information supplied by the Client,
- BSI's library and historical database, and
- BSI'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, BSI 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 BSI risk assessment process divides UXO risk into two tolerances:

- **Tolerable:** negligible risk or low 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 risk or high-risk ratings are intolerable. Proactive risk mitigation measures should be put in place. Various strategies are at BSI'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. BSI 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 comprises two parcels of land located approximately 600m apart; the site areas will be referred to as **Site A** and **Site B** for the purposes of this assessment. Both Site areas are located in Exeter, within Devon. Site A is located approximately 660m north of Exeter St Davids railway station.

Site A (approximately centred on the National Grid Ref: SX 91347 94073) comprises a large part of the University of Exeter campus, including student accommodation blocks and facilities, associated landscaping, areas of undeveloped / open space, hard surfaced roadways, courtyards, pathways, access ways and car parking facilities, as well as pockets of vegetation, largely mature in nature. Peripheral vegetation is also present throughout the Site. It is bound to the north by residential properties on Glenthorne Road, Clydesdale Road and Highcroft Court, to the east by properties and undeveloped ground associated with the University of Exeter, to the south by the Queen's Drive and residential properties and associated garden areas situated on Streatham Drive, Lodge Hill, Birchcote and Elmbridge Gardens, and to the west by Cowley Bridge Road.

Site B (approximately centred on the National Grid Ref: SX 92102 94527) comprises predominantly undeveloped ground consisting of grass and spoil from landscaping activities. A roadway leading off Higher Hoopern Lane is present in the south. It is bound to the north by a footpath and dense mature vegetation, to the east by undeveloped land consisting of grass with some temporary structures, to the south by a multi-storey car park and a ground level car park and to the west by an underground reservoir.

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

3.2 The Proposed Works

The proposed development for **Site A** comprises the demolition of existing structures and the subsequent construction of student accommodation and ancillary amenity facilities with associated infrastructure, , the provision of solar panels at Holland Hall Car Park, general landscaping and the refurbishment of Birks Grange Blocks A-E including external alterations to the appearance of the building. A demolition plan can be seen in **FIGURE 3.2**.

The proposed development for **Site B** comprises the construction of a new Estate Services Centre, comprising offices, a workshop, glasshouses, polytunnels, a growing area and storage buildings, with associated infrastructure and landscaping.

Part of the development will involve piled foundations with a contiguous piled retaining wall. NB: this is thought to be part of the development planned for Site A. However, the exact depths to which piles / further excavations are planned is currently not available.

FIGURE 3: Existing Site Plans

4 SITE HISTORY

4.1 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

Site A:

Period	Map Date	Map Scale	Review
Pre-WWI	1905	1:2,500	The Site is largely comprised by open ground of an assumed agricultural nature. A structure labelled as Belmont is partially encompassed by the western border. An orchard is partially encompassed in the north-west. Pockets of vegetation are situated sporadically throughout. Streatham Hall is situated to the east.
Pre-WWII	1932 – 1938	1:2,500	**FIGURE 4.1:** No significant development has occurred on Site. A small structure is present in the south-west. An access way is present in the north-west. Streatham Hall is now labelled as Reed Hall. Mardon Hall has been constructed to the immediate east. Residential properties have been constructed to the immediate south and south-west. Pomona Nursery is labelled to the immediate south-west. Residential development has occurred to the west on the adjacent side of New North Road.
Post-WWII	1955	1:2,500	**FIGURE 4.2:** No significant development has occurred on Site. Two tennis courts are present within the boundary to the immediate west of Mardon Hall. Tennis courts are also partially encompassed by the boundary, associated with Birks Grange (formerly Belmont) in the east. A property has been cleared to the immediate south of the Site.
	1962 – 1967	1:1,250	A number of structures have been erected in the west and north-west of the Site. These structures are labelled as Birks Halls of Residence, Brendon House, Haldon House, Raddon House, Raddon Lodge and Brendon Lodge – all are associated with the University of Exeter. Further structures have been erected in the southern extent of the Site. Clydesdale Road intersects the Site in the north, running south-eastwards.

Site B:

Period	Map Date	Map Scale	Review
Pre-WWI	1905	1:2,500	The Site is wholly comprised by open ground of an assumed agricultural nature. A pathway intersects the Site, running south-east to west from Hoopern Farm.
Pre-WWII	1932	1:2,500	**FIGURE 4.3:** No significant changes have occurred on Site. Residential development has occurred to the east.
Post-WWII	1952-1954	1:2,500	**FIGURE 4.4:** No significant changes have occurred on Site.
	1968-1970	1:2,500	No significant changes have occurred on Site. A sandpit is located immediately west.

4.3 Aerial Photography

Site A:

Period	Photo Date	Review
Post-WWII	1947	**FIGURE 5.1:** This vertical view photograph was taken approximately two years after the end of WWII (in Europe). The undeveloped areas of the Site appear to be well maintained, with no obvious evidence of bomb damage occurring i.e. cratering, disturbed ground. The structure partially encompassed by the Site's western border appears to have survived externally structurally intact. The tennis courts present in post-WWII OS mapping can be seen in the east and west of the Site. A small area of structural clearance can be seen to the immediate south.

Site B:

Period	Photo Date	Review
Post-WWII	1947	**FIGURE 5.2:** This vertical view photograph was taken approximately two years after the end of WWII (in Europe). The southern extent of the Site is not visible in the photograph. The pathway identified in OS mapping can be seen intersecting the Site. A small herd of livestock can be seen in the north-east, suggesting that the Site was of an agricultural nature. A circular depression is noted in the east of the Site. A further depression is noted to the north-east. These represent potential craters. The residential properties to the east appear to have survived WWII externally structurally intact.

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 found for this Site.

5 UXO RISK - GERMAN BOMBING

5.1 WWII Bombing History of the Site

5.1.1 Exeter

The city of Exeter contained few strategic military Luftwaffe targets, although was home to rail infrastructure and utilities, such as gas works, a power station and water treatment works. The city experienced only minor bombing during the early phase of the war, with the first bombs falling on 7th August 1940. This, like most of the subsequent air raids during 1940 and 1941, was a 'Tip and Run' raid carried out by a solitary German bomber.

Following the end of the nine month 'Blitz' period of bombing over the UK, few further attacks on Exeter were anticipated. However, in 1942, the RAF's bombing of the historic German city of Lübeck resulted in a retaliation bombing campaign (the Baedeker Raids) on some of England's most historic cities, namely Exeter, Bath, Canterbury, Norwich and York.

Exeter was the first city to be attacked as part of this campaign. On the night of 23rd / 24th April 1942, 49 bombers approached Exeter at 22:40hrs. However, due to heavy cloud cover of the target area, most of the raiders missed the city. Only two tons of bombs were dropped on the borough, causing the deaths of five people.

On the following night (24th / 25th April), conditions were more favourable. Between 00:10hrs and 01:55hrs, approximately 44 aircraft dropped 26.5 tons of munitions in good visibility and at low level, causing damage in the west and east of the city. 73 lost their lives with a further 54 injured.

The following night (25th / 26th April) a small-scale nuisance raid was executed. Only half a ton of bombs was dropped by one or two raiders. By this point, at least 160 HE bombs and 8,000small incendiary bombs (IBs) had been dropped on Exeter.

Exeter's final Baedeker Raid occurred on the night of 3rd / 4th May. At 01:36hrs the raid began with hundreds of small IBs dropped. Over a period of one and a half hours, 90 Luftwaffe bombers attacked from the south, devastating the city centre and the Newtown area. In total, 51 tons of munitions were dropped and by 02:00hrs there were 19 reports of large fires. This raid resulted in 164 fatalities. NB: this was a medium weight raid by Luftwaffe standards. An attack was described as a 'Major Raid' if at least 100 tons of HE bombs (in addition to IBs) was delivered to the target area. However, this raid was accurate and concentrated on a relatively small city centre. Consequently, the bombing density would have been relatively high for a medium weight attack.

On the following two nights, single raiders dropped a few HE bombs on the city centre and then on 30th December 1942 Exeter experienced its final raid of the war. This small-scale raid only involved two German aircraft and resulted in five sporadic bomb strikes. By the end of the war Exeter had experienced 19 air aids. Approximately 40 acres of the city centre had been gutted by fire, >1,500 of Exeter's 20,000 houses were destroyed with 2,700 seriously damaged and few of the remaining 16,000 left unscathed.

5.1.2 Site Specific

The Luftwaffe's raids on Exeter were motivated by reprisal and therefore, bombing on the city was indiscriminate and generally aimed at the historic city centre. As such, the Site's relatively peripheral location within the city means it was unlikely to have been targeted specifically. However, it should be noted that Luftwaffe target reconnaissance photography does highlight targets in the wider vicinity, the closest of which was Exeter Central station, approximately 850m south of Site A.

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 4.8km to the south-west of Site A.

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 Devon Heritage Centre 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 Exeter, within which the Site was located during WWII. It gives a breakdown of the types of large German bombs reported and is understood to not include UXBs. These figures were sourced from the National Archives, London.

	County Borough of Exeter
Area Acreage	4,721
High Explosive Bombs (all types/weights)	304
High Explosive Parachute Mines	6
Flam (Oil) Bombs	0
40kg Phosphorus Incendiary Bombs (IBs)	0
40kg 'Fire Pot' IBs	0
V1 Flying Bomb	0
V2 Long Range Rocket	0
Total (excluding V-Weapons and 1kg / 2kg IBs)	310
Bombs Per 1,000 Acres	65.7

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. No APs are understood to have been dropped on Exeter, however, at least 10,000 1kg/2kg IBs were recorded.

5.2.3 Bomb Census Map: 1942

BSI has reviewed a bomb census map for Exeter covering the Baedeker Raid period, as well as the few bombs dropped during the final raid on Exeter in December 1942. This map plots all 'iron' bombs dropped during these raids. A section of this map covering the study areas is displayed at **FIGURE 6**.

Site A (FIGURE 6.1):

- Approximately 13 x 'iron' bombs are plotted within a 400m radius of the Site.
- The closest strike is plotted immediately north-east (500kg).
- Several other incidents are plotted within 100m of the boundary.
- Site A was only bombed during two of the four Baedeker raids (24/25th April and 3rd/4th May 1942).

Site B (FIGURE 6.2):

- Approximately eight x 'iron' bombs are plotted within a 400m radius of the Site.
- The closest strike is plotted immediately west (50kg).
- Four further 50kg bomb strikes are plotted approximately 100m south of the boundary.
- Site B was only bombed during one of the four Baedeker raids (3rd/4th May 1942).

5.2.4 Individual Raid Bomb Plot Maps

BSI has reviewed a collection of contemporary maps held at the Devon Heritage Centre which plot the positions of bombs dropped during all the raids occurring over Exeter during WWII. These maps are of a small scale and only recorded large 'iron' bomb strikes. Those maps that plot incidents in the vicinity of the Site are displayed at **FIGURE 7**.

Two air raids resulted in HE bombs dropped within 400m of the two Site areas; the dates of both raids correspond with the dates given for incidents recorded in proximity to the Site on the bomb census mapping (24th April and 4th May 1942).

No incidents are recorded within either Site footprint. The closest recorded incident to Site A is approximately 50-100m to the south-west (24th April 1942). The closest recorded incident to Site B is approximately 50m west (24th April 1942).

5.2.5 'Living Through WWII at Exeter'

BSI has reviewed an article titled 'Living Through WWII at Exeter' on the University of Exeter website[1]. The article transcribes a series of letters written by a student, John Saunders, who attended the University of Exeter during WWII. In these letters, John detailed his experiences during significant bombing raids by Luftwaffe forces whilst living in Mardon Hall (immediately to the east of Site A).

Unfortunately, the letters were not dated and as such, it has not been possible to corroborate John's accounts with the bomb mapping.

Relevant sections of the letters regarding bombing / damage in the vicinity of the Site areas are transcribed below. Any information relating to bombing / damage within / immediately adjacent to the Site is emboldened:

- ***Reed Hall, which is right beside us, has had most of its windows blown out****, but curiously enough Mardon is practically intact - only two holes in the windows. The shutters were wrenched open in the front of the building and a handle of one of the French windows was blown through the window of the common room. The reason is probably that all the bombs around us fell in soft earth. Anyway, we have had a narrow escape.* ***One line of craters is in a straight line over us, two on each side, so it looks as if Jerry dropped a stick of bombs*** *- (probably the four terrific explosions we heard) right over us and we were lucky in being in between where they fell.* ***There are hundreds of burnt-out incendiaries around. In one valley about 300 yards away there are at least a hundred.***

- ***We have got some unexploded bombs in amongst the college buildings so we shan't have any lectures until they are removed - or go off!***

- *They removed a delayed action bomb from the woods just at the back of us at 3 o'clock this morning and now an airman has been up looking for another one they think has dropped up there somewhere. The woods are only about 50 to 100 yards away from Mardon so if anything goes off it will shake us up.*
    - The woods referred to in this excerpt are thought to be approximately 80m north-east of Site A.

- *All our halls have had either high explosive bombs within a few yards of them or else incendiaries on their roofs. Lots of our chaps have been bringing in complete unexploded incendiary bombs. There are about 6 in a room next but one to mine!! A workman went down by a few minutes ago with a whole stick of unexploded incendiaries in a case it is a part of a "Molotov Cocktail".*

[1] https://www.exeter.ac.uk/alumnisupporters/news/articles/livingthroughwwiiatexeter.html

- ***The airman who was up here looking for the delayed action bomb said that the bombs dropped beside us here were 2000 pounders!!*** *They shook us up enough anyway but it's no wonder if they were as large as that. I have just found out, too, that four of the fellows from here were only about 25 yards from the bomb that went off up at the back of us.*
- *We had a real blitz last night - much worse than last Friday week. Jerry came over at about two o'clock and started dropping flares. Then down came the incendiaries! I have never seen so many incendiaries and never want to see so many again. They fell in a long line right up the valley below us and all over the city.*

  There must have been thousands of them and they lit up the place in an awful glare - made you feel as if every Jerry pilot up above was able to see you. The bombs followed soon after the incendiaries. I was lying down outside when the first couple came down. We heard the plane overhead come screaming down - then came the whistling of the bombs and finally, they burst.

  These two were near enough to us to fill the whole air with a cloud of dust and smoke. *You could scarcely breathe for it. I cleared inside after this.* ***In the next hour I should think twenty bombs and four land mines fell very near us!*** *You could hear the planes diving over and then the scream of the bombs as they were released, the scream becoming less high pitched as they fell towards the ground.*

- ***The nearest we had was a landmine right beside us & only about 30 yards away. I think the only reason why we were not blown up and the fact that it hit the top of a tree and the majority of the blast passed over us.*** *However, it brought down a great deal of plaster and wrenched some of the window frames out of their sockets.*

- *Any of the roads are roped off - there seem to be hundreds of delayed action bombs all over the town.* ***Twelve of these went off in the night & one of them was right beside our library.*** *This one shook Mardon alright and woke everyone up. New cracks have now appeared in our walls as a result, but no more glass was broken.*

- ***The bomb which fell right beside us on Sunday night [It was a bomb & not a land mine as we first thought] landed only 15 yards away from the corner of Mardon. The only thing that saved us was the fact that the bomb hit a large branch high up in a tree and exploded. The plane which dropped the bomb was definitely aiming at us and he would have hit the corner of the building had the tree not been in the way.***

- *As it was, we reckon, the blast went, for the most part, over our heads.* ***There must be other delayed action bombs around us as we heard them whistle over us and then did not hear any explosion.*** *Our drive is already roped off on account of these bombs by the library and only ourselves and the people in the houses in our drive are allowed to go up.*

- *It would be an insult to me to think I enjoyed seeing half of Exeter apparently in flames or enjoyed being dive-bombed by Jerries who definitely had Mardon or Reed Hall, the Science Block, and the Library as their objective.*

    - This excerpt suggests that the university itself was targeted. NB: unfortunately, this cannot be confirmed by official Luftwaffe target records.

5.2.6 Abandoned Bomb Register

Due to the overstretched bomb disposal units during WW2, 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 BSI has obtained a copy. The register should not be relied on for completeness or accuracy. The closest abandoned bomb is recorded <50km south-west.

5.2.7 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. Other than the article discussed in **Section 5.2.5**, no such evidence could be found related to the Site.

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 two air raids affected Site A and at least one affected Site B (possibly more).
Intensity of these Air Raids:	These raids were medium-scale attacks carried out at night.
Bomb Strike Positions	
Closest Bomb Strikes	HE bombs: immediately north-east of Site A (500kg) and immediately west of Site B (50kg). 1kg / 2kg IBs: anecdotal account suggests that incendiary devices fell in close proximity to the Site. Exact location unknown.
Alignment of recorded Bomb Strikes:	**Site A**: Whilst no definite bomb-stick (individual bombload) patterns could be established due to the local density during the heaviest raids, it can be said that a number of potential bomb-sticks are generally aligned with Site A as identified on the 1942 bomb census mapping. Two of these potential bomb-sticks traverse the Site area, whilst three others are recorded in the immediate vicinity. Furthermore, the anecdotal account transcribed in **Section 5.2.5** suggests that aircraft passed over Site A, further evidencing the potential for bomb-sticks to have straddled the Site. Consequently, the possibility cannot be discounted that a German aircraft flew over the Site whilst dropping bombs in the vicinity, potentially resulting in a UXB being released over Site A. **Site B:** Based on the pattern of the bomb strikes falling in the vicinity of Site B, it has not been possible to establish any incidences of bomb-sticks being dropped in alignment with Site B.
Bomb Failure Rate	
Evidence to suggest that the generally accepted failure rate of 10% differs in the vicinity of the site:	None.
UXBs recorded in close proximity to the site:	Site A: 180m south-east. Site B: 620m south-west (same incident).

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.
Site A: Birks Hall (west), Mardon Hall (immediately east), Reed Hall and associated properties (immediately east) and residential properties (immediately south and south-west) appear to have survived the war intact and would therefore have likely remained inhabited throughout. The properties' surrounds are also likely to have experienced frequent access. NB: properties may have been temporarily evacuated for a time following bombing raids. However, one small area of clearance is present to the immediate south. It is conceivable that this plot would have been abandoned for the remainder of the war. Evidence of any subsequent UXB strikes here or immediately adjacent (within the Site area) will have likely remained unseen. Any UXBs falling within the open areas of the Site may have fallen unnoticed during the ensuing chaos caused by a medium-scale raid. These areas are also anticipated to have experienced infrequent access in comparison to the areas occupied by / in close proximity to structures, heightening the chance of any UXBs going unnoticed. **Site B:** Site B is considered likely to have experienced infrequent access throughout WWII owing to its open and insignificant nature. The presence of the footpath in the centre is not considered likely to have significantly increased access levels. **Both Site Areas:** Evidence of firewatchers operating at the university was found. However, due to the severity of the air raids, it is possible that the Site was not under observation during bombing. Additionally, the majority of local air raids occurred during the hours of darkness when residents and workers would have been indoors and / or sheltering. As such, there is generally a lower probability of anyone witnessing any UXB strike to the Site as it fell / occurred.

Bomb Damage
As the bombing campaign continued, damaged areas became vulnerable to unreported UXBs. Bombsite wreckage or soil disturbance at a bomb crater could obscure evidence of a subsequent UXB strike.
Site A: No visually identifiable evidence of significant bomb damage occurring to properties could be found in post-WWII aerial photography. As mentioned above, all properties present within or immediately adjacent to (aside from one) can be said to have survived WWII externally structurally intact. Any incidents occurring to these properties would have caused incontrovertible evidence of UXO, which would have been reported. Furthermore, the open ground within does not display any evidence of cratering or ground disturbance. However, anecdotal evidence suggests that Mardon Hall, immediately to the east, suffered minor blast damage due to bomb strikes occurring in the surrounds. It is feasible that these strikes occurred in the open areas, causing damage to the grass and vegetation which had become obscured by the time the photograph was taken. **Site B:** A roughly circular feature can be seen in the east; this feature may be representative of a crater left behind after a bombing incident. A further feature can be seen to the immediate north-east. **Both Site Areas:** It should be noted that the diameter of the smallest German HE bomb (also the most commonly deployed over Britain) was just 200mm, creating a small easily obscured entry hole. As the majority of the open area

encompassed by Site A and the entirety of Site B are anticipated to have experienced infrequent levels of access, it is possible that minor evidence of damage / small entry holes in these areas may have gone unnoticed and is not visible in available aerial photography.

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.
Site A: Any UXB strike to the property encompassed by the boundary of Site A would have caused incontrovertible evidence of its incidence as it passed through multiple stories and into the ground beneath. The same can be said for some of Site A's neighbouring structures and the road surfaces, where (assuming no cratering) a HE UXB entry hole would have been persistent and easily recognisable. NB: it should be noted however that the J-curve effect (whereby a bomb penetrating the ground travels laterally) may have resulted in UXBs coming to rest beneath the structure, away from an entry hole. **Both Site Areas:** The open ground on Site appears to be well maintained in the aerial photography consulted for this report. However, the possibility that access to the Site was impeded, resulting in the vegetation becoming overgrown/unmaintained, cannot be ruled out. Had this happened, a small UXB entry hole could easily have been obscured within such ground cover. Over time, environmental conditions could have caused this hole to infill, erasing any evidence of a UXB.

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.

However, no air raids occurred in Exeter or the wider Devon area during WWII. As such, the risk posed by German WWI UXBs is considered to be negligible.

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. 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	
	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
250	4.8	13.7	4.8	13.7	6.0	13.1	6.8	15.8
500	6.0	17.3	6.0	17.3	7.6	16.4	8.7	19.8
1,000	7.6	21.9	7.6	21.9	9.6	20.7	10.9	24.9

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:** Site A: River Terrace Deposits, 5 (Sand and Gravel) None recorded in Site B	**Bedrock Deposits:** Crackington Formation (Mudstone and Sandstone)
SI Data	No site-specific borehole logs were provided by the client. However, borehole logs through the same mapped geology as the Site areas were available from British Geological Survey (BGS), approximately 520m south of Site A. A report dated September 1991 (BGS ID: 812490) includes the following description of the ground conditions: - 0.5m of Made Ground (dark brown very sandy silty clay with medium sized gravel) - 0.9m of Made Ground (firm brown mottled light brown sandy silt clay, with occasional fine to medium gravel sized fragments including wood) - 3.05m of Clay (stiff brown to red brown mottled purple thinly laminated silty) - 1.4m of Sandstone, Siltstone and Mudstone (brown interstratified highly weathered with up to 80% of the core recovery being a silty clay matrix, fine to medium grained) - 0.18m of Siltstone and Clay (red brown moderately weathered, weak up to 40% silty) - 0.42m of Mudstone (grey thinly laminated moderately to slightly weathered) - 0.3m of Sandstone (red brown fine to medium grained moderately to slightly weathered) - 0.37m of Mudstone (brown to red brown thinly laminated completely to highly weathered) - 0.41m of Sandstone (brown medium grained moderately to slightly weathered) - 0.18m of Mudstone (grey and brown thinly laminated moderately weathered) - 1.54m of Sandstone (red brown medium grained thinly to thickly laminated completely to slightly weathered) - 0.35m of Sandstone (red brown thinly laminated extremely closely fractured slightly weathered) - 0.42m of Mudstone (grey brown mottled purple thinly laminated slightly weathered) - 0.6m of Siltstone (red brown thinly to thickly laminated moderately to slightly weathered) - 0.54m of Mudstone (brown grey mottled purple thinly laminated (fissile) slightly weathered) - 0.51m of Siltstone and Sandstone (red brown micaceous thickly laminated to very thinly bedded (fissile) slightly weathered / interbeds of fine grained slightly weathered) - 2.27m of Mudstone and Sandstone (brown grey mottled purple thickly laminated to very thinly bedded slightly weathered / moderately weak to moderately strong with bands of fine grained slightly weathered) - 0.56m of Sandstone (red brown fine grained slightly weathered) - 0.64m of Sandstone and Mudstone (red brown very closely to closely interstratified fine grained slightly weathered / thinly laminated slightly weathered) - 0.68m of Mudstone (red brown mottled purple with grey bands thinly laminated (fissile) slightly weathered, weak to moderately weak with occasional red brown silty clay smears) - 0.9m of Sandstone (red brown fine grained becoming medium grained moderately to slightly weathered) - 0.9m of Mudstone (brown thinly laminated moderately to slightly weathered) - 1.48m of Sandstone, Siltstone and Mudstone (brown to red brown closely interbedded fine grained slightly weather / thinly laminated slightly weathered) - 0.6m of Mudstone (red brown thinly laminated slightly weathered, weak to moderately weak with some red brown silty clay smears on bedding surfaces)	

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.

The presence of made ground and a superficial deposit at shallow depths means that accurate bomb penetration depths cannot be calculated. NB: the empirical 1940s evidence appears to record UXBs travelling through uniform geology of only one type. Different lithologies will have had a differing decelerating effect on a HE UXB, both individually and in combination, thereby complicating the estimation of burial depth.

To calculate an approximate maximum bomb penetration depth, BSI would usually take the average of the averages of the two figures for the predominant Site-specific geologies present on Site in the table above. Unfortunately, it has not been possible to calculate an accurate maximum bomb penetration depth below WWII ground level for this particular Site due to the presence of the mudstone, sandstone and siltstone.

NB: theoretically penetration depths could be greater if the UXB was larger, however, War Office statistics confirm that between October 1940 and May 1941 the majority of HE UXBs (>90%) were either 50kg or 250kg, with the 500kg bombs making up most of the remaining 10%.

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 sources of British UXO contamination are therefore WWII AA artillery fire and defensive fortifications.

7.2.2 Barrage Balloon Emplacement

An in-house database records a barrage balloon emplacement in the south of Site A. In 1938, the British Balloon Command was established to protect cities and key targets such as industrial areas, ports and harbours. Following the formation of the command, barrage balloons were developed; large, tethered kite balloons used

to defend ground targets against aerial attack. Steel cables were attached to the balloons, posing a severe collision risk to passing aircraft. Some balloons carried small explosive charges that would be pulled up against the aircraft to destroy it.

Balloons were intended to defend against dive bombers flying at heights up to 5,000 feet (1,500 m), forcing them to fly higher and into the range of concentrated anti-aircraft fire: anti-aircraft guns could not traverse fast enough to attack aircraft flying at low altitude and high speed. By the middle of 1940 there were 1,400 balloons, a third of them over the London area. However, the balloons proved to be of little use against the German high-level bombers, but continued to be manufactured nonetheless, until there were almost 3,000 in 1944.

Despite their designation as a defensive measure, barrage balloons were uncrewed, and any personnel tasked with manning the balloons on the ground were usually unarmed. As such, it is considered that the presence of the balloon is unlikely to have resulted in Allied ordnance contamination occurring on Site.

7.2.3 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.

11 permanent HAA batteries were active within range of the Site during WWII. No evidence of permanent LAA gun batteries defending Vulnerable Points within range of the Site was found. Luftwaffe activity was frequent and intense over the wider area and therefore these guns would have expended a vast quantity of ammunition. Consequently, there is an elevated likelihood of unexploded AA shells striking the Site. However, any such UXO could not have penetrated the ground on Site unseen.

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.

BSI 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. An EOC task was carried out 340m east of Site A and 360m south-west of Site B in October 1980. This task is believed to have been carried out in relation to the presence of Higher Barracks, situated 730m south-east of Site A. No information regarding UXBs / UXO being found was available. NB: given the location of the camp in relation to the recorded location of the task, it is feasible that this task has been misplotted.

UXO encounters on civilian land are often reported in the media and therefore a web search of local media outlets was also carried out. On 26th February 2021, an unexploded 1,000kg WWII bomb was discovered on a building site immediately north of the border of Site A. The bomb was found in an area of undeveloped ground, adjacent to residential structures and a care home on Glenthorne Road. On 27th February 2021, bomb disposal experts from the Royal Navy worked on the incident on Friday to make the bomb safe; however, it was deemed unsafe to move the bomb, and a controlled explosion was ordered.

Personnel from the Army's Royal Logistics Corps assumed control of the situation and a low order technique with a double baldrick was initially undertaken; however, the detonation still went to high order. Hundreds of tonnes of sand were packed around the device to limit the 'ground shock' of the explosion and 1,400 students were evacuated from the university. The subsequent detonation damaged a number of properties in Copplestone Road (approximately 160m north of Site A), blowing out windows and sending shrapnel onto roofs (see **FIGURE 7** for images of the item uncovered and the subsequent detonation).

8.3 Ground Works

Several properties have been constructed throughout Site A, many of which are multi-storey student accommodation blocks. The excavations for the structures are anticipated to have varied from shallow (1-2m bgl for structures >3 storeys) to deep (<2m bgl for structures =/<3 storeys). WWII-era foundations are assumed to remain beneath the structure in the west of Site A, which has survived until the present day.

Site B has remained in the same configuration since WWII-era, aside from the laying of hard surfaced ground in the south. This will have likely disturbed WWII-era soil to a very shallow depth. The same can be said of the hard surfaced ground present in Site A.

8.4 Deductions

The risk associated with any buried German UXBs will have only been mitigated at the locations and down to the maximum depths of each post-WWII installation / excavation. A deep buried UXB could conceivably remain under the Site, either in places not subject to post-WWII excavations or in between / below post-WWII excavations.

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.

- The bomb census map and the individual raid bomb plot maps are not corroborative of one another. A number of incidents recorded during a raid in May 1942 on the bomb census map are not recorded on the individual raid bomb plot map for the same date. This highlights the difficulties in accurate record keeping during frequent, intense bombing raids. It is quite possible therefore that additional local bombing incidents are missing from the maps.
- The anecdotal account suggests that the bombing over the Site was far more frequent than that recorded in official bombing records. The anecdotal account also suggests that incendiary bombs were dropped in the vicinity; however, the mapping unfortunately does not record IBs.

9.2 The Risk of UXO Contamination on Site

German UXO Risk

- Exeter experienced 19 air raids during WWII. Most of these were executed by solitary bombers; however, two raids in April and May 1942 were concentrated medium-scale attacks, during which hundreds of high explosive (HE) bombs and thousands of incendiary bombs (IBs) were dropped causing widespread damage. The Site occupied a peripheral area of the city, away from the Luftwaffe's primary target point (the city centre). Consequently, the study area is likely to have experienced a lower localised bombing density than that of the wider borough and city centre. However, despite the lower localised bombing density, according to official records, the Site areas experienced at least two raids (likely more).
- These two raids resulted in 13 incidents within a 400m radius of Site A and eight incidents within a 400m radius of Site B. The majority of these incidents were recorded during the May 1942 raid, as part of the Baedeker raids on the city. The closest recorded incidents were plotted to the immediate north-east of Site A and the immediate west of Site B.
- From these records, it has been possible to identify a number of potential linear bomb-sticks (individual aircraft bombload) in the local area and therefore, the flightpath orientations of aircraft. This analysis identifies at least five (possibly more) potential occasions during which an unexploded bomb (UXB) (unobserved and unplotted) could have been released over and landed on or adjacent to the Site.
- An anecdotal account describing bombing incidents over the University of Exeter was also reviewed. It suggests that the wider study area experienced incendiary bombing, which was not recorded within either bomb mapping set. In addition, the account suggests that the Site experienced far more intense bombing than the official records suggest, with one extract stating that 24 items of ordnance were dropped over the university campus during one raid.
- Furthermore, the account refers to several UXBs being present in the vicinity of the university. Given Site A's close proximity to the main university buildings, it is entirely feasible that such incidents occurred on Site and went unnoticed. This can also be said for Site B, despite being slightly further away from the college, due to its undeveloped nature.
- As all local air raids occurred during the hours of darkness, there is a greater risk associated with unexploded ordnance (UXO) falling within the Site unobserved. Furthermore, no evidence was found to confirm that night-time observers (fire watchers or anti-aircraft (AA) gunners) were active in the vicinity.

- Additionally, in relation to the undeveloped areas of the Site; these are likely to have only experienced intermittent levels of access and are unlikely to have been subject to specific post-raid searches for German UXBs in the wake of raids. Even if the Site had been searched, which is suggested in the anecdotal account, it is conceivable that a UXB entry hole could have been easily obscured in dense vegetation, areas of crop growth or ploughed soil and gone unreported. This can be evidenced by the discovery of a 1,000kg HE bomb to the immediate north of Site A.

British / Allied UXO:

- 11 permanent heavy anti-aircraft (HAA) batteries were active within range of the Site during WWII. Luftwaffe activity was frequent and intense over the wider area and therefore these guns would have expended a vast quantity of ammunition. Consequently, it is quite possible that an unexploded AA shell struck the Site and remained unnoticed as per the reasons cited above
- 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 (>3m)	HIGH RISK
WWII British Heavy Anti-Aircraft Shells	1.1kg - 1.7kg	Shallow burial (<1.5m)	MODERATE-HIGH RISK
WWII British Land Service Ammunition	<2kg	Shallow burial (<1.5m)	
WWII German 2kg Incendiary / HE Bombs	680g incendiary hazard + ~500g explosive hazard	Shallow burial (<1.5m)	
WWII German 1kg IBs	680g (incendiary, not explosive hazard)	Shallow burial (<1.5m)	MODERATE RISK
WWII British Light Anti-Aircraft Shells	4g - 70g	Very shallow burial (<1m)	LOW-MODERATE RISK

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

As deep intrusions (piling) may be required, a risk pathway exists between these works and deep buried (large) German UXBs. NB: piling is the engineering activity most at risk of initiating a large German UXB, due to the forces involved and the 'blind' nature of the intrusion.

It is also conceivable that a UXB could be encountered during any shallow mechanical excavations beneath the existing ground level in this location.

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. The UXO risk to the proposed works has been assessed as **Moderate.**

Risk Table				
UXO TYPE (ASSOCIATED HAZARD)	LIKELIHOOD OF UXO CONTAMINATION	LIKELIHOOD OF UXO REMAINING	LIKELIHOOD OF ENCOUNTER	OVERALL RISK RATING
WWII German 'Iron' Bombs	Moderate	Moderate-High	Moderate	**Moderate**
WWII British Heavy Anti-Aircraft Shells	Low-Moderate	Low-Moderate	Moderate	**Low-Moderate**
WWII British Land Service Ammunition	Low	Low	Low	**Low**
WWII German 2kg Incendiary / HE Bombs	Low-Moderate	Low-Moderate	High	**Low-Moderate**
WWII German 1kg Incendiary Bombs	Low-Moderate	Low-Moderate	High	**Low-Moderate**
WWII British Light Anti-Aircraft Shells	Low	n/a		**Low**

11 RISK MITIGATION RECOMMENDATIONS

BSI has identified an elevated UXO risk to some of 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 pile positions.

Figures: 1 - 8

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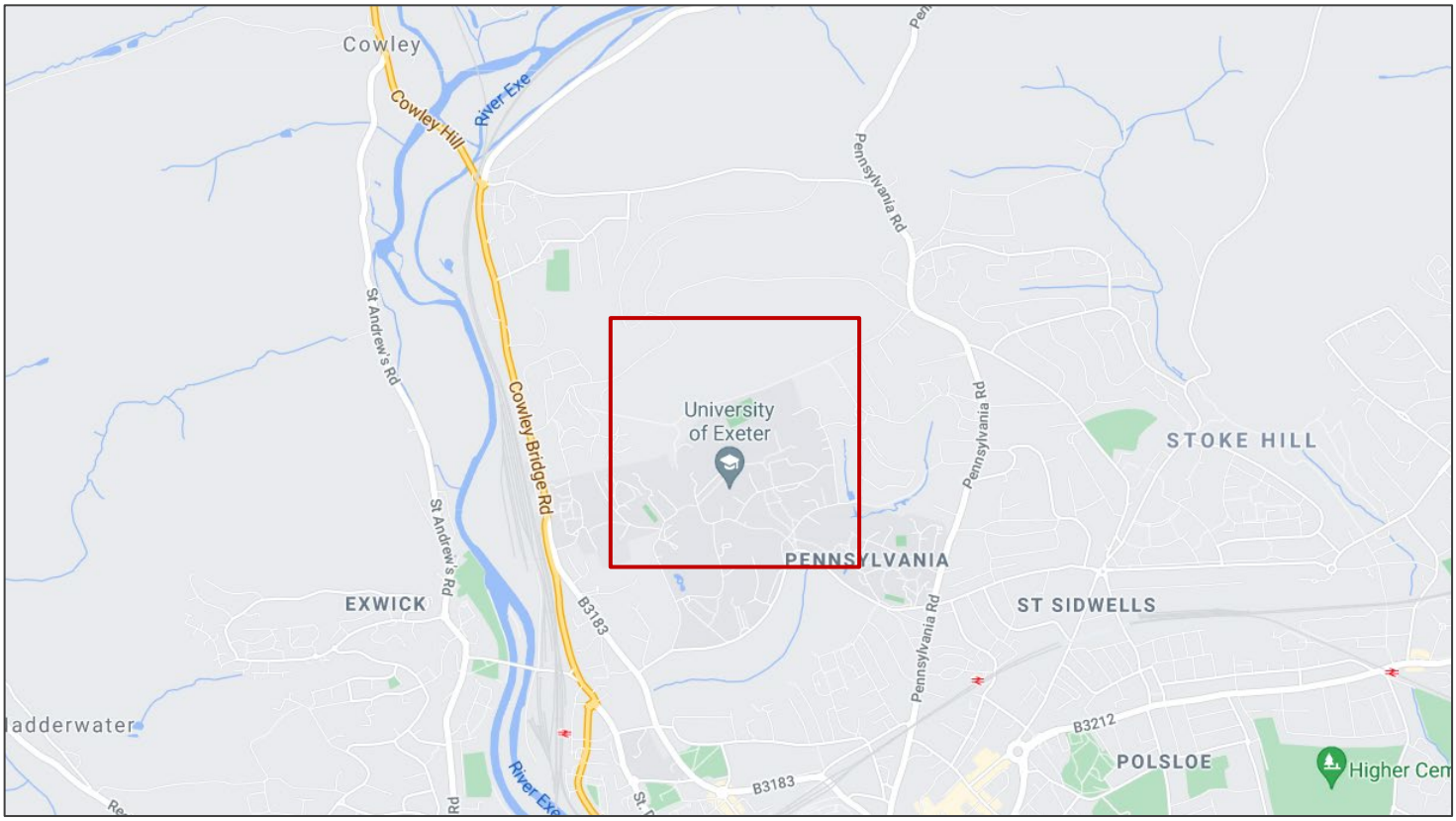
Title:	Site Location Maps	FIGURE: 1



N

Project		University of Exeter
Client:		University of Exeter
Report Ref:		DRA-21-1255-01
General Site Location	Info Source:	Google (open-source)

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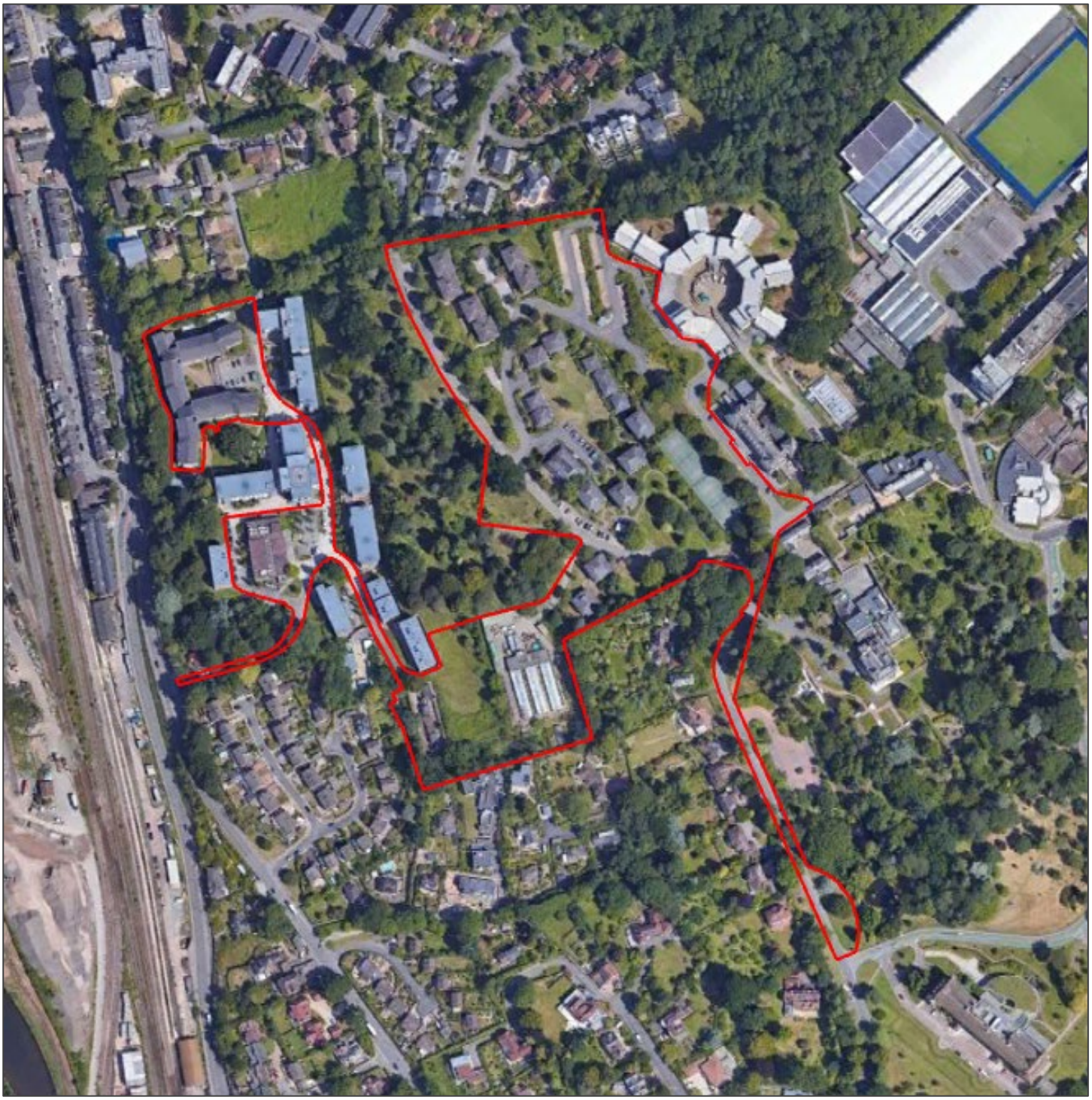
Title:	Recent Aerial Photograph – Site A	FIGURE: 2.1



N

Project	University of Exeter
Client:	University of Exeter
Report Ref:	DRA-21-1255-01
Approx. Site Boundary	Info Source: Google (open-source)

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Title:	Recent Aerial Photograph – Site B	FIGURE: 2.2

N

Project	**University of Exeter**
Client:	**University of Exeter**
Report Ref:	**DRA-21-1255-01**
Approx. Site Boundary	Info Source: Google (open-source)

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Title:	Existing Site Plan – Site A	FIGURE: 3.1

N

Project	**University of Exeter**
Client:	**University of Exeter**
Report Ref:	**DRA-21-1255-01**
Site Boundary	Info Source: University of Exeter

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Title:	Existing Demolition Plan – Site A	FIGURE: 3.2

- Application site boundary
- Other land owned by the applicant
- Buildings and structures to be demolished.
- Existing university campus buildings retained
- Existing university off-campus buildings
- Neighbouring buildings
- Trees within development zone to be retained
- Trees within application boundary to be removed
- Trees that we are seeking permission to remove as part of this outline permission that would be retained if further site investigation of ground conditions permit.
- Root Protection Areas

N

Project	University of Exeter
Client:	University of Exeter
Report Ref:	DRA-21-1255-01
Site Boundary	Info Source: University of Exeter

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Title:	Existing Site Plan – Site B	FIGURE: 3.3

N

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Client:	**University of Exeter**
Report Ref:	**DRA-21-1255-01**
Site Boundary	Info Source: University of Exeter

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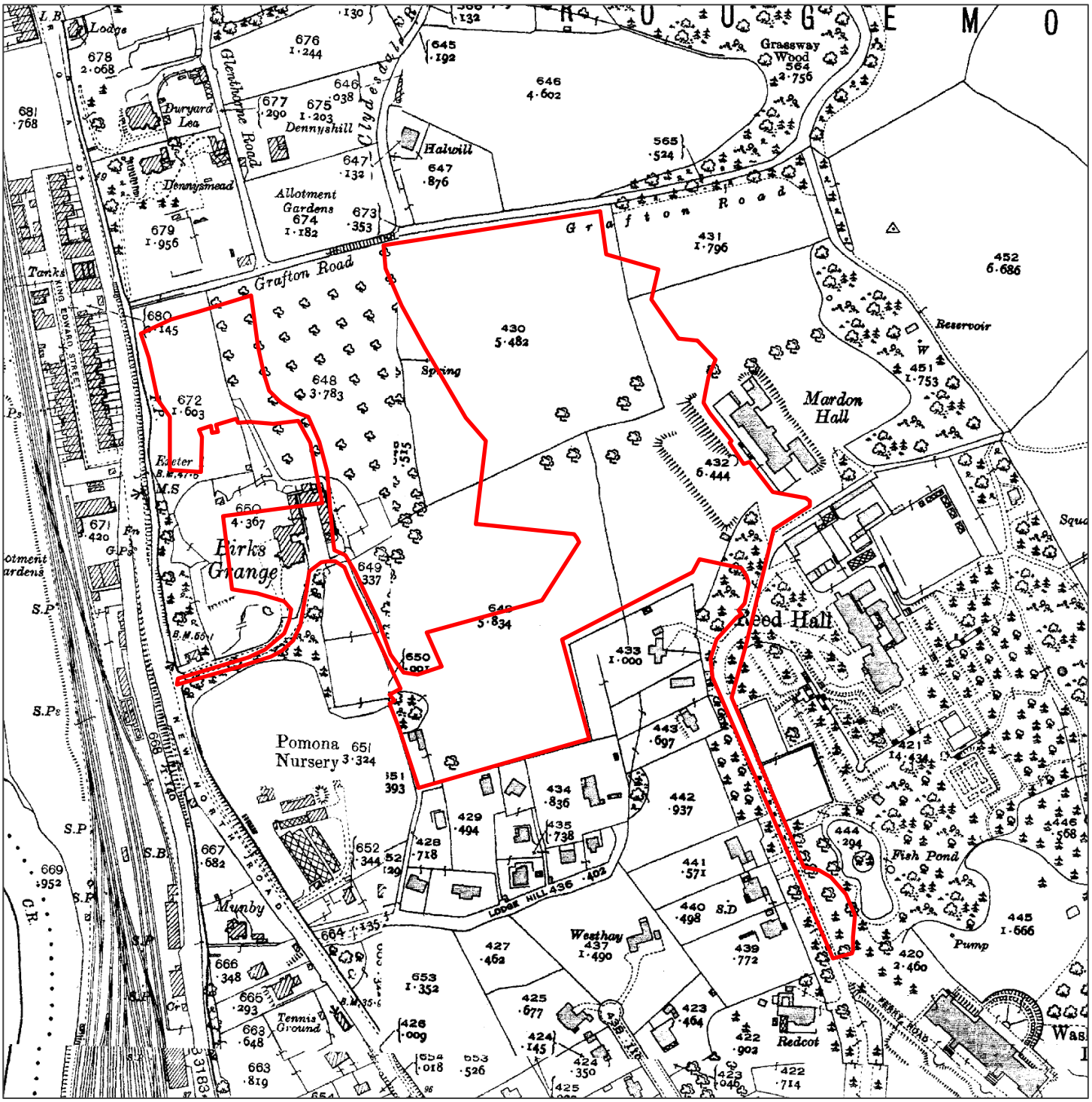
Title:	Historical OS Mapping – 1932-1938 (Site A)	FIGURE: 4.1



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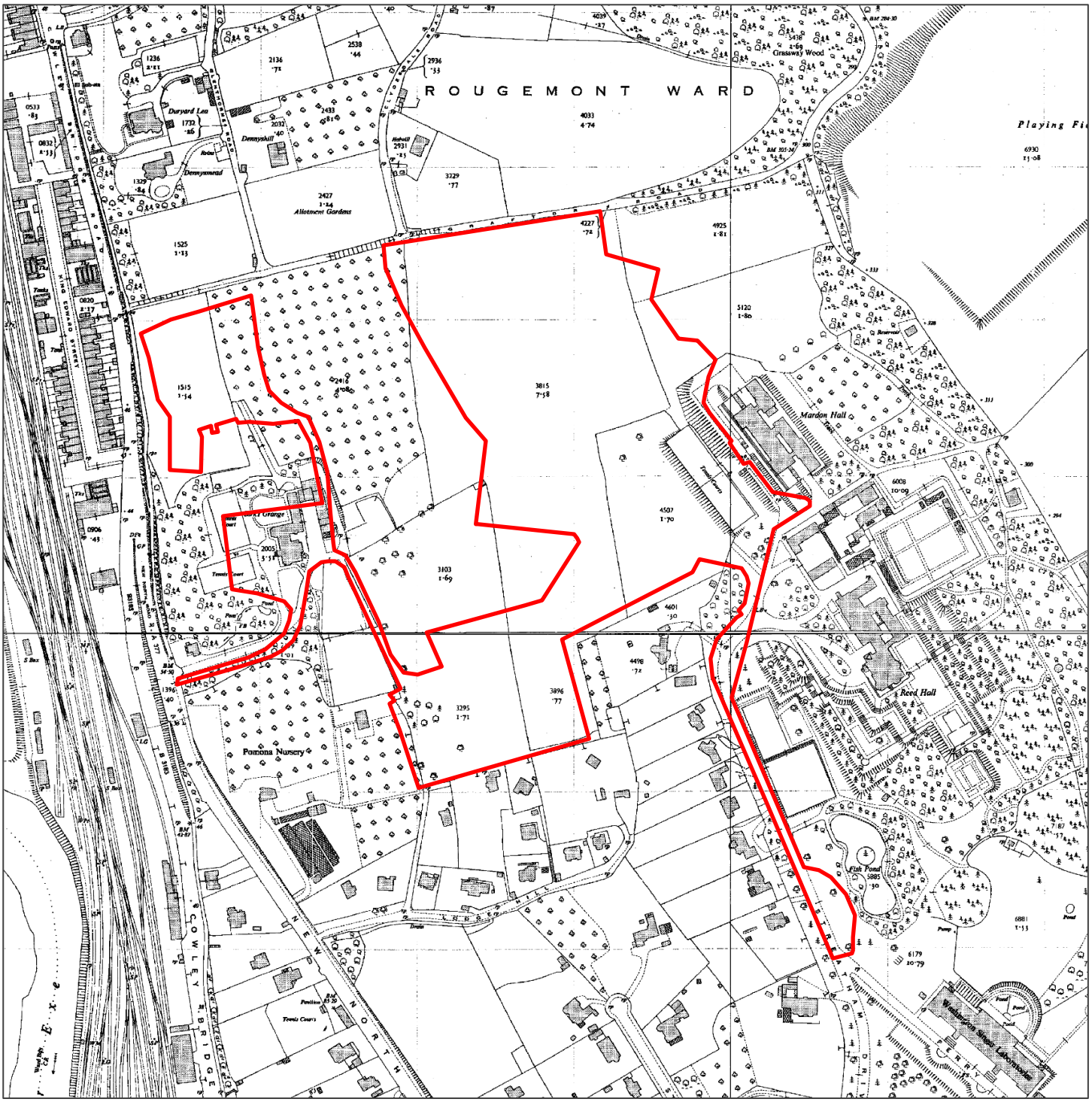
	Approx. Site Boundary	Info Source: Promaps	

Title:	Historical OS Mapping – 1955 (Site A)	FIGURE: 4.2



N	Project	University of Exeter
	Client:	University of Exeter
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	Approx. Site Boundary	Info Source: Promaps

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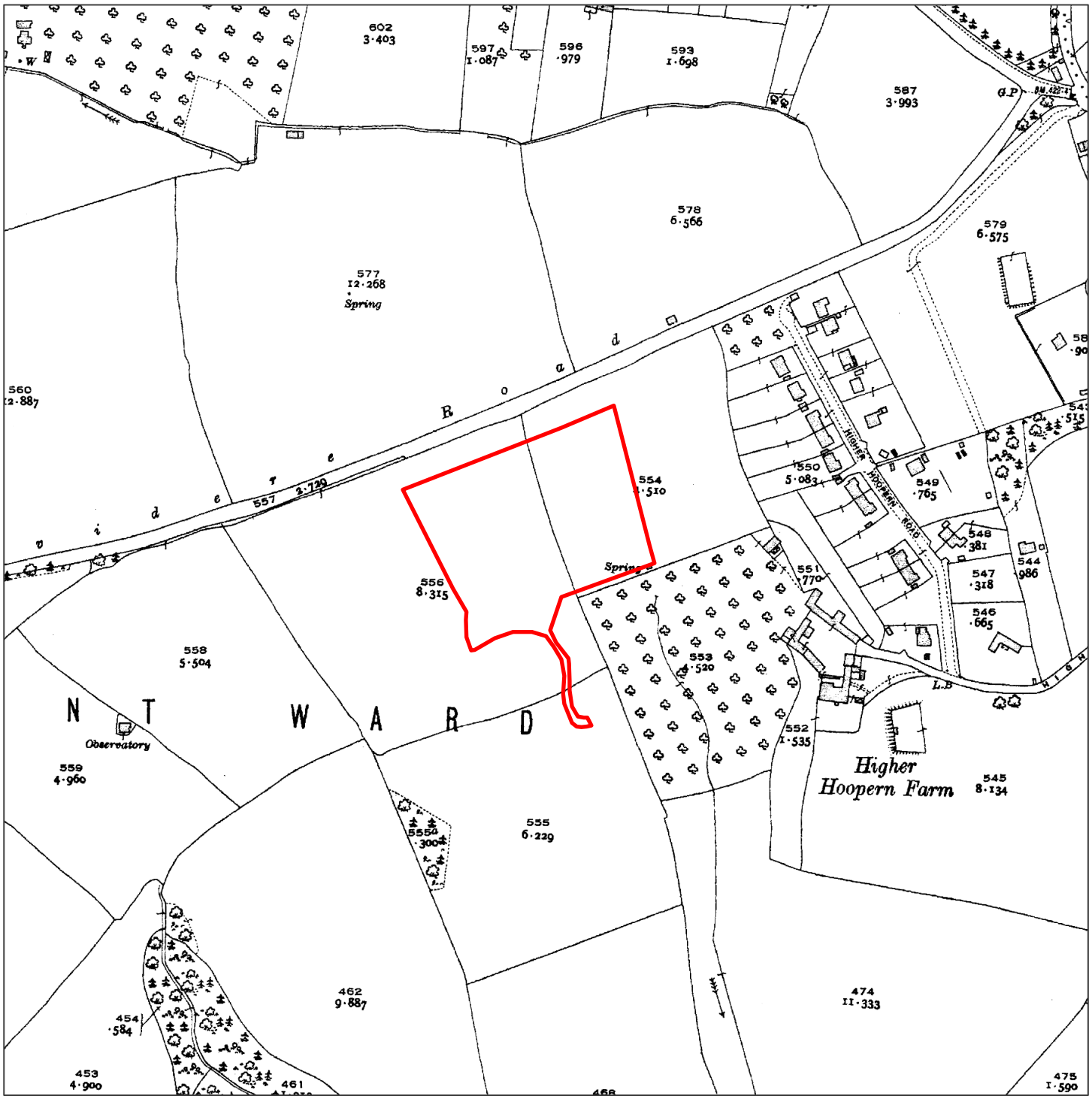
Title:	Historical OS Mapping – 1932 (Site B)	FIGURE: 4.3



N	Project	University of Exeter
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	Approx. Site Boundary	Info Source: Promaps

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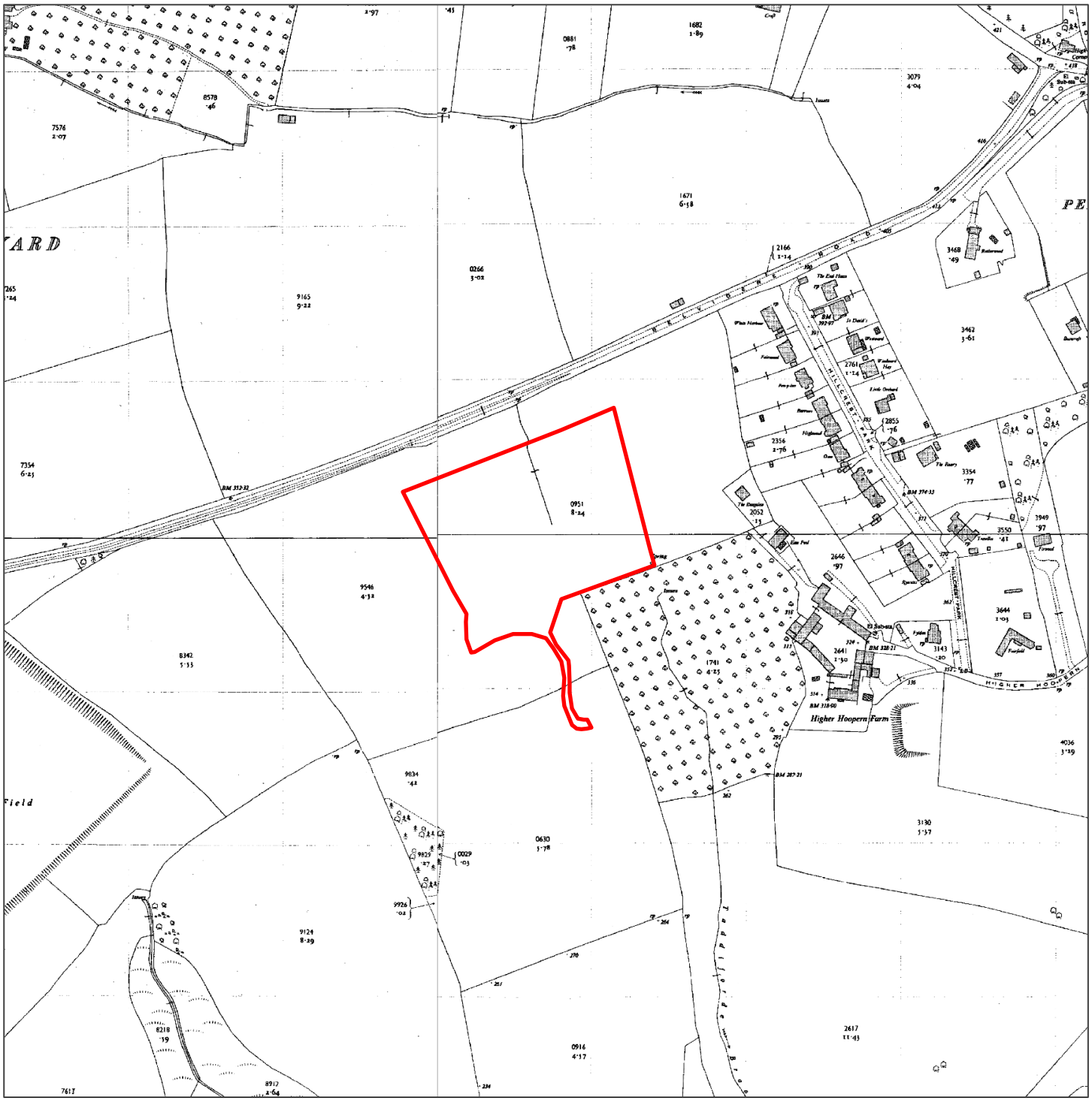
Title:	Historical OS Mapping – 1952-1954 (Site B)	FIGURE: 4.4



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Title:	Historical Aerial Photography - 1947	FIGURE: 5.1

Structural clearance

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	Report Ref:	DRA-21-1255-01
Approx. Site Boundary	Info Source:	Historic England

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Title:	Historical Aerial Photography - 1947	FIGURE: 5.2

Potential bomb crater

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Client:	University of Exeter	
Report Ref:	DRA-21-1255-01	
Approx. Site Boundary	Info Source:	Historic England

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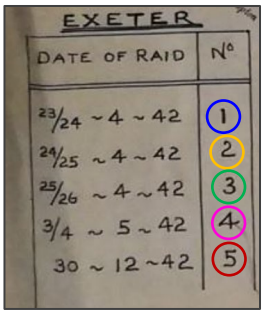
Title:	1942 Bomb Census Map – Site A	FIGURE: 6.1

- 50kg HE bomb
- 250kg HE bomb
- 500kg HE bomb
- Unclassified HE bomb

Potential bomb-stick



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Project	University of Exeter
Client:	University of Exeter
Report Ref:	DRA-21-1255-01
Approx. Site Boundary	Info Source: National Archives, London

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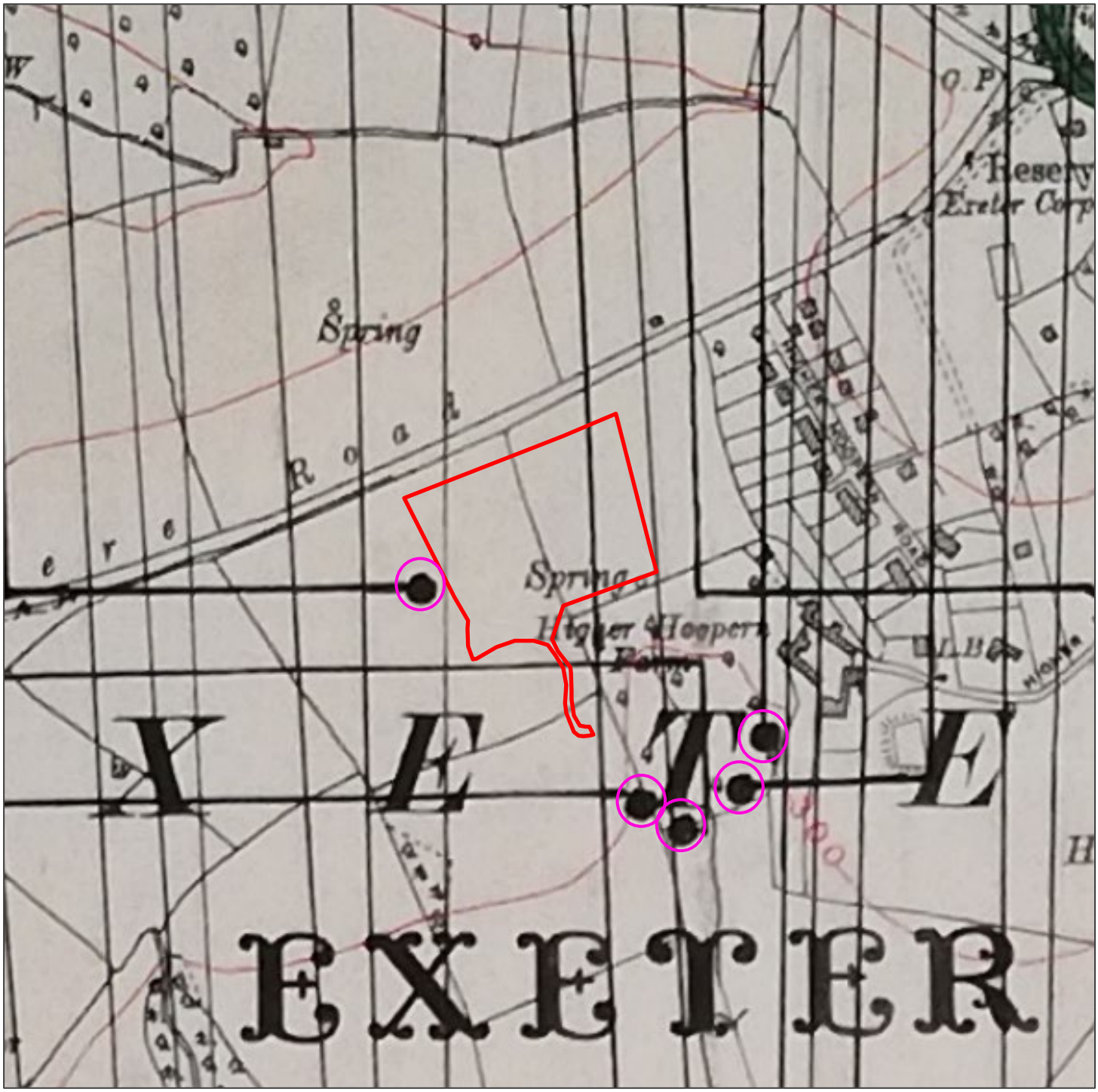
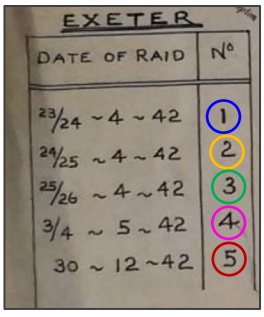
Title:	1942 Bomb Census Map – Site B	FIGURE: 6.2



- 50kg HE bomb
- 250kg HE bomb
- 500kg HE bomb
- Unclassified HE bomb


EXETER

DATE OF RAID	Nº
23/24 ~ 4 ~ 42	1
24/25 ~ 4 ~ 42	2
25/26 ~ 4 ~ 42	3
3/4 ~ 5 ~ 42	4
30 ~ 12 ~ 42	5

N

Project	University of Exeter
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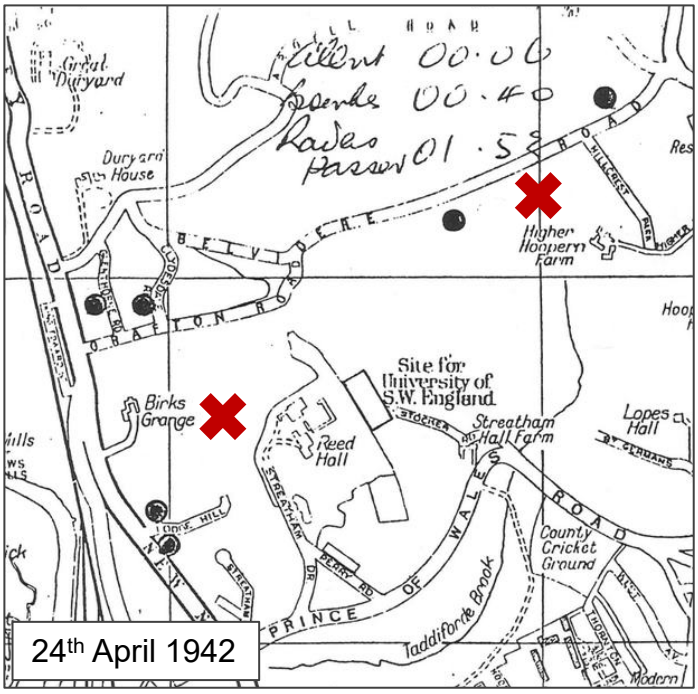
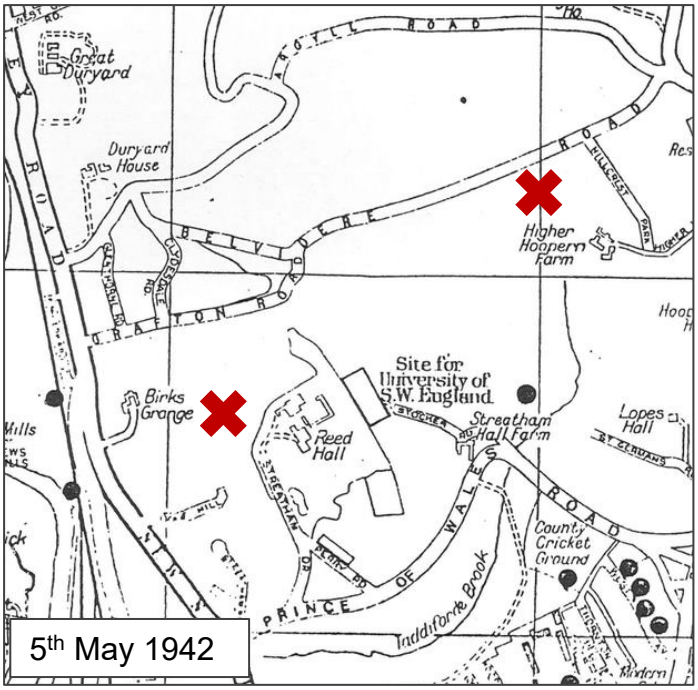
Title:	Select Individual Raid Bomb Plot Maps	FIGURE: 7





● 'Iron' bomb

N	Project	University of Exeter
	Client:	University of Exeter
	Report Ref:	DRA-21-1255-01
✖ Approx. Site Location	Info Source:	Devon Heritage Centre

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Title:	Exeter UXB Find – 27th February 2021	FIGURE: 8

Above: item of unexploded ordnance uncovered during development works immediately north of University of Exeter campus.

Above: detonation of item of unexploded ordnance.

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Report Ref:	DRA-21-1255-01	+44 (0) 207 117 2492 www.brimstoneuxo.com enquire@brimstoneuxo.com
Info Source:	Various sources	

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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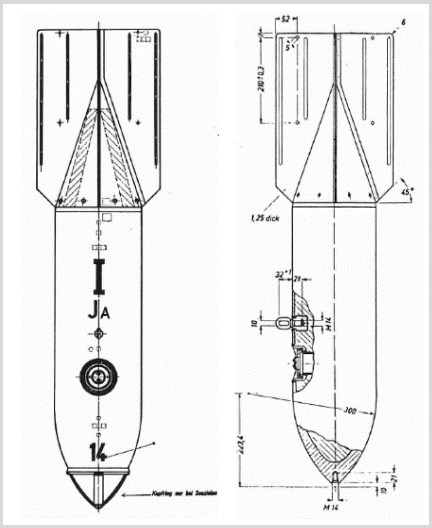
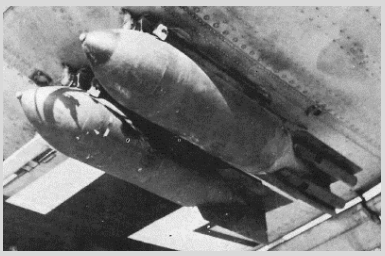
SC 50

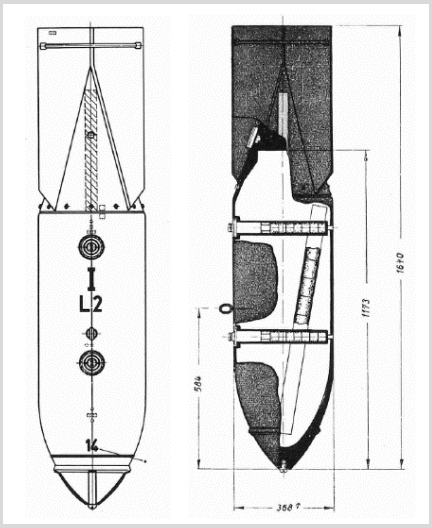
Bomb Weight:	40-54kg (110-119lb)
Explosive Weight:	25kg (55lb)
Filling:	TNT, Amatol or Trialen
Charge/Weight Ratio:	46%
Fuse Type:	Electrical impact fuse or mechanical delayed action fuse
Body Dimensions:	1,100mm length x 200mm diameter
Appearance:	Bomb body and tail painted grey/green with a yellow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





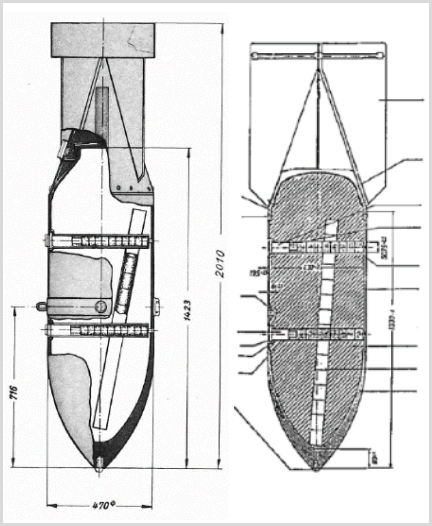
SC 250

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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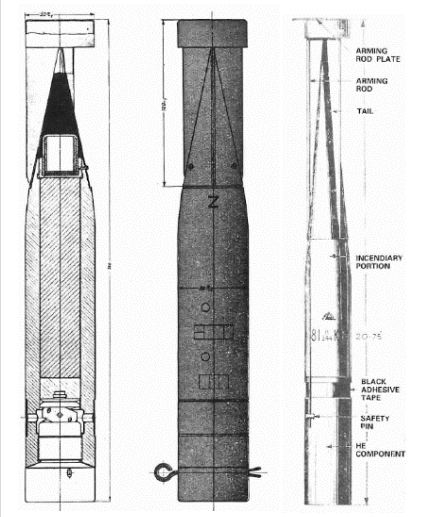
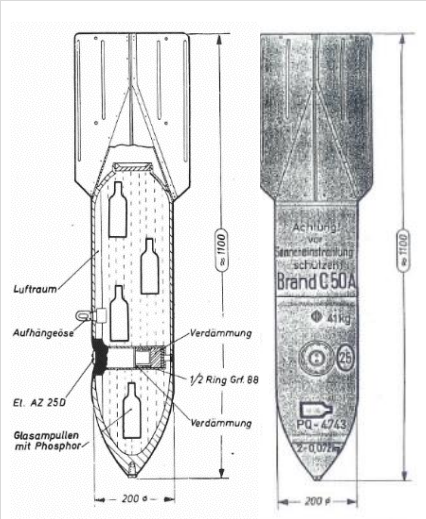
B-1E Sub-Munition

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.



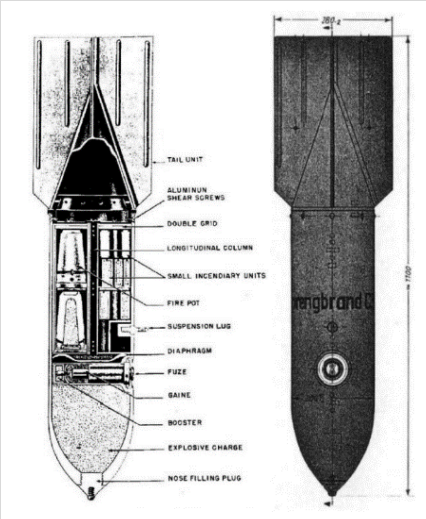
Brand C50

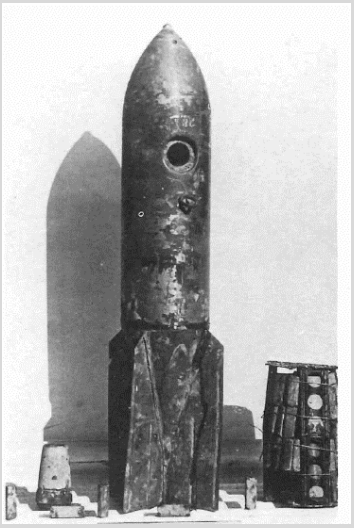
Bomb Weight:	41kg (90.4lb)
Incendiary Weight:	13kg (30lb)
Filling:	Main fill (86% Benzine, 10% Rubber) plus 4% Phosphorus in glass bottles
Fuse Type:	1 x electrical impact fuse
Bomb Dimensions:	762mm length x 203mm diameter
Appearance:	bomb body and tail painted grey or green with the rear of the bomb 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		**University of Exeter**
Client:		**University of Exeter**
Report Ref:		**DRA-21-1255-01**
	Info Source:	*W, Ramsey.1988 / various news sources*

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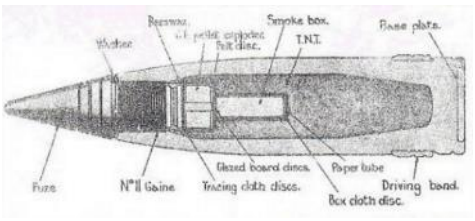
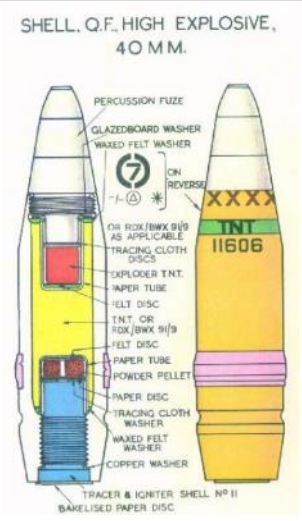
HAA Battery - 3.7" QF Shell

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.



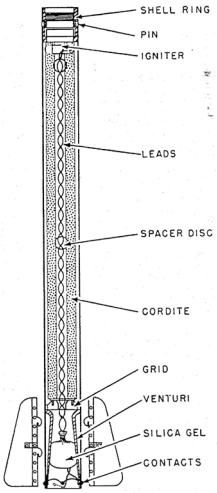
LAA Battery - 40mm Bofors Shell

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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- ***Bates. H. E***, Flying Bombs Over England, Frogletts Publications Ltd, 1994.
- ***Bulloch. G***, Steeds J E, Green K, Sainsbury M G, Brockwell J S & Slade N J, Land Contamination: Technical Guidance on Special Sites: MoD Land, Environment Agency, 2001.
- ***Castle. I,*** London 1914-17: The Zeppelin Menace, Osprey Publishing Ltd, 2008.
- ***Castle. I,*** London 1917-18: The Bomber Blitz, Osprey Publishing Ltd, 2010.
- ***CIRIA***, C681: Unexploded Ordnance (UXO), A Guide for the Construction Industry, 2009.
- ***Clarke. N. J***, Luftwaffe Target Reconnaissance, German Aerial Photography 1939-1942, 1996.
- ***Clarke. N. J***, Adolf's British Holiday Snaps: Luftwaffe Aerial Reconnaissance Photographs of England, Scotland and Wales, 2012.
- ***Cocroft. W. D***, Dangerous Energy, Historic England, 2000.
- ***Dobinson. C. S,*** AA Command: Britain's Anti-Aircraft Defences of the Second World War, Methuen Publishing Ltd, 2001.
- ***Dobinson. C. S***, Fields of Deception - Britain's Bombing Decoys of World War II, Methuen Publishing Ltd, 2013.
- ***Fleischer. W***, German Air-Dropped Weapons to 1945, Midland Publishing. 2004.
- ***Jappy. M. J,*** Danger UXB: The Remarkable Story of the Disposal of Unexploded Bombs during the Second World War. Channel 4 Books, 2001.
- ***Morris. J***, German Air Raids on Britain: 1914-1918, Nonsuch Publishing, 2007.
- ***Price. A***, Blitz on Britain 1939-45, Sutton Publishing Ltd, 2000.
- ***Ramsey. W,*** The Blitz Then and Now: Vol 1, Battle of Britain Prints International Limited, 1987.
- ***Ramsey. W,*** The Blitz Then and Now: Vol 2, Battle of Britain Prints International Limited, 1988.
- ***Ramsey. W,*** The Blitz Then and Now: Vol 3, Battle of Britain Prints International Limited, 1990.
- ***Whiting. C***, Britain Under Fire: The Bombing of Britain's Cities 1940-1945, Pen & Sword Books Ltd, 1999.

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