FIELDWORK - Insitu Gas Monitoring - Instrument Record

Project **BACTON LOW RISE, GOSPEL OAK, NORTH LONDON**

Project No **PC124991**

Borehole **BH9**

Client **ROLTON GROUP**

Sheet No. **1 (1 of 2)**

Installation Details

Installation Type	**Standpipe**	Diameter	**-**
Depth to Base	**5.00m**	Cover Type	**Flush lockable protective cover**
Filter Zone	**-**	Ground Level	**42.09 m OD**
Date Installed	**16 August 2012**		

Date	Time	Depth to Water (m bgl)	Methane CH4 (% VOL)	Methane CH4 (% LEL)	Carbon Dioxide CO2 (% VOL)	Oxygen O2 (% VOL)	Hydrogen Sulphide H2S (ppm)	Carbon Monoxide CO (ppm)	Remarks
13-Sep-2012	00:00:00	4.76					<1	<1	
13-Sep-2012	00:00:05		<0.1	<2	<0.1	20.6			
13-Sep-2012	00:00:30		<0.1	<2	0.2	20.3			
13-Sep-2012	00:01:00		<0.1	<2	0.2	20.1			
13-Sep-2012	00:02:00		<0.1	<2	0.2	20.1			
3-Oct-2012	00:00:00	4.48					<1	<1	
3-Oct-2012	00:00:05		<0.1	<2	<0.1	20.6			
3-Oct-2012	00:00:30		<0.1	<2	0.1	20.4			
3-Oct-2012	00:01:00		<0.1	<2	0.1	20.4			

Remarks

geotechnics

Form 003/1

FIELDWORK - Insitu Gas Monitoring - Instrument Record

Project **BACTON LOW RISE, GOSPEL OAK, NORTH LONDON**

Project No **PC124991**

Borehole **BH9**

Client **ROLTON GROUP**

Sheet No. **1 (2 of 2)**

Installation Details

Installation Type **Standpipe**
Depth to Base **5.00m**
Filter Zone **-**
Date Installed **16 August 2012**

Diameter **-**
Cover Type **Flush lockable protective cover**
Ground Level **42.09 m OD**

Date	Time	Barometric Pressure (mBars)	Air Temp. (DegC)	Diff. Pressure (mBars)	Flow Rate (Peak/Stable) (l/hr)	Remarks
13-Sep-2012	00:00:00	1012	8.00	+0.01	-0.0	
13-Sep-2012	00:00:05					
13-Sep-2012	00:00:30					
13-Sep-2012	00:01:00					
13-Sep-2012	00:02:00					
3-Oct-2012	00:00:00	997	9.70	-0.04	-0.0	
3-Oct-2012	00:00:05			-0.04	-0.0	
3-Oct-2012	00:00:30					
3-Oct-2012	00:01:00					

Remarks

geotechnics

ANNEX D
COPYRIGHT INFORMATION

THIS PAGE CONTAINS IMPORTANT INFORMATION ABOUT YOUR RIGHTS TO READ AND USE THE CONTENT OF THIS DOCUMENT

COPYRIGHT

This document is the copyright of Rolton Group Ltd ("**Rolton Group**"). The reproduction or transmission of all or part of this document, whether by photocopying or storing in any medium by electronic means or otherwise, without the prior written consent of Rolton Group or pursuant to a formal licence is prohibited.

This document and any copies of it shall only be used for the purpose for which this document was originally supplied by the Rolton Group and for no other purpose ("**Intended Purpose**").

NON-DISCLOSURE

This document contains confidential information. In consideration of Rolton Group disclosing such confidential information this document should be held and maintained in confidence and should only be disclosed to:

1. EC Harris LLP (The Client);
2. Professional advisors to the Client;
3. Camden Council (the site owner and Local Authority);
4. The Environment Agency;
5. Client's permitted assignees established by written assignment; and
6. Professional advisors of permitted assignees.

This document shall not be disclosed or made available to any other individual, firm, company or organisation without the prior written consent of Rolton Group.

The confidential information in this document shall only be used for the Intended Purpose.

FREEDOM OF INFORMATION

Authorised or unauthorised copies of this document may come into the possession of organisations that are designated under the Freedom of Information Act 2000 ("**the Act**"). Such organisations that are designated in the Act are requested by Rolton Group to respect the above statements relating to confidentiality and copyright. Rolton Group has invested and imparted substantial skill, economic resources and labour in producing this document and any disclosure shall prejudice the commercial interests of the Rolton Group.

DISCLAIMER

The information in this document should only be used by suitably skilled and experienced individuals. Unless expressly agreed otherwise in writing, Rolton Group shall not have any responsibility or liability to any individual, firm, company or organisation for the content of this document or any information derived from it other than to the client of the Rolton Group that has commissioned the document and any permitted assignees established by written assignment. Rolton Group does not seek to exclude or limit its liability for death or personal injury resulting from its negligence.

If you do not accept the terms above then do not read the content and return this document to Rolton Group at the address given on the flyleaf.

ENQUIRIES

Any enquiries regarding this document and its content should be directed to Rolton Group: Tel: +44 (0)870 726 0000 E Mail: enquiries@rolton.com.

Appendix D . UXO report

Detailed Unexploded Ordnance (UXO) Threat assessment by 1st Line Defence Solutions

1ST LINE DEFENCE
UXO SOLUTIONS

Detailed Unexploded Ordnance (UXO) Threat Assessment

Project Name	Gospel Oak Site		
Client	Rydon		
Site Address	Wellesley Road, Gospel Oak, Camden, NW5 4PN		
Report Reference	OPN2585	Revision	00
Date	19th November 2015		
Originator	SM		

1ST LINE DEFENCE
UXO SOLUTIONS

Find us on Twitter and Facebook

Company No: 7717863 VAT No: 128 8833 79
www.1stlinedefence.co.uk

1st Line Defence Limited
Unit 3, Maple Park, Essex Road, Hoddesdon, Herts. EN11 0EX
Tel: +44 (0)1992 245 020 info@1stlinedefence.co.uk

Executive Summary

Site Location

The site is situated in the London Borough of Camden in the area of Gospel Oak.

The site is located in a primarily residential area. Immediately to the north of the site is a high-rise flat building, with a railway line just beyond this. To the north-east is a range of structures on Vicars Road including district offices, while to the east is a church and apartment blocks. South of the site is a set of commercial buildings and to the west the Wendling housing estate. Gospel Oak railway station is approximately 0.5km to the north-east, which serves the London Overground.

The site is centred on the approximate OS grid reference: **TQ 2808485245**

Proposed Works

The proposed work include the demolition of all structures on the site and the construction of a new housing estate, which will house 290 new homes.

Geology and Bomb Penetration Depth

The British Geological Survey (BGS) map shows the site to be underlain by the London Clay formation – Clay, Silt and Sand, of the Palaeogene Period. Site-specific geology data was not available to 1st Line Defence at this time.

UXO Risk Assessment

1st Line Defence believes that there is a **Medium Risk** from UXO across the site. This assessment is based on the following factors:

- During WWII the Metropolitan Borough of St. Pancras was subjected a Moderate density bombing campaign, however the area surrounding the site sustained a relatively high concentration of bombing.
- St. Pancras contained both St. Pancras and King's Cross Station (both approximately 3km south-east of the site) as well as other major pieces of railway infrastructure and gas / electrical works, which were targeted by the Luftwaffe. It would also have received bombing as a result of the indiscriminate bombing of the civilian population.
- London bomb census mapping record at least four HE bombs within the boundaries of the site. Several more are plotted just outside of these borders, and an incendiary shower immediately the north-east.
- Historical mapping indicates that the site was occupied by dense residential properties during WWII, as well as bordering roads. This, as well as its proximity to a roundabout, railway line, a school and a church, would suggest that the site received a high degree of access. However, it is likely that this dramatically decreased following damage, and further bombs may not have been recorded or detected (particularly in less visible parts such as gardens, which were projected towards the centre of the site).
- Garden areas are also of a concern because of the unclear condition of groundcover – it has not been possible to precisely identify this from RAF aerial imagery from the immediate post-war period. In areas of soft, vegetated ground, as may have been present in the gardens, there is the potential for dropped UXO to go unnoticed. While the structures and roads would have explicitly displayed signs of disruption caused by heavier UXO, where bomb damage had been inflicted, the resulting debris or rubble would not have been conducive to noticing dropped ordnance during subsequent raids.
- Aerial photography from immediately post-war, bomb damage mapping and alterations in historical mapping make clear the presence of significant bomb damage across the site. This resulted in several clearance areas and the erection of prefabricated homes on site. All structures on site (covering most of its premises) appear to have sustained some degree of damage. Even though this is in some instances light and perhaps not a result of direct bomb hits, its proximity to areas of major disruption would indicate potential risk of the J-curve effect (unexploded bombs falling unnoticed within damaged or open areas and coming to rest at a lateral offset from point of entry, sometimes beneath structures which survived the war intact – recent UXB finds in London have been attributed to this effect). An incident overlay is presented in **Annex R** to show the spread of recorded strikes and damage.
- There is no evidence that the site formerly had any military occupation or usage that could have led to contamination with other items of ordnance.

Recommended Risk Mitigation Measures
The following risk mitigation measures are recommended to support the proposed works at the Gospel Oak site: **All works** • Site Specific Unexploded Ordnance Awareness Briefings to all personnel conducting intrusive works **Shallow intrusive works (trial pits, open excavations, shallow foundations etc.)** • Unexploded Ordnance (UXO) Specialist Presence on Site to support shallow intrusive works **Deep intrusive works (boreholes and piles)** • Intrusive Magnetometer Survey of all Borehole and pile locations down to a maximum bomb penetration depth

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

Contents

Annexes

List of Report Annexes	
Annex A	Site Location Maps
Annex B	Recent Aerial Photography
Annex C	Site Plan
Annex D	Pre and Post-WWII Historical Maps
Annex E	Examples of German Air Delivered Ordnance
Annex F	Example of 50kg Bomb Entry Hole
Annex G	Examples of UXO Incidents
Annex H	London WWI Bomb Plot Map
Annex I	London WWII Bomb Density Map
Annex J	Image of Gospel Oak Bomb
Annex K	London ARP Consolidated Bomb Census Maps
Annex L	London ARP Weekly Bomb Census Maps
Annex M	London V1 Flying Bomb Map
Annex N	London County Council Bomb Damage Map
Annex O	1946 RAF Aerial Photography of the Site
Annex P	1945 Aerial Photography
Annex Q	Examples of Anti-Aircraft Projectiles
Annex R	Incident Overlay

1st Line Defence Limited
Detailed Unexploded Ordnance (UXO) Threat Assessment

Site: Gospel Oak Site
Client: Rydon

1. Introduction

1.1. Background

1st Line Defence has been commissioned by Rydon to produce a Detailed Unexploded Ordnance (UXO) Threat Assessment for the proposed works at the Gospel Oak site.

UXO in the UK can originate from three principal sources:

1. Munitions deposited as a result of military training procedures and exercises.
2. Munitions lost, burnt, buried or otherwise discarded either deliberately, accidentally or ineffectively.
3. Munitions resulting from wartime activities including German bombing in WWI and WWII, long rang shelling, defensive activities or area denial.

In certain parts of the UK buried UXO can present a significant risk to construction works and development projects. Whilst UXO may certainly present a safety risk even the simple discovery of a suspected device during on-going works can cause considerable disruption to production and cause unwanted delays and expense.

This report will examine in detail all the factors that could potentially contribute to a threat from UXO at the site in question. For the majority of sites in the UK the likelihood of encountering UXO of any sort is minimal and generally no further action will be required beyond an initial desktop risk assessment. However, if a potential risk is identified, the report will make recommendations for the most appropriate and work-specific measures available in order to reduce the threat to as low as reasonably practicable. Full analysis and evidence will be provided to allow to client to fully understand the basis for the assessed risk level and any recommendations.

The report directly follows the guidelines set out in the document CIRIA C681 'Unexploded Ordnance (UXO) A Guide for the Construction Industry'.

2. UK Regulatory Environment

2.1. General

There is no formal requirement for undertaking an assessment of UXO risk for construction projects in the UK, nor any specific legislation covering the management or mitigation of UXO risk. However, it is implicit in the legislation outlined below that those responsible for intrusive works (archaeology, site investigation, drilling, piling, excavation etc.) do undertake a comprehensive and robust assessment or potential risks to employees and that mitigation measures are put in place to address any identified hazards.

2.2. CDM Regulations 2015

This legislation defines the responsibilities of all parties (primarily the Client, the CDM Co-ordinator, the Designer and the Principal Contractor) involved with works. Under CDM2015, the client has the 'legal responsibility for the way that a construction project is managed and run and they are accountable for the health and safety of those working on or affected by the project'.

Although UXO is not specifically addressed, the regulations effectively place obligations on all these parties to:

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

2.3. The 1974 Health and Safety at Work Act

All employers have a responsibility under the Health and Safety at Work Act of 1974 (and the Management of Health and Safety at Work Regulations of 1999) to ensure, so far as is reasonably practicable, the health and safety of their employees and that of other persons who are affected by their work activity (including the general public).

2.4. Additional Legislation

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

3. Role of Commercial UXO Contractors and The Authorities

3.1. Commercial UXO Contractors

The role of an experienced UXO specialist such as 1st Line Defence is to provide expert knowledge and guidance to the client on the most appropriate and cost effective approach to UXO risk management on a site.

The undertaking of Preliminary and Detailed UXO Risk Assessments is the first step in this risk management process. The extensive amount of specialist experience, weapons knowledge, datasets and historical information available to 1st Line Defence in particular, allows a robust, detailed and realistic assessment of the potential risk, and the recommendation of suitable mitigation measures if deemed necessary.

In addition to undertaking specialist Risk Assessments, a commercial UXO contractor will be able to provide pre-construction site survey and clearance/avoidance, as well as a reactive response to any suspect finds.

The presence on site of a qualified UXO Specialist with ordnance recognition skills will avoid unnecessary call-outs to the authorities and allow for arrangement to be made for the removal and disposal of low risk items. If high risk ordnance is discovered, actions will be co-ordinated with the authorities with the objective of causing the minimum possible disruption to site operations whilst putting immediate, safe and appropriate measures in place.

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

3.2. The Authorities

The Police have the responsibility for co-ordinating the emergency services in the case of an ordnance-related incident on a construction site. They will make an initial assessment and if they judge necessary, impose a safety cordon and/or evacuation and call the military authorities Joint Services Explosive Ordnance Disposal (JSEOD) to arrange for investigation and/or disposal. In the absence of an UXO Specialist on site many Police Officers will use the precautionary principle, impose cordon/evacuation and await advice from the JSEOD. The discovery of UXO will invariably cause work to cease on the site and may require the evacuation of the site and neighbouring properties.

The priority JSEOD will give to the police request will depend on their judgement of the nature of the UXO threat, the location, people and assets at risk and the availability of resources. They may respond immediately or as resources are freed up. It can take 1-2 days and often longer for the authorities to respond and deal with a UXB.

Depending on the on-site risk assessment the item of ordnance may be removed from site or destroyed by controlled explosion. In the latter case additional cordons and/or evacuations may be necessary and the process will take longer.

It should be noted that following the discovery of an item of UXO, the military authorities will only carry out further investigations or clearances in very high profile or high risk situations. If there are regular UXO finds on a site the JSEOD may not treat each occurrence as an emergency and will recommend the construction company puts in place alternative procedures i.e. the appointment of a commercial contractor to manage the situation.

4. The Report

4.1. Report Objectives

The aim of this report is to undertake a fair, proportionate and comprehensive assessment of the potential risk from UXO at the Gospel Oak site. Every reasonable effort will be made to ensure that all available and pertinent historical information and records are accessed and checked. Full analysis and evidence will be provided where possible to allow the Client to fully understand the basis for the risk assessment.

Site specific risk mitigation measures will be recommended if deemed necessary, to reduce the threat from explosive ordnance during the envisaged works to as low as reasonably practicable.

4.2. Risk Assessment Process

1st Line Defence undertakes a five-step process for assessing the risk posed by UXO:

1. The risk that the site was contaminated with UXO.
2. The risk UXO remains on the site.
3. The risk that UXO may be encountered during the proposed works.
4. The risk that UXO may be initiated.
5. The consequences of initiating or encountering UXO.

In order to address the above, 1st Line Defence has considered in detail, site specific and non-site specific factors including:

- Evidence of German bombing, delivery of UXBs, records of abandoned bombs and maximum bomb penetration depth assessment.
- Site history, occupancy and conditions during WWII.
- The potential legacy of Allied military activity.
- Details of the specific UXO threat and any known UXO clearance work.
- The extent of any post-war redevelopment.
- The extent and nature of any proposed works.

4.3. Sources of Information

In order to produce a robust and thorough assessment of UXO risk, detailed historical research has been carried out by specialist researchers. Military records and archive material held in the public domain have been accessed. Information from the following sources has been consulted for this report:

- The National Archives, Kew and Camden Local Studies and Archive Centre.
- Landmark Maps.
- Historic England National Monuments Record.
- Relevant information supplied by Rydon.
- Available material from 33 Engineer Regiment (EOD) Archive.
- 1st Line Defence's extensive historical archives, library and UXO geo-datasets.
- Open sources such as published book and internet resources.

Research involved a visit to the Camden Local Studies and Archive Centre, and the National Archives, Kew.

5. Reporting Conditions

5.1. General Considerations

It is important to note that this desktop assessment is based largely upon research of historical evidence. Although every effort has been made to locate all significant and pertinent information, 1st Line Defence cannot be held accountable for any changes to the assessed level of risk or risk mitigation measures based on documentation or other data that may come to light at a later date, or which was not available to 1st Line Defence at the time of the report's production.

It is often problematic and sometimes impossible to verify the completeness and accuracy of WWII-era records – see 'Background to Bombing Records'. As a consequence, conclusions as to the exact location, quantity and nature a UXO threat can rarely be definitive. To counter this, it is essential that as many different sources and types of information as possible are consulted and analysed before a conclusion is reached. 1st Line Defence cannot be held responsible for inaccuracies or gaps in the available historical information.

5.2. Background to Bombing Records

In September 1940, the Government started to collect and collate information relating to damage sustained during bombing raids. The data became known as the 'Bomb Census'. Initially, only information relating to London, Birmingham and Liverpool was collated, but quickly the bomb census was extended to cover the rest of the UK.

Its purpose was to provide the Government with a complete picture of raid patterns, types of weapon used and damage caused – in particular to strategic services and installations such as railways, factories and public utilities.

Information was gathered locally by police, Air Raid Wardens and military personnel. They noted when, where and what types of bombs had fallen during an air raid, and passed this on to the Ministry of Home Security. Records of strikes were made either through direct observation or by post-raid surveys. However, the immediate priority was to deal with casualties and minimise damage. As a result, it is only to be expected that the records kept were often incomplete and contradictory.

Prior to the official 'Bomb Census', record keeping in the early months of the war was not comprehensive. The quality, detail and nature of record keeping could vary considerably from borough to borough and town to town. Many records were even damaged or destroyed in subsequent attacks. Records of raids that took place on sparsely or uninhabited areas were often based upon third party or hearsay information and are not always reliable. Furthermore, records of attacks on military or strategic targets were often maintained separately from the general records and have not always survived.

6. The Site

6.1. Site Location

The site is situated in the London Borough of Camden in the area of Gospel Oak.

The site is located in a primarily residential area. Immediately to the north of the site is a high-rise flat building, with a railway line just beyond this. To the north-east is a range of structures on Vicars Road including district offices, while to the east is a church and apartment blocks. South of the site is a set of commercial buildings and to the west the Wendling housing estate. Gospel Oak railway station is approximately 0.5km to the north-east, which serves the London Overground.

The site is centred on the approximate OS grid reference: **TQ 2808485245**

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

6.2. Site Description

The proposed site is an irregular-shaped parcel of land. It consists of the Bacton Low Rise estate – a housing complex made up of several low-rise flat buildings, recreational areas (vegetated ground) and parking / pathway areas. As well as this, it also includes much of Wellesley Road which runs round the northern, eastern and southern borders of the site, and Haverstock Road which runs on the western border.

A recent aerial photograph, site boundary and plan drawing of the site area are presented in **Annex B** and **Annex C** respectively.

7. Scope of the Proposed Works

7.1. General

The proposed work include the demolition of all structures on the site and the construction of a new housing estate, which will house 290 new homes.

8. Ground Conditions

8.1. General Geology

The British Geological Survey (BGS) map shows the site to be underlain by the London Clay formation – Clay, Silt and Sand, of the Palaeogene Period.

8.2. Site Specific Geology

Site-specific geology data was not available to 1st Line Defence at this time.

9. Site History

9.1. Ordnance Survey Historical Maps

Pre and post-WWII historical maps for the site were obtained by 1st Line Defence from Landmark Maps. These are presented in **Annex D.**

WWI Period		
Date	**Scale**	**Description**
1915 – 1916	1:2,500	This map shows the site to be covered by dense residential housing. Its premises also include part of Allcroft Road on the eastern border, Garfield Crescent through the centre, and Haverstock Road on the western border. Lismore Circus, a roundabout, is present directly to the north. A railway line is shown to run horizontally under this. Other points of interest are a school and a church just outside of the site's north-eastern border, while the east, south, and west are exclusively residential.

Post-WWII		
Date	**Scale**	**Description**
1953 – 1954	1:1,250	This map shows significant changes within the site boundary and its surroundings. Within the site, several properties are seen to be missing. In their place are either cleared ground, structures annotated to be 'ruins', and prefabricated homes (in the south-western corner). The overall layout of the surrounding area appears to be mostly the same, though instances of ruins are evident by the railway line to the north, and areas of cleared ground to the south-east and just out of site borders to the west. The school to the north-east has also been replaced by a Corporation Yard, containing what appears to be a new building.
1973 – 1980	1:1,250	This map shows that the site and its vicinity has undergone major re-development. Blocks of housing in and outside of the site have been removed and now the site is exclusively occupied by the Bacton housing estate, as in the present-day. The railway line and roundabout to the north remain, while small alterations to structures have taken place in the Corporation Yard to the north-east. Much of the south-east is empty with a few new buildings evident including the commercial complex immediately to the south, while the Wendling housing estate neighbours the site to the west.

10. Aerial Bombing Introduction

10.1. General

During WWI and WWII, many towns and cities throughout the UK were subjected to bombing which often resulted in extensive damage to city centres, docks, rail infrastructure and industrial areas. The poor accuracy of WWII targeting technology and techniques often resulted in all areas around a specific target being bombed.

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

The main focus of this report with regards to bombing will be weapons dropped during WWII, although WWI bombing will also be considered.

10.2. Generic Types of WWII German Air-delivered Ordnance

The type and characteristics of the ordnance used by the Luftwaffe during WWII allows an informed assessment of the hazards posed by any unexploded items that may remain in situ on a site. A brief summary of these characteristics is given below. Examples of German air delivered ordnance are presented at **Annex E.**

Generic Types of WWII German Air Delivered Ordnance	
High Explosive (HE) Bombs	
Frequency	In terms of weight of ordnance dropped, HE bombs were the most frequent weapon deployed by the Luftwaffe during WWII.
Size/Weight	Most bombs were 50kg, 250kg or 500kg (overall weight, about half of which was high explosive) though larger bombs of up to 2000kg were also used.
Description	High explosive bombs are thick-skinned and typically have sufficient mass and velocity and a suitably streamlined shape to enable them to penetrate the ground if they failed to explode on the surface.
Likelihood of detecting Unexploded	Although efforts were made to identify the presence of unexploded ordnance following a raid, often the damage and destruction caused by bombs which did detonate often made observation of UXB entry holes impossible. The entry hole of an unexploded bomb can be as little as 20cm in diameter and easily overlooked in certain ground conditions (See **Annex F**). Furthermore, ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded 50kg bomb. UXB's therefore present the greatest risk to present–day intrusive works.
Aerial or Parachute Mines	
Frequency	These were much less frequently deployed than HE and Incendiary bombs due to their size, cost and their difficulty technically to deploy.
Size/Weight	Their weight was either 500kg or 1000kg (overall weight, of which about 2/3 was explosive) depending on the type of mine. Their length ranged from 1.73-2.64m.
Description	The Luftmines (LMA-500kg and LMB-1000kg) were magnetic sea mines which were thin walled, cylindrical in shape with a hemispherical nose and were deployed under a green artificial silk parachute about 8m in diameter. They were fitted with magnetic and later with acoustic or magnetic/acoustic firing. When the mine hit the water and sank to more than 8ft, hydrostatic pressure and the dissolution of a soluble plug actuated the magnetic device and the mine became operational against shipping. The mine was also armed with a clockwork bomb fuze which caused the bomb to explode when used against land targets, and this was started by the impact of hitting the ground. The Bombenmine (BM 1000, Monika, or G Mine) was also used. This was fitted with a tail made from Bakelite which broke up on impact. It had a photoelectric cell beneath a cover which detonated the bomb if exposed to light to counteract the work of bomb disposal units.
Likelihood of detecting Unexploded	The aerial mines were either 500kg or 1000kg (overall weight, of which about 2/3 was explosive) depending on the type of mine. Their length ranged from 1.73-2.64m. They were much less frequently deployed than H.E. and Incendiary bombs due to their size, cost and the fact that they could not be delivered to point targets. If functioning correctly, parachute mines would generally have had a slow rate of descent (falling at about 40 mph) and were very unlikely to have penetrated the ground. Where the parachute failed, mines would have simply shattered on impact if the main charge failed to explode. There have been extreme cases when these items have been found unexploded. However, in these scenarios, the ground was either extremely soft or the munition fell into water. When operating as designed they caused considerable damage due to the high weight of explosive and their detonation at or near the

	surface. However 1st Line Defence does not consider there to be a significant threat from unexploded aerial mines on land.
1kg Incendiary Bombs	
Frequency	In terms of number of weapons dropped these small Incendiaries were the most numerous. Millions of these weapons were dropped throughout WWII.
Size/Weight	1kg
Description	These thermite filled devices were jettisoned from air-dropped containers. Some variants had explosive heads and these present a risk of detonation during intrusive works.
Likelihood of detecting Unexploded	They had very limited penetration capability and in urban areas especially would usually have been located in post-raid surveys. If they failed to initiate and fell in water, on soft vegetated ground, or bomb rubble, they could easily have gone unnoticed.
Large Incendiary Bombs	
Frequency	These items of ordnance were not as common as the 1kg Incendiaries however they were still more frequently deployed than the Parachute Mines and Anti-Personnel Bomblets.
Size/Weight	These could weigh up to 350kg.
Description	They had various flammable fill materials (including oil and white phosphorus), and a small explosive charge. They were designed to explode and burn close to the surface. Although they were often the same shape as HE bombs, they were thin-skinned and generally did not penetrate the surface.
Likelihood of detecting Unexploded	If they did penetrate the ground, complete combustion did not always occur and in such cases they could remain a risk to intrusive works.
Anti-personnel (AP) Bomblets	
Frequency	They were not commonly used and generally considered to pose a low risk to most works in the UK.
Size/Weight	The size and weight ranged depending on the type used. The most common was the "Butterfly Bomb" (SD2) which weighed 2kg and contained 225 grams of TNT.
Description	The 'Butterfly Bomb' had an 8cm long, thin, cylindrical, cast iron outer shell which hinged open when the bomblet deployed gave it the superficial appearance of a large butterfly. A steel cable 15 cm long was attached via a spindle to an aluminium fuze. The wings at the end were canted at an angle to the airflow, which turned the spindle anti-clockwise as the bomblet fell. After the spindle had revolved approximately 10 times (partially unscrewing itself from the bomb) it released a spring-loaded pin inside the fuze, which fully armed the SD2 bomb. They were generally lethal to anyone within a radius of 10 metres (33 ft) and could inflict serious shrapnel injuries. There were a number of variants, the most common being the SD2 which weighed 2kg and contained 225 grams of TNT. They were not commonly used and generally considered to pose a low risk to most works in the UK.
Likelihood of detecting Unexploded	SD2 bomblets were not dropped individually, but were packed into containers holding between 6 and 108 submunitions however, AP bombs had little ground penetration ability and should have been located by the post-raid survey unless they fell into water, dense vegetation or bomb rubble.

10.3. Failure Rate of German Air-Delivered Ordnance

It has been estimated that 10% of the German HE bombs dropped during WWII failed to explode as designed. This estimate is based on the statistics of wartime recovered UXBs and therefore will not have taken account of the unknown numbers of UXBs that were not recorded at the time. It is therefore quite likely that the average failure rate would have been higher than this.

There are a number of reasons why an air-delivered weapon might fail to function as designed:

- Many German bombs were fitted with a clockwork mechanism which could jam or malfunction.
- Malfunction of the fuze or gain mechanism (manufacturing fault, sabotage by forced labour or faulty installation)
- Failure of the bomber aircraft to arm the bombs due to human error or equipment defect.
- Jettison of the bomb before it was armed or from a very low altitude. Most likely if the bomber was under attack or crashing.

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

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

10.4. V-Weapons

From mid-1944, Hitler's 'V-weapon' campaign began. It used newly developed unmanned cruise missiles and rockets. The V1 known as the *Flying Bomb* or *Doodlebug* and the V2, a Long Range Rocket, were launched from bases in Germany and occupied Europe. A total of 2,419 V1s and 517 V2s were recorded in the London Civil Defence region alone.

Although these weapons caused considerable damage their relatively low numbers allowed accurate records of strikes to be maintained. These records have mostly survived. It should be stressed that there is a negligible risk from unexploded V-weapons on land today since even if the 1000kg warhead failed to explode, the weapons are so large that they would have been observed and the threat dealt with at the time. Therefore V-weapons are referenced in this report not as a viable risk factor, but primarily in order to help account for evidence of damage and clearance reported.

11. UXB Ground Penetration

11.1. General

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

- Mass and shape of bomb
- Height of release
- Velocity and angle of bomb
- Nature of the groundcover
- Underlying geology

Geology is perhaps the most important variable. If the ground is soft, there is more potential for deeper penetration – peat and alluvium are easier to penetrate than gravel and sand for example and the bomb is likely to come to rest at deeper depths. Layers of hard strata will significantly retard and may stop the trajectory of a UXB.

11.2. The J Curve Effect

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

11.3. WWII UXB Penetration Studies

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

They concluded that the largest common German bomb, 500kg, had a likely penetration depth of 6m in sand or gravel but 11m in clay. The maximum observed depth for a 500kg bomb was 11.4m and for a 1000kg bomb 12.8m. Theoretical calculations suggested that significantly greater penetration depths were probable.

11.4. Site Specific Bomb Penetration Considerations

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

- WWII Geology – London Clay Formation
- Impact Angle and Velocity – 10-15° from Vertical and 270 metres per second.
- Bomb Mass and Configuration – The 500kg SC (General Purpose) HE bomb, without retarder units or armour piercing nose. This was the largest of the common bombs used against Britain.

It has not been possible to determine maximum bomb penetration capabilities due to the lack of available borehole information.

12. Initiation of Unexploded Ordnance

12.1. General

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

12.2. UXB Initiation Mechanisms

There are a number of ways in which UXB can be initiated. These are detailed in the table below.

UXB Initiation	
Direct Impact	Unless the fuze or fuze pocket is struck, there needs to be a significant impact e.g. from piling or large and violent mechanical excavation, onto the main body of the weapon to initiate a buried iron bomb. Such violent action can cause the bomb to detonate.

Re- starting the Clock	A small proportion of German WWII bombs employed clockwork fuzes. It is probable that significant corrosion would have taken place within the fuze mechanism over the last 70+ years that would prevent clockwork mechanisms from functioning. Nevertheless it was reported that the clockwork fuze in a UXB dealt with by 33 EOD Regiment in Surrey in 2002 did re-start.
Friction Impact	This is the most likely scenario resulting in the weapon detonating; friction impact initiating the shock-sensitive fuze explosive. The combined effects of seasonal changes in temperature and general degradation over time can cause explosive compounds to crystallise and extrude out from the main body of the bomb. It may only require a limited amount of energy to initiate the extruded explosive which could detonate the main charge.

Annex G2 details UXB incidents where intrusive works have caused UXBs to detonate, resulting in death or injury and damage to plant.

12.3. Effects of Detonation

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

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

13. The Threat from German UXBs

13.1. World War I

During WWI London was targeted and bombed by Zeppelin Airships and by Gotha and Giant fixed-wing aircraft. An estimated 250 tons of ordnance (high explosive and incendiary bombs) was dropped on Greater London, more than half of which fell on the City of London. The WWI bomb census map can be seen in **Annex H**. It is believed that WWI bombs fell in the general area however there is no specific evidence that points to bombs landing on the proposed site.

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

13.2. World War II Bombing of St. Pancras / Camden

The Luftwaffe's objective for the attacks on London was to paralyse the commercial life of the capital by bombing the docks, warehouses, wharves, railway lines, factories and power stations. The Metropolitan Borough of St. Pancras (in which the site was located during WWII) was subject to a

Moderate bombing density. The district and neighbouring areas contained some targets of significance for the Luftwaffe which resulted in a relatively heavy bombardment throughout the region. These included the St. Pancras and King's Cross Stations, both approximately 3km south-east of the site, with an electricity generating station and gas works also located in the area. Luftwaffe reconnaissance flights would take place over London and highlight such buildings / features which would be supplied to military planners and bomber crews.

Much of the area is residential in make-up however this did not mean it escaped the worst of the raids on the city. The neighbouring area of Hampstead experienced a relatively high density of bombing for a location of its nature. Some of this can be attributed to the aforementioned railway presence. The site neighboured railway infrastructure which would have provided incoming Luftwaffe raids with potential targets. Its close proximity to Central London should also be taken into account when considering the levels of bombing for the area. Certain concepts of 'total war', i.e. less differentiation between combatants and civilians, brought the war to the doorstep of civilian Londoners with the belief that it was possible to break the country's will if the civilian population were directly impacted. Large scale raids were therefore designed to carpet bomb certain areas and not just target individual industry hubs and military establishments.

Gospel Oak received its fair share of disruption. One notable event was a landmine dropping on Fleet School on Mansfield Road (now the premises of Gospel Oak Primary School, approximately 400m north of the site) in 1940 while it was acting as a temporary fire station. This resulted in the structure being designated a dangerous building and its closure until a new school was built post-war. An image of an unexploded bomb dropping in the same location in 1941 can be seen in **Annex J**.

Records of bombing incidents in the civilian areas of London were collected by the Air Raid Precautions wardens and collated by the Civil Defence Office. Some other organisations, such as the London Port Authority and railways, maintained separate records.

Records would be in the form of typed or hand written incident notes, maps and statistics. Bombing data was carefully analysed, not only due to the requirement to identify those parts of the capital most needing assistance, but also in an attempt to find patterns in the Germans' bombing strategy in order to predict where future raids might take place.

Records of bombing incidents for the Metropolitan Borough of St. Pancras are presented in the following sections.

13.3. Second World War Bombing Statistics

The following tables summarise the quantity of German bombs (excluding 1kg incendiaries and anti-personnel bombs) falling on the Metropolitan Borough of St. Pancras between 1940 and 1945.

Record of German Ordnance Dropped on the Metropolitan Borough of St. Pancras		
Area Acreage		**2,694**
Weapons	High Explosive Bombs (all types)	641
	Parachute Mines	8
	Oil Bombs	14
	Phosphorus Bombs	11
	Fire Pot	0
	Pilotless Aircraft (V1)	20
	Long Range Rockets (V2)	2
Total		**696**

Number of Items per 1000 acres	**258.4**

Source: Home Office Statistics
This table does not include UXO found during or after WWII.

Detailed records of the quantity and locations of the 1kg incendiary and anti-personnel bombs were not routinely maintained by the authorities as they were frequently too numerous to record. Although the incendiaries are not particularly significant in the threat they pose, they nevertheless are items of ordnance that were designed to cause damage and inflict injury and should not be overlooked in assessing the general risk to personnel and equipment. The anti-personnel bombs were used in much smaller quantities and are rarely found today but are potentially more dangerous.

13.4. London Air Raid Precautions Bomb Census Maps

During WWII, the Ministry of Home Security produced consolidated and weekly bomb census maps for London. The maps covering the area of the site were checked for this report. Those showing bomb strikes on and in the vicinity of the site are presented in **Annexes K & L** and are discussed below:

London Consolidated Bomb Maps – Annex K	
Date Range	**Comments**
Night Bombing up to 7th October 1940	No strikes are recorded on the site or in the immediate vicinity, though several HE bombs are recorded to the south-east and south-west of the site at a distance of around 250-300m.
7th October 1940 to 6th June 1941	**3 HE bombs** are recorded on the site, roughly in the north-eastern part, the southern part, and the north-western part. **3 more** are noted just outside site borders to the north, south and west, and many more in the surrounding area (though the density is lower to the north).

London Weekly Bomb Maps – Annex L	
Date Range	**Comments**
4th – 11th November 1940	No bombs are recorded within site perimeters, though **a HE bomb** is noted just outside the site's south-western border and three more within 400m to the west.
11th – 18th November 1940	A 1000kg HE is recorded roughly 250m to the north.
6th – 13th January 1941	**A HE bomb** is recorded in the southern part of the site (matching the consolidated mapping). Two to the east and three to the west are evident within 250m.
5th – 12th May 1941	**Three HE bombs are recorded** on the site, two in the southern part and one on the western border. **A large incendiary shower** is also present just out of site borders to the north-east, and two HE bombs within 200m to the south. An unexploded bomb is recorded further out, roughly 500m to the north-west.

13.5. London V-Weapon Maps

Plots showing the location of all the V-1 strikes in the London area were compiled by the Ministry of Home Security. The area covering the site was checked and a section of it is presented in **Annex M**.

V-Weapon Map – Annex M	
Date Range	**Comments**

Post-war consolidated Bomb Plot Map	**2 V1 Flying Bomb strikes** are recorded roughly 600m to the north and south-east.

13.6. London County Council Bomb Damage Map

A map from the London County Council showing the extent of bomb damage on the borough was compiled during / after WWII. The section showing the area of the site is presented in **Annex N**.

London County Council Bomb Damage Map – Annex N	
Date Range	**Comments**
Post-War Consolidated Bomb Damage Map	The bomb damage map shows a range of significant damage on the residential properties present within the site boundaries. This varies from slight 'blast damage' all the way up to 'total destruction' – 12 buildings on site receive this designation. It does not appear that any buildings on site survived unaffected. This damage stretches into the greater area, affecting the school and church to the north-east as well as housing to the east, south and west, though the area covered by the site appears to be the worst impacted.

13.7. Metropolitan Borough of St. Pancras Bomb Incident Records

A transcript of the associated written records for the bombs which fell in the area is not available for reference. Attempts were made to locate and then access bombing records for this area however it appears that they have either been lost or even destroyed.

13.8. WWII-Era Aerial Photographs

High resolution scans of WWII-era aerial photography for the site area were obtained from the National Monuments Record (Historic England). Imagery dated 10th May 1946 is presented in **Annex O**.

Imagery shows the site to have sustained significant damage, resulting in several areas of clearance, as well as a patch of land in the south-western corner housing prefabricated homes. Further areas of clearance are evident in the greater area within a distance of around 100m from the site borders. Due to the small-scale detail of the image, it has not been possible to highlight more specific indications of damage, such as roofing or ground disturbance. However, the spread of instance of significant damage is sufficient to indicate that most of the site would have been impacted to some degree, particularly in light of the potential J-curve effect. Visible damage indications are annotated in **Annex O2**, and a wider view of the site is presented in **Annex O3**.

Another image from 1945 was obtained and is shown in **Annex P** (also annotated with damage). While the quality is very low, prefabricated homes and a large clearance area are evident within the site, as with the 1946 image. As well as this, serious damage can be seen just out of site borders to the west, suggesting that clearance had not yet taken and consequently confirming that it was not simply a result of general re-development.

13.9. Abandoned Bombs

A post-air raid survey of buildings, facilities and installations would have included a search for evidence of bomb entry holes. If evidence were encountered, Bomb Disposal Officer Teams would normally have been requested to attempt to locate, render safe and dispose of the bomb. Occasionally evidence of UXBs was discovered but due to a relatively benign position, access problems or a shortage of