Appendix E - Detailed UXO threat Assessment Desk Top Study

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Detailed Unexploded Ordnance Risk Assessment

In Respect Of:
Associated British Ports

For:
Immingham Eastern Ro-Ro Terminal

Report Reference:
9048 RA

safelaneglobal.com

2020
Awarded to
SafeLane Global Limited

Distribution

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This Report has been produced in compliance with the Construction Industry Research and Information Association guidelines for the preparation of Detailed Unexploded Ordnance Risk Assessments in the management of UXO risks in the construction industry.

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Executive Summary

The Site	
Address:	Immingham East Junction, Queens Road, Immingham, North East Lincolnshire, DN40 1QR
OS National Grid Reference:	TA 20391 15249
Site Description:	The site is located within the east of the Immingham Dock facility. The project site is irregular in shape, encompassing large areas of hard standing, several commercial buildings and peripheral dense vegetation. The northern part of the site extends northwards into the Humber port approaches.
Proposed Works	
Associated British Ports (ABP), the owner and operator of the Port of Immingham, is proposing to construct a new roll-on/roll-off (Ro-Ro) facility within the Port to service the embarkation and disembarkation of principally commercial and automotive traffic. The proposed development will involve marine works (an approach jetty, a linkspan with bankseat, floating pontoon, finger piers) within the Humber Estuary and landslide works (terminal, building and internal bridge construction) on existing statutory port estate.	
Risk Assessment	
Risk Assessment Methodology: In accordance with CIRIA guidelines this assessment has carried out research, analysed the evidence and considered the likelihood that the site has been contaminated with unexploded ordnance; that such items remained on site; the risk that they could be encountered during any intrusive works and the consequences that could result. Appropriate risk mitigation measures have been proposed.	
UXO Risk Rating	**MEDIUM from the following UXO types:** **German Air-Delivered HE bombs** **Anti-Aircraft Projectiles**
The full UXO Risk Assessment and a breakdown of the UXO Risk Level can be found in Section 11.	
Maximum Bomb Penetration Depth	It has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between **8-10m** below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth. For information on bomb penetration in the marine section of the site, please see section 8.5.5.

<table>
<tr><th colspan="4">Recommended Risk Mitigation</th></tr>
<tr><th>Risk Level</th><th>Environment</th><th>Planned Site Activity</th><th>Recommendations</th></tr>
<tr><td rowspan="4">Medium</td><td rowspan="2">Land-based</td><td>Shallow Intrusive Works e.g. excavations</td><td>• UXO Safety & Awareness Briefing (Toolbox Brief, TBB)
• Site Specific Safety Instructions (SSSIs) Training Course
• Non-Intrusive (NI) Magnetometer Survey (Greenfield areas only)
• Target Investigation (Required as a follow-on from NI magnetometer survey)
• Search & Clear
• Explosive Ordnance Disposal (EOD) Engineer Watching Brief (for brownfield areas unsuitable for NI magnetometer survey)</td></tr>
<tr><td>Deep intrusive works (e.g. piling)</td><td>• UXO Safety & Awareness Briefing (Toolbox Brief, TBB)
• Site Specific Safety Instructions (SSSIs) Training Course
• Intrusive Magnetometer Survey of pile/borehole positions</td></tr>
<tr><td rowspan="2">Marine based</td><td>Shallow Intrusive Works e.g. excavations</td><td>• UXO Safety & Awareness Briefing (Toolbox Brief, TBB)
• Site Specific Safety Instructions (SSSIs) Training Course
• Non-Intrusive Magnetometer UXO Survey
• Non-Intrusive 3D Seismic Investigation from the 2m contour</td></tr>
<tr><td>Deep intrusive works (e.g. piling)</td><td>• UXO Safety & Awareness Briefing (Toolbox Brief, TBB)
• Site Specific Safety Instructions (SSSIs) Training Course
• Seismic Investigation: Further Non-Intrusive Survey over exact locations to identify and mitigate risk and geological assessment for further risk management.</td></tr>
<tr><td colspan="4">In making this assessment and recommending these 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, SafeLane Global should be consulted to see if re-assessment of the risk or mitigation recommendations is necessary.</td></tr>
</table>

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Glossary of Terms

AAA	Anti-Aircraft Artillery
ARP	Air-raid Precautions
BDO	Bomb Disposal Officer
EOD	Explosive Ordnance Disposal (current term for "bomb" disposal)
HE	High Explosive
HG	Home Guard
IB	Incendiary Bomb
Kg	Kilogram
LM	Land Mine
LSA	Land Service Ammunition (includes grenades, mortars, etc.)
Luftwaffe	German Air Force
m bgl	Metres Below Ground Level
MoD	Ministry of Defence
OB	Oil Bomb
PM	Parachute Mine
RAF	Royal Air Force
SI	Site Investigation
SAA	Small Arms Ammunition (small calibre cartridges used in rifles & machine guns)
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V-1	"Doodlebug" the first cruise type missile, used against London from June 1944. Also known as 'Flying Bomb'
V-2	The first ballistic missile, used against London from September 1944
WWI	First World War (1914 -1918)
WWII	Second World War (1939 – 1945)

Detailed Unexploded Ordnance Risk Assessment

In Respect of

Immingham Eastern Ro-Ro Terminal

1 Introduction

AECOM, on behalf of Associated British Ports, has commissioned SafeLane Global to conduct a Detailed Unexploded Ordnance Risk Assessment of the Immingham Eastern Ro-Ro Terminal.

Unexploded Ordnance (UXO) presents a significant risk to construction projects in parts of the UK as a result of enemy actions during the two 20th Century World Wars and historic British and Allied military activity.

One of the legacies of this conflict is buried unexploded air-dropped bombs or anti-aircraft projectiles resulting from the failure of a proportion of the weapons to function as designed. It is commonly accepted that the failure rate of these munitions was approximately 10% and, depending on their shape, weight, velocity and ground conditions, many penetrated the ground and came to rest at depth.

In addition, it is estimated that over 20% of the UK landmass has been used by the military at some point and between 2006 and 2009, over 15,000 items of British / Allied ordnance (excluding small arms ammunition) were found on UK construction sites (CIRIA).

Intensive efforts were made during and after the war to locate and render safe all UXO but, unsurprisingly, not all were found and dealt with. This is evidenced by the regular, on-going discoveries of UXO during construction-related intrusive ground works.

As a result of a generally increased risk awareness amongst professionals involved in ground engineering works and proactive health and safety measures, the risk to life and limb from UXO has been minimised. However even the simple discovery of a suspected device during on-going works can cause considerable disruption to production and cause unwanted delays and expense.

Such risks can be more fully addressed by a better understanding of the site-specific risk and the implementation of appropriate risk mitigation measures.

2 Construction Industry Duties and Responsibilities

2.1 The UK Regulatory Environment

There is no legal requirement for the control and mitigation of UXO risk in the construction industry, but guidelines for good practice, information, and solutions with regards to UXO risk are detailed within CIRIA (C681): Unexploded Ordnance (UXO) A Guide for the Construction Industry.

These guidelines provide the construction industry with a set process for the management of risk associated with UXO, from preliminary risk assessment to implementation of site-specific risk mitigation strategies.

Specific legislation does however exist for health and safety, and is addressed under a number of regulatory instruments, as outlined below.

In practice, the regulations impose a responsibility on the construction industry to ensure that they discharge their obligations to protect those engaged in ground-intrusive operations (such as archaeology, site investigation, drilling, piling or excavations) from any reasonably foreseeable UXO risk.

2.2 The Health and Safety at Work Act, 1974

The Act places a duty of care on an employer to put in place safe systems of work to address, as far as is reasonably practicable, all risks (to employees and the general public) that are reasonably foreseeable.

2.3 Construction (Design and Management) Regulations 2015

CDM 2015 ensures that health and safety within the construction industry is continually improved:

- Works are sensibly planned and managed.
- Competent staff are engaged in the works.
- Risks are identified and managed.
- All parties cooperate and coordinate activities.
- Communication flows to those who require it.
- Workers are consulted and engaged about risks and how they are being managed.

In line with CDM 2015 legislation, SafeLane Global are able to assist parties in their discharge of CDM duties as follows:

- Assist Principal Designers with pre-construction information and risk assessments.
- Assist the Designer with the Designer's Risk Assessment.
- Issue UXO risks as have been identified and manage risks accordingly.
- Assist the Principal Contractor with the construction phase information, in particular risk assessments and mitigation strategies.
- Plan, manage and monitor survey and clearance works under SafeLane Global's control.

2.4 Other Legislation

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

3 The Role of the Authorities and Commercial Contractors

3.1 The Authorities

The Police have the responsibilities for co-ordinating the emergency services in the case of an ordnance-related incident on a construction site. They will make an initial assessment (i.e. is there a risk that the find is ordnance or not?) and if they judge necessary impose a safety cordon and/or evacuation and call the military authorities (JSEODOC - Joint Services Explosive Ordnance Disposal Operations Centre) to arrange for investigation and/or disposal. In the absence of an EOD specialist on site many Police Officers will use the precautionary principle, impose cordon(s)/evacuation and await advice from the JSEODOC.

The priority given to the request by JSEODOC will depend on their judgement of the nature of the risk (ordnance, location, people and assets at risk) and the availability of resources. They will respond immediately or as resources are freed up. Depending on the on-site risk assessment the item of ordnance may be removed or demolished (by controlled explosion) in situ. In the latter case additional cordons and/or evacuations may be necessary.

Note, that the military authorities will only carry out further investigations or clearances in very high profile or high-risk situations. If there are regular ordnance finds on a site, the JSEODOC may not treat each occurrence as an emergency and will encourage the construction company to put in place alternative procedures (i.e. the appointment of a commercial contractor) to manage the situation and relieve pressure from the JSEOD disposal teams.

3.2 Commercial Contractors

In addition to pre-construction site surveys and follow-on clearance work, a commercial contractor is able to provide a reactive service on construction sites. The presence of a qualified EOD Engineer with ordnance recognition skills will avoid unnecessary call-outs to the authorities and the contractor will be able to arrange for the removal and disposal of low risk ordnance. 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.

4 This Report

4.1 Aims and Objectives

The aim of this report is to examine the possibility of encountering any explosive ordnance during any intrusive works at the site. Risk mitigation measures will be recommended in line with the CIRIA C681 guidelines, to reduce the risk of initiating UXO, and the subsequent risk of harm / damage during the envisaged works to as low as reasonably practicable (ALARP).

4.2 Risk Assessment Methodology

The following issues will be addressed in the report:

- The likelihood that the site was contaminated with unexploded ordnance.

- The likelihood that unexploded ordnance remains on site.
- The likelihood that ordnance may be encountered during any intrusive works.
- The risk that ordnance may be initiated.
- The consequences of initiating or encountering ordnance.

Risk mitigation measures, appropriate to the assessed level of risk and site conditions, will be recommended.

4.3 Approach

In preparing this Unexploded Ordnance Risk assessment, SafeLane Global has considered general and, as far as possible, site-specific factors including:

- Evidence of German bombing and delivery of UXBs.
- Site history, occupancy and conditions during WWII.
- The legacy of Allied military activity.
- Details of any known EOD clearance activity.
- The extent of any post war redevelopment.
- Scope of the current proposed works.

4.4 Sources of Information

SafeLane Global has carried out detailed historical research for this Unexploded Ordnance Risk Assessment including accessing military records and archived material held in the public domain and in the MoD.

Material from the following sources has been consulted:

- The National Archives.
- Britain From Above
- Groundsure Limited.
- Relevant information supplied by the client.
- Available material from 33 Engineer Regiment (EOD) Archive.
- SafeLane Global's extensive archives built up over many years of research and hands-on Explosive Ordnance Disposal activities in the UK.
- Open sources such as published books, local historical records and the internet.

4.5 Reliability of Historical Records

4.5.1 General Considerations

This report is based upon research of historical evidence. Whilst every effort has been made to locate all relevant material SafeLane Global cannot be held responsible for any changes to the assessed level of risk or risk mitigation measures based on documentation or other information that may come to light at a later date.

The accuracy and comprehensiveness of wartime records is frequently difficult or impossible to verify. As a result, conclusions as to the exact location, quantity and nature of the ordnance risk can never

be definitive but must be based on the accumulation and careful analysis of all accessible evidence. SafeLane Global cannot be held responsible for inaccuracies or gaps in the available historical information.

4.5.2 Bombing Records

During WWII, considerable efforts were expended in recording enemy air raids. Air Raid Precautions (ARP) wardens were responsible for making records of bomb strikes either through direct observation or by post-raid surveys. However, their immediate priority was to deal with casualties and limit damage, so it is to be expected that records are often incomplete and sometimes contradictory. Record keeping in the early days of bombing was not comprehensive and details of bombing in the early part of the war were sometimes destroyed in subsequent attacks. Some reports may cover a single attack, others a period of months or the entire war.

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; records of attacks on military or strategic targets were often maintained separately from the general records and have not always survived.

5 The Site and Scope of Proposed Works

Site Address	Immingham East Junction, Queens Road, Immingham, North East Lincolnshire, DN40 1QR	
OS National Grid Reference	TA 20391 15249	
Site Description	The site is located within the east of the Immingham Dock facility. The project site is irregular in shape, encompassing large areas of hard standing, several commercial buildings and peripheral dense vegetation. The northern part of the site extends northwards into the Humber port approaches.	
Proposed Works	Associated British Ports (ABP), the owner and operator of the Port of Immingham, is proposing to construct a new roll-on/roll-off (Ro-Ro) facility within the Port to service the embarkation and disembarkation of principally commercial and automotive traffic. The proposed development will involve marine works (an approach jetty, a linkspan with bankseat, floating pontoon, finger piers) within the Humber Estuary and landslide works (terminal, building and internal bridge construction) on existing statutory port estate.	
References	**Site Location Maps**	**Annex A**
	Recent Aerial Photograph	**Annex B**

6 Ground Conditions

Data Source		Description
British Geological Survey Borehole	Borehole Reference	TA21NW10
	Location	On site (south)
	Date	April 1946
	Recorded Shallow Geology	• ~0.4m of "made up ground" • ~3.4m of "soft brown warp" • ~5.6m of "soft blue warp" • ~0.6m of "peat" • ~5.6m of "marl clay" • ~7.8m of "chalk gravel" • ~8.5m of "chalk"
British Geological Survey Mapping	Superficial Deposits	Tidal Flat Deposit – Clay & Silt (south of the site) Beach & Tidal Flat Deposits (undifferentiated) – Clay, Silt & Sand (north of site)
	Bedrock	Flamborough Chalk Formation - Chalk
Client Provided Data	Groundsure Enviro+Geo Insight, 2021[1]	Most of the land-based project site comprises made ground, with small exceptions. These other areas within the site comprise infilled ground, the first area located towards the northern extent, just south of the dock/Humber, the second area in the south-eastern extent. Information regarding the material and date of origin for these infilled areas is not provided within this document.

[1] Groundsure Limited, Enviro + Geo Insight, 08/10/2021, Ref: Project_Sugar_60664611

7 Historical Mapping

7.1 Pre and Post-WWII OS Mapping

	Date	Observations	Reference	Source
Pre-WWII	1910-30	• The available coverage of the northern extent of the site is dated 1910, while the remainder of the site is covered by a 1930 map. As such, the conditions of the site will have undergone additional changes at its northern extent after the production of this map. • The north of the site is predominantly shown to be undeveloped, with its very northern extent encroaching into the water. • The south-west of the site is occupied by railway lines and sidings, with surrounding open ground and small associated structures. • The south-east of the site is bisected by a road with embankments. On the eastern side of this road, the site comprises open pasture and vegetated fields. Some small buildings are visible. • The remainder of the site is not shown to be occupied by any structures. However, it is possible that certain features such as railway lines have been omitted from this map. • The surrounding area is predominantly rural to the east and south, with *Immingham Dock* and its associated railway infrastructure located to the west.	Annex C-1	Landmark Maps
Post-WWII	1947-51	• Several cleared buildings are visible in the surrounding area, predominantly to the east of the site around the Dock facilities. • Evidence of clearance is often indicative of bomb damage on early post-WWII OS mapping. • The site does not appear to have undergone any significant changes, aside from the installation of a railway line parallel to the river front. • Several instances of development are evident in the surrounding area, the most significant of which to the west of the northern extent. • Aside from the aforementioned clearance and development, no futher significant changes appear to have occurred in the surrounding area.	Annex C-2	Landmark Maps

7.2 Immingham Dock Plan, c. 1912

A plan of Immingham Dock dated around 1912 was obtained.

Date	Observations	Reference	Source
c.1912	• This plan confirms that during WWI, the project site was occupied primarily by rail lines and sidings, along with associated structures within the rail infrastructure. • The northern parts of the site were mostly occupied by open ground, with the northernmost extent extending outwards into the Humber.	Annex D	Open Source

8 The Threat from Aerial Bombing

8.1 General Bombing History of Immingham

8.1.1 First World War

The UK suffered aerial bombardment during WWI, beginning with indiscriminate night raids by Zeppelin airships. However as British defensive measures became more effective and aircraft development progressed, the German military switched to daylight raids by fixed wing aircraft in June 1917.

The area surrounding Kingston upon Hull has bombed several times by Zeppelin airships between 1915 and 1918, including the Immingham area.

On 28th/29th July 1916, a Zeppelin crossed the estuary to Immingham before dropping 6x HE bombs on Stallingborough Marsh, near to Immingham Halt station. One of the bombs fell near the electric railway line. A 12-pdr gun at Immingham Halt reportedly fired 2 rounds into the fog, but without result. Bombs were also dropped on the Killingholme area.[2]

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. When combined with the relative infrequency of attacks and an overall low bombing density the risk from WWI UXBs is considered low and will not be further addressed in this report.

8.1.2 Second World War

At the start of WWII, the Luftwaffe planned to destroy key military installations, including RAF airfields and Royal Navy bases, during a series of daylight bombing raids, mainly in southern and eastern England; July to October 1940.

After the Battle of Britain these tactics were modified to include both economic and industrial sites across the entire country. Targets included dock facilities, railway infrastructure, power stations, weapon manufacturing plants, gas works, etc. In the autumn of 1940, as a result of aircraft losses, daylight raids were reduced in favour of attacking targets under the cover of darkness.

The Luftwaffe strategy became the destruction of civilian morale by the large scale "carpet bombing" of Britain's cities; London, Liverpool, Birmingham, etc. This initial nine-month Blitz period came to an end in May 1941 as the vast majority of Luftwaffe was diverted east to prepare for 'Operation Barbarossa'; the invasion of the Soviet Union. Sporadic attacks continued in the Humber region till the end of the war, however these comprised smaller formations of German aircraft.

During WWII, north-east Lincolnshire was predominantly agricultural in character and, aside from a number of RAF airfields, contained few potential Luftwaffe targets. However, Immingham Port and the associated rail infrastructure, coal yards and industry on and in close proximity to the site would have constituted a significant Luftwaffe bombing target. Similarly, the neighbouring seaport of Grimsby to the south-east and city of Hull to the north, which both contained large areas of dock and port infrastructure, were regularly attacked throughout the war - along with other major industrial

[2] http://www.iancastlezeppelin.co.uk/2829-jul-1916/4591795878

centres in the north of England. As a consequence, it is probable that the surrounding area was subjected to both targeted raids and 'tip and run' bombing incidents[3].

8.2 Generic Types of WWII German Air-delivered Ordnance

The nature and characteristics of the ordnance used by the Luftwaffe allows an informed assessment of the hazards posed by any unexploded items that may remain today.

- HE Bombs: In terms of weight of ordnance dropped, HE bombs were the most frequent weapon deployed. Most bombs were 50kg, 250kg or 500kg (overall weight, about half of which was the high explosive) though large bombs of up to 2,000kg were also used. HE bombs had the weight, velocity and shape to easily penetrate the ground intact if they failed to explode. Post-raid surveys would not always have spotted the entry hole or other indications that a bomb penetrated the ground and failed to explode, and contemporary ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded 50kg bomb. Unexploded HE bombs therefore present the greatest risk to present–day intrusive works.
- Blast Bombs/Parachute Mines: Blast bombs generally had a slow rate of descent and were extremely unlikely to have penetrated the ground. Non-retarded mines would have shattered on most ground types, if they had failed to explode. There have been extreme cases when these items have been found unexploded, but this was where the ground was either very soft or where standing water had reduced the impact. SafeLane Global does not consider there to be a significant risk from this type of munition on land.
- Large incendiary bombs: This type of bomb ranged in size from 36kg to 255kg and had a number of inflammable fill materials (including oil and white phosphorus), and a small explosive charge. They were designed to explode and burn close to the surface, but their shape and weight meant that they did have penetration capability. If they penetrated the ground, complete combustion did not always occur, and, in such cases, they remain a risk to intrusive works.
- 1kg Incendiary Bombs (IB): These bombs, which were jettisoned from air-dropped containers, were just over 30cm in size and therefore highly likely to go unnoticed. They had the potential to penetrate soft ground and left a very small entry hole. Furthermore, if bombs did not initiate and fell in water or dense vegetation or became mixed with rubble in bomb damaged areas, they could have remained hidden to this day. Some variants had explosive heads, and these present a risk of detonation during intrusive works, particularly due to their shape, which leads them to often be misidentified.
- Anti-personnel (AP) Bomblets: 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.
- Specialist Bombs (smoke, flare, etc): These types do not contain high explosive and therefore a detonation consequence is unlikely. They were not designed to penetrate the ground.

Examples of the most commonly deployed German bombs are presented in the following figures.

[3] When German aircraft were not able to reach their intended target due to heavy anti-aircraft fire or fighter interception and jettisoned their bomb load indiscriminately.

SC50 (High Explosive)

Bomb Weight: 40-54kg (110-119lb)

Explosive Weight: c.25kg (55lb)

Fuze Type: Impact fuze / electro-mechanical time delay

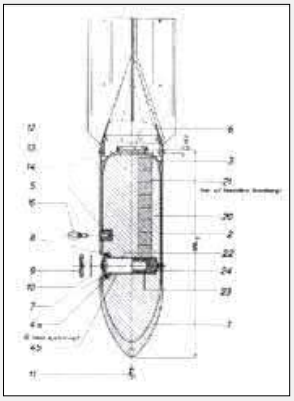
Body Dimensions: 1,090 x 280mm (22.9 x 11.0in)

Body Diameter: 200mm (7.87in)

Use: Against lightly damageable materials, hangars, railway rolling stock, ammunition depots, light bridges, and buildings up to three-storeys.

Remarks: The smallest and most common conventional German bomb. Nearly 70% of bombs dropped on the UK were 50kg.

50kg HE bomb, London Docklands

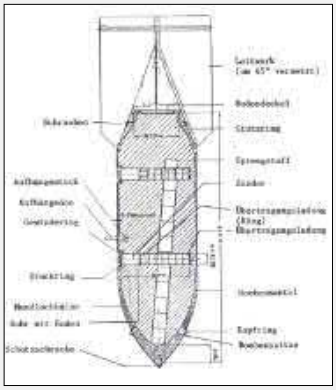


SC 50 JA (Güteklasse 1)

50kg HE bomb (minus tail section)

250kg HE bomb, Hawkinge

SC250 attached to undercarriage of Messerschmitt Bf109



SC 250 JA (Güteklasse 1)

SC250 (High Explosive)

Bomb Weight: 245-256kg (540-564lb)

Explosive Weight: c.125-130kg (276-287lb)

Fuze Type: Electrical impact fuze / mechanical time delay fuze

Body Dimensions: 1,640 x 512mm (64.57 x 20.16in)

Body Diameter: 368mm (14.5in)

Use: Against railway installations, embankments, flyovers, underpasses, large buildings and below-ground installations.

1kg Incendiary Bomb

Bomb Weight: 1.0 & 1.3kg (2.2 & 2.87lb)

Filling: 680gm (1.3lb) Thermite

Fuze Type: Impact Fuze

Body Dimensions: 350 x 50mm (13.8 x 1.97in)

Body Diameter: 50mm (1.97in)

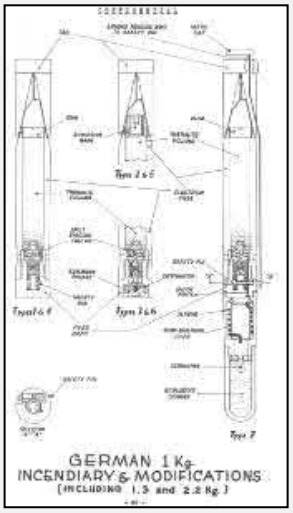
Use: As incendiary – dropped in clusters against towns and industrial complexes.

Remarks: Jettisoned from air-dropped containers. Magnesium alloy case. Sometimes fitted with high explosive charge.

1. Ordinary scaffold pipe

2. 1kg incendiary bomb

3. Incendiary bomb recently found on site in UK



1kg German Incendiary Bomb next to a 30cm ruler

8.3 Second World War Bombing Statistics

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

Record of German Ordnance Dropped on the Rural District of Grimsby	
Area Acreage	39,647
High Explosive Bombs (all types)	204
Parachute Mines	6
Oil Bombs	-
Phosphorus Bombs	27
Fire Pots	17
Pilotless Missile (V1)	-
Long Range Rocket (V2)	-
Total	254
Items Per 1,000 Acres	**6.4**

Source: Home Office Statistics

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

8.4 Site Specific WWII Bombing Records

8.4.1 Secondary Source / Anecdotal Evidence

Anecdotal evidence of local bombing incidents was sought from publications and web resources. The following references to incidents on site or in the surrounding area were found.

Date	Weapon	Details
12/02/1940	250kg HE bomb	The merchant ship SS Kildare arrived in Immingham with a bomb wedged in the main deck. The bomb was subsequently defused. A similar incident reportedly occurred in the following June.[4]
February 1941	Not specified	In February, the main weight of attacks fell on the north of the county, Grimsby, Cleethorpes and the North Killingholme areas being raided most.[5]
22/03/1941	HE bombs	A Heinkel strayed over the Humber defences after becoming lost. It was hit by AA fire and then flew into a balloon cable. The aircraft jettisoned its bomb load at low level across the railway sidings at Immingham and crashed just beyond what is now Hawthorne Avenue.[6] This incident could have occurred within the project site's location.
22/03/1941	HE bombs	A further report taken from the same day notes that a Heinkel came under fire after entering the Humber estuary. It jettisoned its bombs on wasteland between Immingham Docks and the loco sheds, before crashing in a field beside the Immingham-Habrough Road.[7] This record confirms the events of the previous entry and could have resulted in bombs landing within the site boundary.
11/08/1942	Not specified	The Docks at Immingham were damaged.[8]

8.4.2 Bombing Decoy Sites

A national decoy authority headed by Colonel John Fisher Turner was set up in July 1940, and following earlier experiments in Glasgow and Sheffield, a system of urban lighting decoys was set up. These were known as "Civil" sites; Civil 'QL' for urban lighting simulation, and Civil 'QF' for dummy fires. "Q" - sites were equipped with assorted electrical and pyrotechnical apparatus to simulate the flare given from furnace doors, steel-making, railway marshalling yards, and light given off by inefficient blackout precautions.

Other sites simulated small fires started by incendiary bombs, with oil-storage area fire simulation being developed near large oil installations. A further variation on fire decoy sites was the "SF", or "Special Fires" sites. A larger, longer-burning type of fire was provided at these sites - known as

[4] https://www.rafmuseum.org.uk/blog/a-short-history-of-raf-bomb-disposal/
[5] Air Raids on Lincolnshire 1940-1945, County Constabulary Headquarters, Lincoln, 5th December 1945
[6] https://www.northlincsweb.net/RAFElshamWolds/html/22nd_march_1941_-_5-kg4-_eindhoven_-_heinkel_he_iii_p-4_-_2938_-.html
[7] Ramsey, (1988).
[8] Ramsey, (1990).

"Starfish" sites - to draw incendiary bombs, and hopefully as a consequence the full enemy payload, from falling on the larger conurbations and defence installations during heavy air raids. Decoy sites were effective in drawing the Luftwaffe's attacks away from legitimate airfields – in 1940 alone 'Q' and 'Starfish' sites received nearly 200 attacks.

Records show that one naval decoy site was located <3.5km to the south-east of the site, at Immingham Range. It was built as part of the "N-Series" of naval decoys to deflect enemy bombing from Royal Navy installations on the Humber estuary. This site operated as both a "Permanent Starfish" and "QL" decoy. The site is referenced as being in use during 1941 and 1942.[9]

In addition to this site, two bombing decoy sites were established further to the north-west of the site, to deflect attention away from the nearby airfields.

The presence of such installations indicates that it was anticipated that the region would receive Luftwaffe attention due to the strategically important targets situated nearby.

8.4.3 WWII-era RAF Aerial Photography

The following WWII-era aerial photography was reviewed for the site:

Date	4th May 1950
Source	Britain From Above
Image Type	Oblique
Image quality	High resolution, small scale, partial coverage
Observations	• The site appears mostly as shown on OS mapping, predominantly comprising vegetated open ground. • The south of the site encompasses part of the railway siding's infrastructure. • The northern extent of the site, located in the river, is not visible on this image. A second photograph was consulted (not annexed[10]), which confirms that this part of the site encroaches into the river. • Throughout the war, this area would have varied in water depth, at times comprising tidal mud / sediment. • No obvious signs of bomb damage are visible within the site boundary. However, the nature of the ground cover means evidence of bombing will not be easily observable. • Two gun battery sites are visible to the south and east.
Reference	**Annex E**

[9]https://www.heritagegateway.org.uk/Gateway/Results_Single.aspx?uid=f1bf76dc-6feb-4409-ae1e-ceb5092ea060&resourceID=19191
[10] https://www.britainfromabove.org.uk/en/image/EAW029090

8.4.4 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 was encountered, Bomb Disposal Officer teams would normally have been requested to attempt to locate, render safe and dispose of the bomb. Occasionally evidence of UXBs was discovered but due to a relatively benign position, access problems or a shortage of resources the UXB could not be exposed and rendered safe. Such an incident may have been recorded and noted as an Abandoned Bomb.

Given the inaccuracy of WWII records and the fact that these bombs were 'abandoned', their locations cannot be considered definitive, nor the lists exhaustive. The MoD states that 'action to make the devices safe would be taken only if it was thought they were unstable'. It should be noted that other than the 'officially' abandoned bombs, there will inevitably be UXBs that were never recorded.

SafeLane Global holds records of officially registered abandoned bombs at or near the site	✖
Additional Comments	n/a

8.5 UXB Ground Penetration

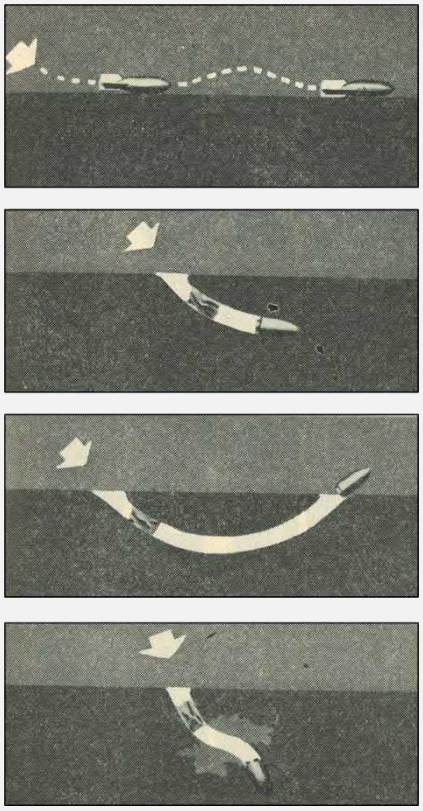
8.5.1 General Considerations

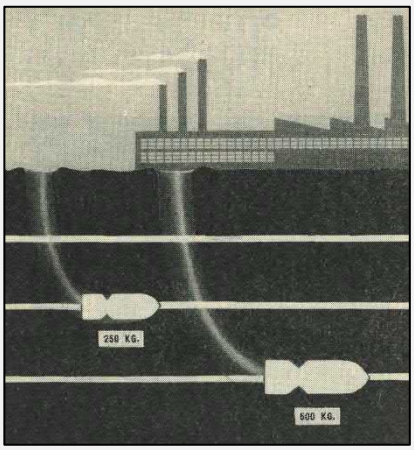
The actual penetration depth of aerial delivered bombs into the ground will have been determined by the mass and shape of the bomb, the velocity and angle of the bomb on impact (dependent on the height of release) and the nature of the ground and ground cover; the softer the ground, the greater the potential penetration. Peat, alluvium and soft clays are easier to penetrate than gravel and sand. Bombs are brought to rest or are commonly deflected by bedrock or large boulders.

8.5.2 The "j" Curve Effect

An air-dropped bomb released from normal bombing altitude (approx. 5,000m) on its curved trajectory can reach a terminal velocity of between 350-400 ms-1. In this case of high-level bombing, the angle of which the bomb enters the earth is approx. 15° from the perpendicular and its exact path is difficult to trace. The bomb is being driven by its kinetic energy can unless deflected, will continue its line of flight and can turn in an upwards curve towards the ground surface as it comes to rest. The upwards curve is caused by the transfer of energy as the bomb travels through the ground. The nose of the bomb travels slower than the rear of the bomb due to the drag/friction of it passing through the ground. The rear of the bomb, having more energy due to less drag/friction is travelling much quicker.

The location of the bomb is thus ''offset'' from the hole of entry. This ''offset'' from vertical is generally understood to be about one third of the penetration depth but can reach up to (and have been found at) 15m/50 ft from point of entry, dependent on ground conditions and the bomb's angle of impact. The figure below depicts the various paths of UXB through homogenous ground, showing how the J-curve effect can lead to a UXB coming to rest beneath undamaged buildings.





A UXB can come to rest beneath undamaged buildings due to the J-Curve effect if it lands in nearby soft ground.

Image source: Field Manual for Unexploded Bombs: Organisation and Operation For Disposal, United States War Department 1943

Left: Path of UXB in soft ground:

1. Ricochet resulting from low level attack: UXB stays perpendicular to ground and rests at surface.
2. Buried UXB with J-Curve: Bomb curves horizontally and rests perpendicular to surface.
3. UXB returning to surface due to J-Curve: Bomb points towards surface but may remain partially or completely below ground level.
4. UXB deflected by buried objects: Results in unpredictable path and unusual shift.

8.5.3 Second World War Bomb Penetration Studies

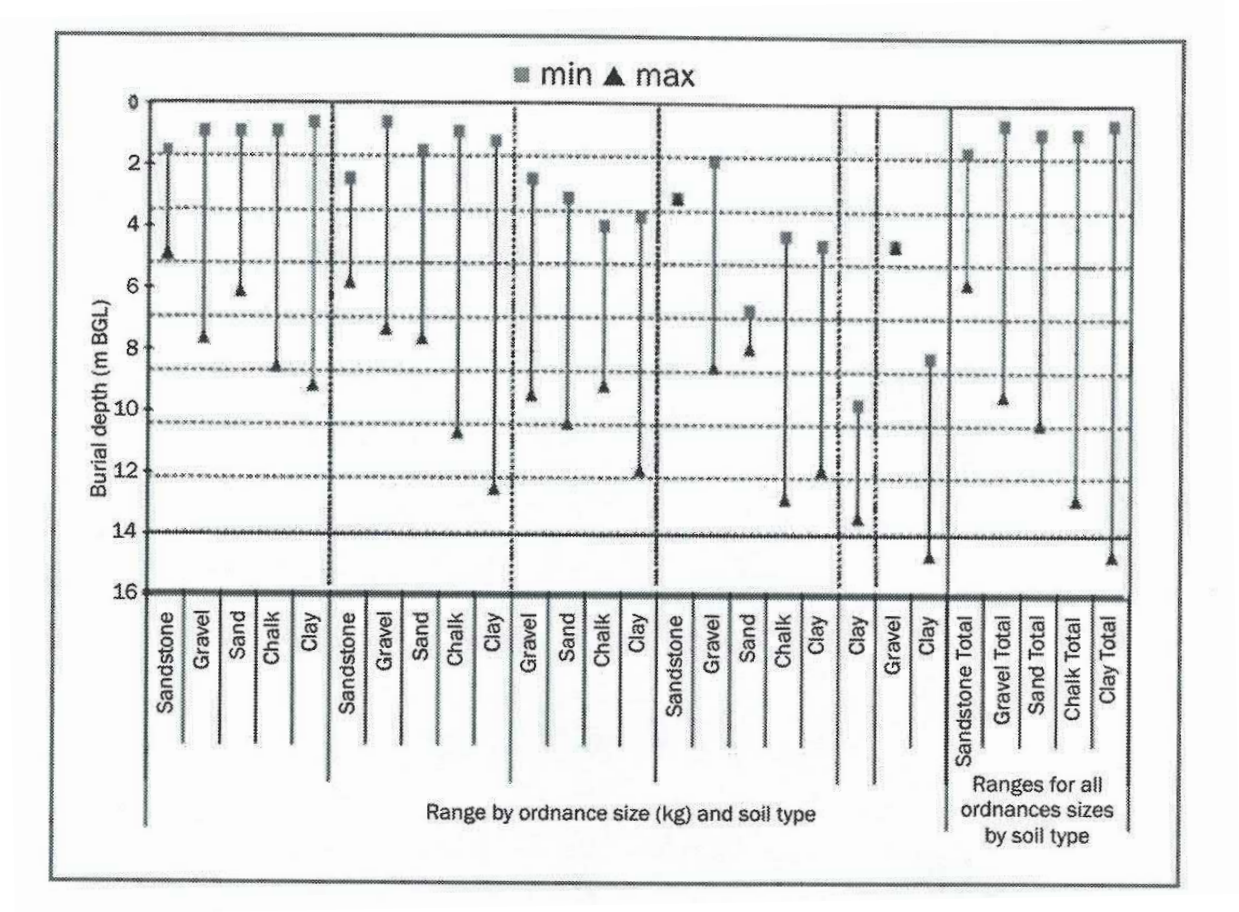
During WWII, the Ministry of Home Security undertook a major study on actual bomb penetration depths, carrying out statistical analysis on the measured depths of 1,328 bombs as reported by Bomb Disposal, mostly in the London area. They then came to conclusions as to the likely average and maximum depths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

The median penetration of 430 x 50kg German bombs in London Clay was 4.6m and the maximum penetration observed for the SC50 bomb was 9m.

They concluded that the largest common German bomb, 500kg, had a likely penetration depth of 6m in sand or gravel but 8.7m in clay. The maximum observed depth for a 500kg bomb was 10.2m and for a 1,000kg bomb 12.7m. Theoretical calculations suggested that significantly greater penetration depths were probable.

8.5.4 CIRIA Bomb Penetration Depth Specifications

As stated within C681, the ground conditions at any individual site are likely to be highly variable and this results in a large range of burial depths for each different size bomb. The below chart shows the observed variation in burial depths of various sizes of air-delivered UXO for different ground conditions.



8.5.5 Site Specific Bomb Penetration Considerations

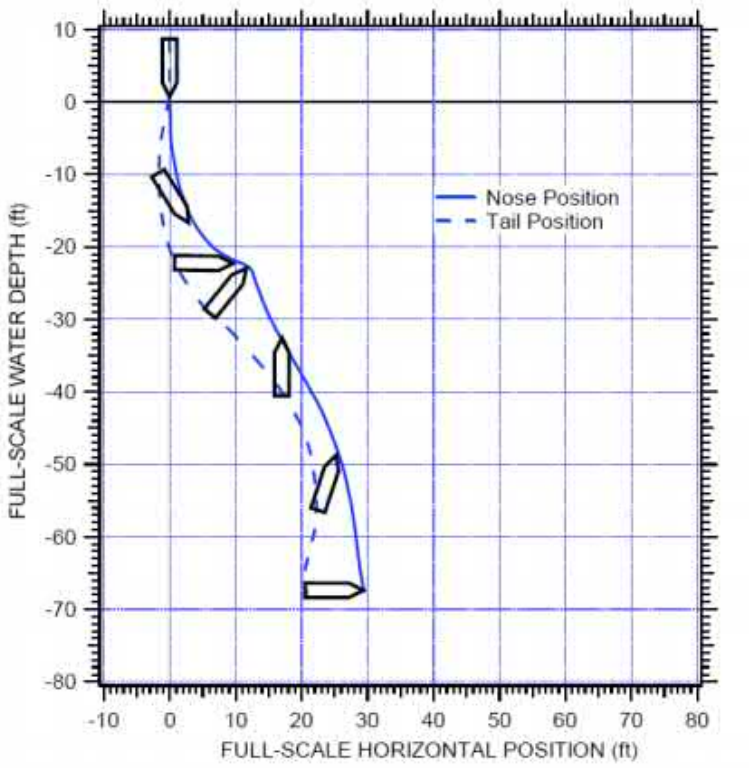
When considering an assessment of the bomb penetration at the site, the following parameters would be used:

- Geology – Tidal Flat Deposits (Clay & Silt – land) and Beach & Tidal Flat Deposits (Clay, Silt & Sand – marine), underlain by Flamborough Chalk Formation bedrock.
- Impact Angle and Velocity – 80-90° from horizontal and 267 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.

Taking into account the above-mentioned factors it has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between 8-10m below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

Within any section of the site occupied by the river, the lowest possible water depth above the locations of the proposed works during WWII will also be considered.

For any part of the site located below the water mark of the lowest mean tide, calculating a maximum bomb penetration assessment is more problematic as the water column produces a decelerating effect that is not easily calculated.



Penetration into the riverbed by bombs with a standard tangent Ogive nosecone is not well predicted as the bomb will deviate from its original path. The velocity at which a bomb is travelling becomes irrelevant in water deeper than several metres because the water has such a decelerating effect that a bomb will essentially "float" down to the seabed, however not necessarily in a vertical orientation; see graph (left) - plotting the trajectory of an American MK-84 (925kg) HE bomb with no tail section into water at an entry velocity of 296m/s.[11]

By approximately 6m water depth the bomb has become fully horizontal and therefore has lost most of its ability to significantly penetrate the bed.

Note, that this 925kg bomb is approximately twice the weight of the 500kg bomb used above. This means that the bomb used in this American experiment struck the water with more force than the vast majority of those deployed over the UK during WWII.

Therefore, where the water depth above the study area exceeds approximately 4m, a 500kg UXB striking the water surface is unlikely to have had the required kinetic energy to achieve complete burial beneath the riverbed.

Further research confirms the following key features:

- Ignoring surface tension there will be an immediate loss of inertia due to rapid energy losses; sound, wave, splash, bubble formation and cavitation.
- The drag force rapidly decelerates the bomb. If there is sufficient water depth then acceleration will become 0m/s2 and the terminal velocity in water will be achieved; 11m/s.
- Once the terminal velocity in water is reached the bomb impacts the riverbed as a free-fall penetrator.

Analysis of the air-water-soil regime is complex and difficult to measure. The current model assumes that 5m of water column is required in order to achieve the terminal velocity of a German WWII HE UXB in water. Impacts at this speed will cause a riverbed sediment penetration of 2.3m, assuming a bearing capacity of 75kPa.[12]

[11] P. Gefken, Underwater Bomb Trajectory Prediction for Stand-off Assault (Mine/IED) Breaching Weapon Fuse Improvement (SOABWFI), 2006

[12] *Department of The US Army., TM 5-855-1 Fundamentals of Protective Design for Conventional Weapons, 1986*

8.6 Likelihood of Post-raid UXO Detection

Utilising the available historical bombing records as reviewed in Section 8.4, it is possible to make an assessment of the likelihood that evidence of UXO would have been noted on a site during the war and the incident dealt with or recorded at the time. Factors such as bombing density, frequency of access, ground cover, damage and failure rate have been taken into consideration.

8.6.1 Density of Bombing

Bombing density is an important consideration for assessing the possibility that UXBs remain in an area. A very high density of bombs will have increased the likelihood of errors in record keeping at the time, as civil defence personnel and emergency services may have been overwhelmed. A higher density of bombing also increases the number of UXBs actually occurring in a given area.

The type and specific location of recorded bomb strikes is also an important consideration. If a stick of bombs (one individual aircraft's bomb load) is plotted in line with a site or is shown to straddle a site, then this raises the possibility that an unrecorded UXB from the same stick struck that site.

8.6.2 Bomb Damage

In Blitzed cities / towns throughout Britain, bomb sites were often not cleared of rubble until after the war and mid-war repairs to buildings were only carried out on the most vital facilities (power stations, gas works, weapons factories etc.). However, if a building only sustained bomb damage to its upper floors, any subsequent UXB strike to the structure will still have caused obvious damage, at ground floor level, which would have been reported and dealt with at the time.

HE bomb strikes to open ground will have resulted in a large crater and local soil disturbance. Any subsequent UXB strike will not have resulted in an easily identifiable entry hole and as such is likely to have gone unnoticed amongst the disturbed ground.

In London and south-east England, the German V1 Flying Bomb and V2 Long Range Rocket campaigns caused widespread devastation. However, as these weapons began to be utilised after the final significant Luftwaffe air raids had occurred, any serious damage caused by such weapons does not necessarily indicate an increased risk of Luftwaffe freefall UXB contamination. However, it is quite possible that serious damage inflicted during the 1940-1944 campaigns by Luftwaffe freefall bombs could have been erased by a subsequent V Weapon strike.

8.6.3 Frequency of Access

A UXB strike at a site where human access was infrequent would have had a lower chance of being observed, reported and recorded compared to a site which was developed and subject to regular access. UXB strikes during night-time raids (when German planes could more easily evade anti-aircraft defences) are also more likely to have fallen unobserved than ones dropped during a daylight attack.

In frequently bombed cities / towns, ARP Wardens were tasked with carrying out searches for UXBs within recently bombed residential areas and schools. Similarly, many important home front facilities (factories, gas works, power stations, docks etc.) had their own dedicated ARP teams or Fire Watchers tasked with observing local air raids. Fire Watchers were mainly responsible for extinguishing 1kg incendiary bombs as well as reporting any UXB strikes. Anecdotal evidence however indicates that Fire Watchers did not always turn up for their shifts and therefore such UXB mitigating activities should not be assumed in the absence of site-specific evidence. Less important buildings sustaining bomb damage would have been abandoned until after the German bombing campaign in that area had ceased and repairs could be made, greatly decreasing the level of access to that site.

Schools closed due to the evacuation of children were often requisitioned by the Civil Defence authorities to be utilised as night time First Aid posts and reception centres (providing emergency accommodation for bombed out civilians). Therefore, an increased level of access is likely at these locations.

8.6.4 Ground Cover

The entry hole of a 50kg UXB (the most commonly deployed German HE bomb) could have been as little as 20cm in diameter. Wartime records also confirm that small German Incendiary Bombs, weighing just 1kg, were capable of significant penetration into soil, resulting in very small entry holes (5cm) or complete burial.

The quantity and type of ground cover present on a site during WWII would have had a significant effect, at ground level, on the visual evidence of buried UXO.

Evidence of UXO could be obscured in dense vegetation, soft ground, rubble, railway ballast or amongst stockpiled material (such as aggregate, coal or refuse heaps). A UXB strike to waterlogged ground or open water would have been immediately obscured from view beneath the waterline. Had such an incident occurred within a tidal mudflat or riverbank, the resulting entry hole will have remained only temporarily, before becoming in-filled by water and sediment. Any HE UXB strike to elevated risk ground cover could potentially have come to rest beneath neighbouring undamaged buildings or hard-standing due to the 'J-Curve' Effect.

UXB strikes to undamaged/superficially damaged buildings and hard-surfaced ground will still have caused substantial damage or an easily identifiable and persistent entry hole. Similarly, it is unlikely that an HE UXB entry hole on well-maintained / manicured lawns (tennis courts, bowling greens, golf course fairways / greens, gardens in affluent areas etc), would have been overlooked. Such incidents would have been reported and the UXB subsequently removed.

8.6.5 German Air-Delivered Ordnance Failure Rate

Based on empirical evidence, it is generally accepted that 10% of the German HE bombs dropped during WWII failed to explode as designed. This estimate is probably 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 and is probably an underestimate.

The reasons for failures include:

- Fuze or gaine malfunction due to manufacturing fault, sabotage (by forced labour) or faulty installation.
- Clockwork mechanism failure in delayed action bombs.
- Failure of the bomber aircraft to arm the bombs (charge the electrical condensers which supplied the energy to initiate the detonation sequence) 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 50kg 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, UXO is still regularly encountered across the UK.

Note, due to manufacturing fault or failure of the bomber crew to correctly arm their munitions, whole bomb loads often failed to detonate. Therefore, the presence of reported UXBs increases the likelihood of an additional unrecorded UXB in the vicinity.

8.6.6 Site Specific Analysis

The following table will place the site in context with these factors, in order to assess the likelihood of post-raid UXO detection within the project site.

Likelihood of Post Raid UXO Detection on Site			
Site-Specific Factors			**Additional Comments**
Density of Bombing Assessment	Based on wartime records or secondary source information, what was the bombing density over the site?	Low	The overall bombing density for Grimsby Rural District was low, however, the site's location within the dock and railway infrastructure, the localised bombing density is likely to be respectively higher.
	Was the site ever subjected to one or more large-scale (>100 tons of ordnance) night time Blitz raids?	✘	
	Were any HE bomb strikes recorded on site?	✓	Anecdotal evidence records bombing to the railway sidings and the dock areas. As such, it is likely that at least 1 HE bomb landed within the site boundary.
	How many HE, Parachute Mine, Oil Incendiary, Phosphorus Incendiary or Fire Pot bombs (large bombs) were recorded within a 300m radius of the site?	n/k	Precise and accurate site-specific bombing records are unavailable for the site. However, it is likely that multiple bombs over multiple raids had fallen within 300m of the site.
	Were any nearby sticks of large bombs recorded in line with the site?	✓	The aforementioned bombing incidents will have incorporated at least 1 stick of bombs in line with the site.
	Were any 1kg incendiary bomb showers recorded over the site?	✘	No records found
Bomb Damage Assessment	A comparison of the historical records confirms that buildings within the site boundary sustained serious bomb damage.	✘	The site contained only very few buildings, recording no evidence of significant damage. However, potential damage has been recorded to some of the surrounding buildings, and the dock was

			recorded to have sustained a level of bomb damage.
	Direct or indirect evidence of HE bomb craters in open ground (within the site boundary) has been found.	✘	
	Buildings on site were seriously damaged by a V1 and / or V2 strike.	✘	
	Buildings on site could have been seriously damaged prior to the nearby V1 or V2 strike?	n/a	
Frequency of Access Assessment	The site was situated in a densely populated urban area during WWII and therefore would have been accessed at the outbreak of WWII.	✘	A large proportion of the site comprised water, vegetated open ground and open pasture during WWII.
	The site was exclusively or partially developed during WWII.	✓	The south of the site contained railway lines and sidings.
	Buildings on site survived WWII intact and therefore likely remained inhabited or in use, suggesting these localities and their immediate environs were accessed throughout the war.	✓	No damage recorded to the small building in the south-east.
	The site was crossed by roads / pavements or footpaths which would have been regularly used / subject to daily footfall.	✘	The site was crossed by a number of railway lines which are likely to have been regularly used.
	The site was occupied by small residential back yards / gardens, likely to have been put to use for cultivation as a result of the government's Dig for Victory Campaign.	✘	
	The site was occupied by a school during WWII.	✘	
	Part of the site is likely to have been subject to post-raid searches for UXO.	✓	The railway lines are likely to have been checked for buckling or direct bomb damage, however the surrounding ballast or soft ground is not.
	Buildings on site sustained serious bomb damage and as a result were likely abandoned (along with any associated gardens / open ground) for the remainder of the war.	✘	
	The site was occupied by peripheral open ground / wasteland, with no apparent use, which may have been neglected.	✓	

	The site may have been occupied by recreational land / sports fields which may have only experienced seasonal access.	✖	
	The site was occupied by a graveyard which would have experienced limited access.	✖	
	The site was occupied by agricultural land, rural countryside or woodland which would not have been accessed in full, either regularly or frequently.	✓	
	The site was occupied by railway sidings which may not have been as regularly checked for buckling as mainline railway tracks.	✓	
	The site was occupied by soft railway embankments which are likely to have been neglected during the war.	✓	
Ground Cover Assessment	The site was partially or entirely abandoned, due to bomb damage, resulting in associated open ground likely becoming overgrown.	✖	
	The site was occupied by dense, inaccessible vegetation during WWII.	✓	A large proportion of the site was occupied by vegetated open ground, the densest of which was located in the south-eastern extent.
	The site may have been susceptible to waterlogged conditions during WWII.	✓	The open ground may have been susceptible to flooding or saturation.
	The site was occupied by (possibly) unmaintained grass field during WWII.	✓	
	The site was part occupied by a canal, river, dock basin, lake or reservoir during WWII.	✓	
	The site was occupied by tidal mud or marshland during WWII.	✓	
	The site was occupied by railway tracks crossing soft ground during WWII.	✓	
	The site was occupied by stockpiled material during WWII.	✓	Parts of the site are likely to have been used for stockpiling materials.
	The site was occupied by buildings, hard-standing or other manmade structures that did not sustain any degree of bomb damage.	✓	

	A comparison of the historical records confirms that buildings on site sustained inconsequential minor / moderate damage.	✖	
	The site was occupied by well-maintained, manicured lawn during WWII.	✖	
	Undamaged, developed parts of the site would have been vulnerable to the J-Curve Effect.	✓	
Bomb Failure Rate	Evidence has been found which suggests that the bomb failure rate in the vicinity of the site would have been different from the "approximately 10%" figure normally used.	✖	

9 The Threat from Allied Military Ordnance

The following potential historical and modern sources of UXO contamination on site or in the surrounding area have been considered:

Potential Source of Contamination on Site	
Army, Navy and RAF Bases / Installations	✓
Military Training Areas / Weapons Ranges	✓
Ordnance / Explosives Factories and Storage Depots	✗
Sites Requisitioned for Military Use	✓
Sites Used or Occupied by the Home Guard	✓
Military Fortifications and Coastal Defences	✓
Locations of Army Explosive Ordnance Clearance Tasks	✗
WWII Anti-Aircraft Batteries	✓
WWII Pipe Mined Locations and Beach Minefields	✗

The risk of contamination from Allied UXO on site is discussed below.

9.1 WWI Military Activity at Immingham

During WWI, Immingham was a submarine base for the British D-class submarines. As such, the port area was used extensively for WWI operations. Due to the port's importance, it was defended by anti-aircraft gun emplacements, and the area was targeted by the German air force.

Immingham was set up before WWI as a Balloon Station by the Royal Naval Air Service. Tethered kite balloons were trailed from convoy escort ships, taking observers aloft in a wicker basket to around 3000ft to watch for sea mines, torpedo tracks and submarines.

In addition to the primary ballooning role, some aircraft were based here, such as the 154 DFW Military Arrow Biplane. Limited numbers of airship operations were also conducted from Immingham during the war. On 1st April 1918, the RAF assumed command and was known as Number 8 Balloon Station until its closure.[13]

[13] https://imminghamheritage.co.uk/about/immingham-in-the-1900s/

9.2 WWII Military Activity at Immingham

9.2.1 Home Guard Activity

The Home Guard (HG) was a defence organisation of the British Army, operational between 1940 and 1944. It comprised 1.5 million local volunteers, otherwise ineligible for military service and acted as a secondary defence force in case of enemy invasion. The HG guarded the coastal areas of Britain and other important facilities such as airfields, factories and explosives stores. They were also active in county towns and cities.

Official records were rarely kept by the HG and therefore any present-day evidence is usually anecdotal. However, it is known that HG personnel often carried out training (including weapons training) in open countryside on the outskirts of cities / towns. Today, items of ordnance related to the HG are occasionally encountered by members of the public and the construction industry in the British countryside. This suggests a culture of ill-discipline regarding live ammunition within HG units.

HG personnel are known to have purposefully buried caches of ammunition and weapons in tactical positions, to be exhumed and used in case of invasion. Records of such caches were not rigorously kept, and some were therefore forgotten about. This is substantiated by several HG UXO finds over recent years. The below table shows just a handful of examples:[14]

Home Guard UXO Finds:	
	Unexploded Spigot Mortar Round, used by the Home Guard in WWII, found and disposed of in Hayle, Cornwall – January 2021
	24 x WWII grenades found buried in a field in Sibton, Suffolk – May 2019

[14] Various News Sources

	A cache of 80 phosphorous grenades buried by the Home Guard found in Eastbourne – September 2015
	Home Guard Phosphorous Grenades found buried beneath a bridge in Herne Bay – July 2015

9.2.2 Coastal Defence and Defensive Fortifications

The English coastline, particularly in the south and east, underwent a significant change with the introduction of anti-invasion fortifications and defences. The more easily accessible landing points were therefore designated for the highest level of defences.

Pivotal locations all across Britain were designated as Nodal Points, and defensive stop lines were installed across the country in preparation for an invasion.

Many of these locations were typically fortified with pillboxes, defence huts, trenches, weapons / ammunition caches. Pillboxes were small brick or concrete built structures, strategically placed to cover angles of likely attack and designed to provide a machine gun team with protection.

During the period when the threat of enemy invasion was high, such positions would have been manned by armed troops and therefore the likelihood of UXO contamination is locally higher at these places.

9.2.3 Soldier Accommodation

During WWII Army, Royal Marine and Home Guard detachments were temporarily accommodated at sites requisitioned by the military for training and / or defence purposes. Soldiers could face serious disciplinary action if found to have misplaced ammunition, therefore it was not uncommon historically for troops to hoard extra items of ammunition to make up for any lost during exercises. Once these surplus items became redundant, they were often buried or hidden.

This is substantiated by anecdotal evidence, for example, a grenade was found in an accommodation block drainpipe within the Rowcroft Barracks (Ashford, Kent). Also, whilst SafeLane Global carried out EOD clearance works at Church Crookham Barracks near Fleet, a search and clear dog team

sent into a disused barracks building discovered a grenade. In 2003, SafeLane Global encountered a grenade hidden in the roofing of another disused barrack block at Colchester Garrison. Thus, such a scenario cannot be discounted.

9.2.4 Anti-Aircraft Gun Batteries

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) and Light Anti-Aircraft Artillery (LAA). The LAA batteries were intended to engage fast low flying aircraft and were typically deployed around airfields or strategic installations. These batteries were mobile and could be moved to new positions with relative ease when required. With four guns per battery firing several rounds per minute, AA batteries could expel numerous shells in even the shortest engagements. Numerous unexploded AAA shells were recovered during and following WWII and are still occasionally encountered on sites today.

The maximum ceiling height of fire at that time was around 11,000m however, as the war progressed, improved variants of the 3.7" gun were introduced and, from 1942, large 5.25-inch weapons were brought into service. These had significantly improved ceiling heights of fire reaching over 18,000m.

When the supply of clockwork fuses from Switzerland was cut off, Britain was forced to make its own. After four years of war, the country still lacked the engineering skills to produce a reliable fuse. This resulted in a considerable number of AA projectiles exploding prematurely, killing the gunners or failing to explode at all and falling to the ground as UXBs. In January 1944, more people in London were killed by HAA shells than by German bombs.

9.3 Site-Specific Threat from Allied Military Ordnance

The following table identifies the potential threat to the site of contamination from British / Allied UXO.

Potential Source	Details
Nearest Home Guard Battalion to the site	7th Lindsey (Grimsby Rural) Battalion
Home Guard Activity on site	• No evidence of Home Guard activity on site has been found. • However, it is possible that Home Guard personnel may have been active in the general Immingham Dock area, for patrols, training, or manning the nearby defences. • As such, it cannot be entirely discounted that such activity may have occurred within the project site.
Defensive features within the vicinity	• WWI-era Pillbox (~1.3km south-east) • Coast Artillery Searchlight (~ 1.4km south-east) • Coast Battery (~1.4km south-east) • The 'G' Flight HQ was based in Grimsby and barrage balloons were based around Immingham (Skitter Road) and to the east of the Admiralty Oil Tanks near

	Immingham, Chase Hill Farm and Brickyard Lane. Also, floating barrage balloons were raised on vessels in the Humber, close to Sunk Island.[15]
Troop Accommodation on site	• Post-WWII aerial photography of the Immingham Docks identifies a WWII-era US Army Camp located approximately 250m to the west of the site. Troops will have been accommodated here during wartime, and as such it is likely that training exercises will have occurred in the surrounding area. • No evidence of soldier accommodation specifically within the project site boundary has been found.
Ordnance use, storage and disposal on site	• During both WWI and WWII, the general Immingham Dock area was home to military personnel. As such, the presence of armed navy and army personnel cannot be disregarded on site and in the surrounding area. • The presence of a nearby military camp indicates that training exercises may have occurred within or near to the project site. The unused, open ground adjacent to the camp itself may have presented an ideal location to conduct training exercises. However, although such a scenario cannot be discounted, no evidence of such activity has been found. • During WWII, it is likely that a range of ordnance and ammunition could have been stored near to the site, relating to the nearby military camp. While no plan of the military camp adjacent to the site has been located, it is likely that ammunition storage will have been located within the facility. No evidence of storage structures has been found within the project site boundary. • Anecdotal accounts suggest that faulty or surplus ordnance / ammunition on WWII military sites would often be burnt, buried or otherwise disposed of locally. In many cases, designated burning pits were located at peripheral open ground within with site perimeter. • It is possible that ordnance disposal could have occurred within the vicinity of the project site, as the open ground and peripheral locations within the north of the project site would have been ideal conditions to bury or burn unwanted munitions. • However, no evidence of such activity has been found. • Furthermore, the camp was located adjacent to the River Humber. Often, rivers, docks and other bodies of water near to military camps offered a quick and easy unofficial method of disposal to the military personnel. Hundreds of items of small arms and land service ammunition are found across Britain's waterways every year due to this very reason. As such, the possibility that surplus, faulty or unwanted items of ammunition may have been discarded into the marine section of the site during military occupation in the area. • Had such a scenario occurred along this part of the Humber, it is also possible that items could have then migrated with the river's current into or out of the site boundary itself.
Number of HAA batteries within 5km of the site	9

[15] https://nlahcentre.com/baloons-and-aa-sites-around-humber/

Threat to the site from unexploded AA shells	• HAA battery from WWI, armed with 2 x 1-pounder guns on travelling carriages in 1916, and a 12-pounder gun in 1917. This was located approx. 1.4km south of the site. • HAA Battery Number H21, located less than 300m east of the site. This was reportedly unarmed in 1941.[16] • HAA Battery Number H22, located on site. This battery was listed as unarmed in 1941.[17] • HAA Battery Humber L, a WWII HAA battery at Homestead Park (>1km west of the site). This was manned by 270 Battery of the 91st Royal Artillery Regiment.[18] • In addition to the aforementioned HAA batteries, 111 LAA Battery was based at Immingham.[19] These were at first manned by the army, but from circa 1942, they were manned by the Home Guard. • A photograph, dated circa 1940s, is presented in **Annex F**. This shows anti-aircraft gunnery training in Immingham. • Had an unexploded AA shell landed in the parts of the site occupied by the river, it would have been immediately obscured beneath the waterline. If it had landed within the tidal mud, it is unlikely to have resulted in a persistent entry hole, and would have been quickly infilled by the soft, mobile surrounding sediment. Following such a scenario, the item could easily have been left undiscovered. • Had an unexploded AA shell landed within the parts of the site occupied by unused, soft, open ground, ballast, or vegetation, it could have been left unnoticed. • However, had such an item landed directly onto railway tracks, undamaged buildings, or any other undamaged man-made structures, it could have caused significant damage which is more likely to have been noticed and dealt with at the time.

[16]https://www.heritagegateway.org.uk/Gateway/Results_Single.aspx?uid=41818b45-da86-42d2-bcf9-8811a890b3b2&resourceID=19191
[17]https://www.heritagegateway.org.uk/Gateway/Results_Single.aspx?uid=a94ce491-1067-44a1-ac1d-ce6d16bf71cd&resourceID=19191
[18]https://www.heritagegateway.org.uk/Gateway/Results_Single.aspx?uid=f74fe2de-27dd-4c0d-8adc-3c1cbe4caaf5&resourceID=19191
[19] https://nlahcentre.com/baloons-and-aa-sites-around-humber/

9.4 Generic Types of WWII British / Allied Unexploded Ordnance

9.4.1 Land Service Ammunition (LSA)

9.4.1.1 General

The term Land Service Ammunition covers all items of ordnance that are propelled, placed or thrown during land warfare. They may be filled or charged with explosives, smoke, incendiary or pyrotechnics. They can be broken into five main groups:

i. Mortars
ii. Grenades
iii. Projectiles
iv. Rockets
v. Landmines

Unexploded or partially unexploded Mortars and Grenades are among the most common items of UXO encountered in the UK. They are commonly encountered in areas used by the military for training and are often found discarded on or near historic military bases.

9.4.1.2 Mortars

A mortar bomb is a fin-stabilised munition, normally nose-fuzed and fitted with its own propelling charge (primary cartridge). Range is increased by adding extra propellant (augmenting charges). They are either HE or Carrier and generally identified by their tear-dropped shape (older variants however are parallel sided) and a finned 'spigot tube' screwed or welded to the rear end of the body housing the propellant charge.

A mortar relies on a striker hitting a detonator for explosion to occur. It is possible that the striker may already be in contact with the detonator and that only a slight increase in pressure would be required for initiation. Discarded augmenting charges are often encountered around mortar firing areas/bases.

Typical 2" High Explosive Mortar

Weight: 1.02kg (2.25lb)

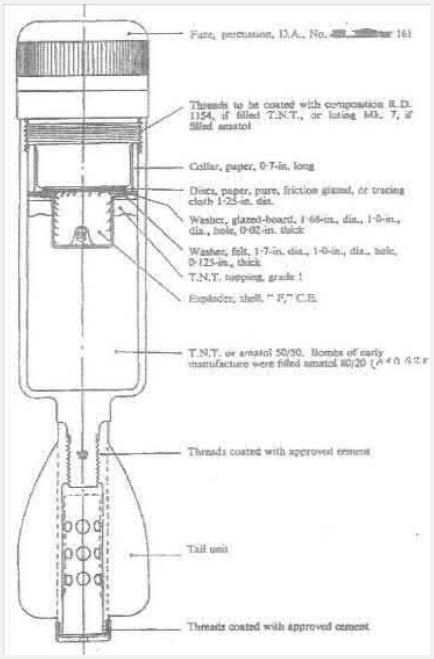
Type: High Explosive

Dimensions: 51 x 290mm (2in x 11.4in)

Filling: 200g RDX/TNT

Maximum Range: 457m (500yds)

Remarks: Fitted with an impact fuze which detonates the fuze booster charge (exploder) and, in turn, the high explosive charge. The main charge shatters the mortar bomb body, producing near optimum fragmentation and blast effect at the target.



Typical 3" Smoke Mortar

Type: Smoke

Dimensions: c.490 x 76mm (19.3in x 3in)

Filling: Typically white phosphorous

Maximum Range: 2515m (2,750yds)

Remarks: On impact, the fuze functions and initiates the bursting charge. The bursting charge ruptures the mortar bomb body and disperses the white phosphorous filler. The white phosphorous produces smoke upon exposure to the air.

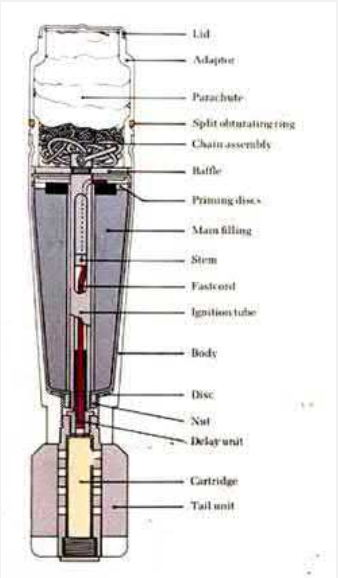
Typical 2" Illuminating Mortar

Type: Illuminating

Dimensions: 51 x 290mm

Filling: Various

Remarks: The expulsion charge ignites and ejects the candle assembly. A spring ejects the parachute from the tail cone. The parachute opens, slowing the descent of the burning candle which illuminates the target



9.4.1.3 Grenades

A grenade is a short-range weapon which may be thrown by hand, fired from the end of a rifle or projected/propelled from a special purpose grenade launcher. They are divided into two categories; HE and Carrier (generally smoke). As with mortars, a grenade striker may either be in contact with the detonator or still be retained by a spring under tension, and therefore shock may cause it to function. A grenade can have an explosive range of 15-20m. Common older variants have a classic 'pineapple' shape; modern grenades tend to be smooth-sided.

No. 36 "Mills" Grenade

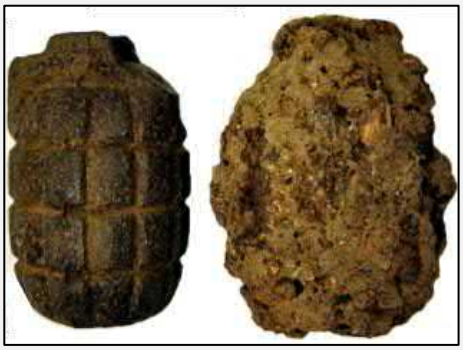
Weight: 0.7kg filled (1lb 6oz)

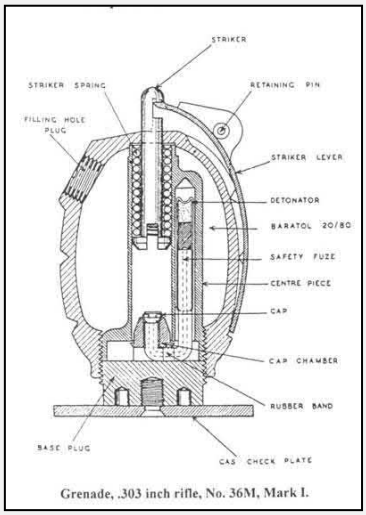
Type: Hand or discharger, fragmentation

Dimensions: 95 x 61mm (3.7 x 2.4in)

Filling: Alumatol, Amatol 2 or TNT

Remarks: 4 second hand-throwing fuze with approximate range of 30m





Grenade, .303 inch rifle, No. 36M, Mark I.

No. 69 Grenade

Weight: 0.38kg filled (0.8lb)

Type: Percussion / Blast

Date Introduced: December 1940

Remarks: Black Bakelite body. Blast rather than fragmentation type. After unscrewing the safety cap, a tape is held when throwing the grenade releasing the safety bolt in the throwing motion. Detection is problematic due to it's very low metal content.

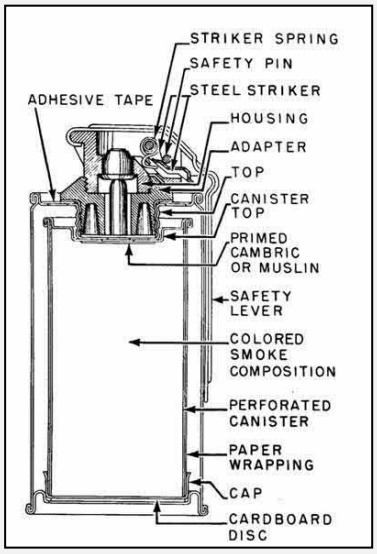
Typical Smoke Grenade

Dimensions: Approx. 65 x 115mm (2.5 x 4.5in)

Type: Smoke

Date Introduced: Current MoD issue

Remarks: Smoke grenades are used as ground-to-ground or ground-to-air signalling devices, target or landing zone marking devices, and screening devices for unit movement.

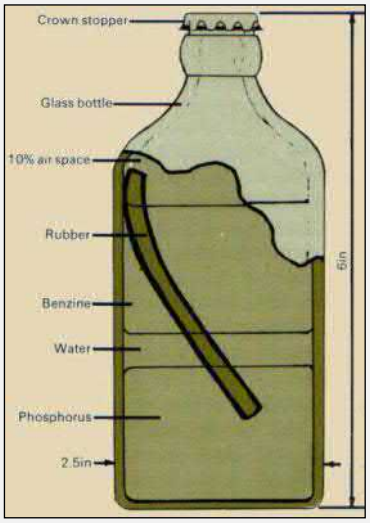


9.4.1.4 Examples of Home Guard Weapons

The following figures show examples of common ordnance used by the Home Guard for defensive purposes in WWII.

Self Igniting Phosphorous (SIP) Grenades

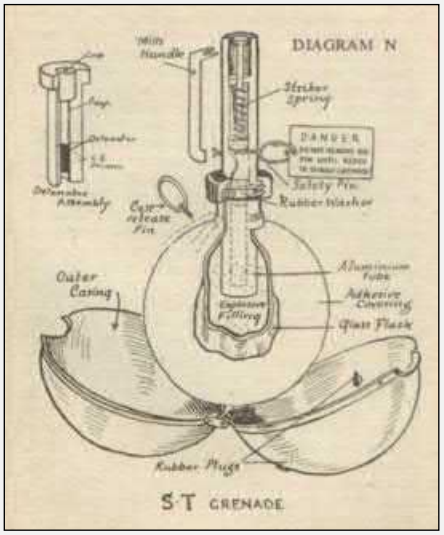
The grenade comprised a glass bottle with a total volume of approximately 1 pint. It was filled with White Phosphorous, benzene, a piece of rubber and water. Over time, the rubber dissolved to create a sticky fluid which would self-ignite when the bottle broke. Fired by hand or Northover Projector.

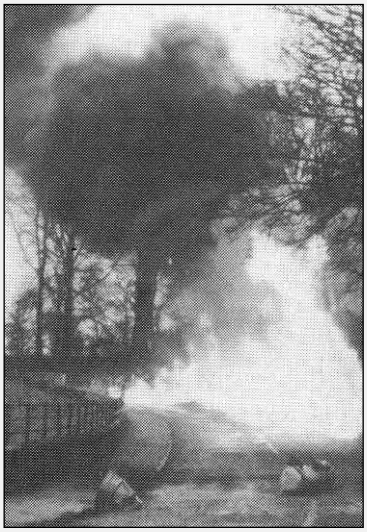


Sometimes called the "A & W" (Albright & Wilson) grenade.

No 74 Grenade (Sticky Bomb)

Designed as an anti-tank grenade and used by the Home Guard. The grenade consisted of a glass ball on the end of a Bakelite (plastic) handle. Inside the glass ball was an explosive filling whilst on the outside was a very sticky adhesive covering. Until used, this adhesive covering was encased in a metal outer casing.





Flame Fougasse Bomb

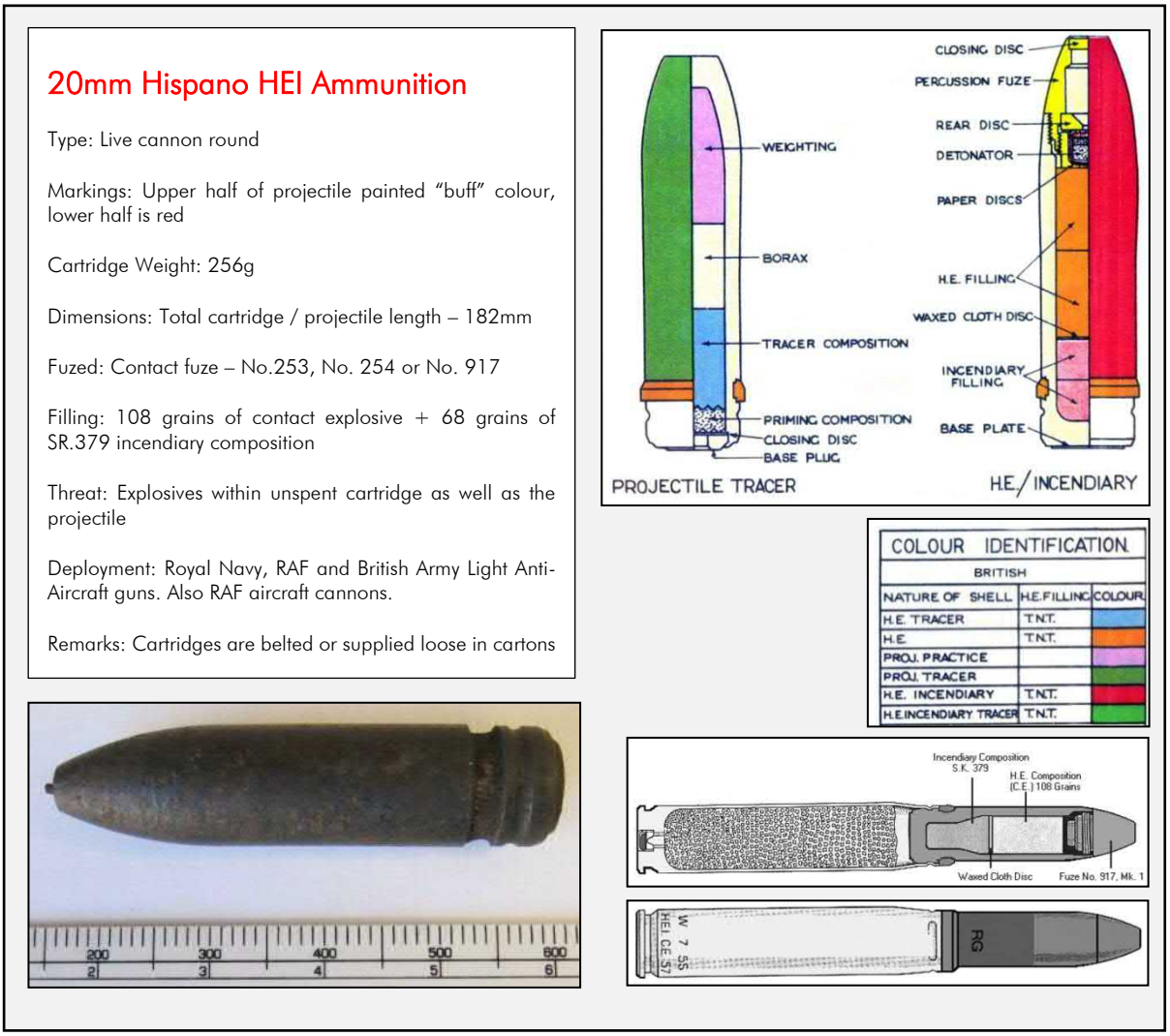
A Flame Fougasse was a weapon in which the projectile was a flammable liquid, typically a mixture of petrol and oil. It was usually constructed from a 40-gallon drum dug into the roadside and camouflaged. Ammonal provided the propellant charge which, when triggered, caused the weapon to shoot a flame 3m (10ft) wide and 27m (30 yards) long. Initially, a mixture of 40% petrol and 60% gas oi was used. This was later replaced by an adhesive gel of tar, lime and petrol known as 5B.

9.4.2 Small Arms Ammunition (SAA)

The most likely type of ordnance to be encountered on site are items of SAA (bullets), especially .303" ammunition which was the standard British and Commonwealth military cartridge from 1889 until the 1950s.

However even if an item such as this functioned, the explosion would not be contained within a barrel and detonation would only result in local overpressure and very minor fragmentation from the cartridge case.

Some LAA guns and RAF fighter cannons in use with British forces during WWII utilised the 20mm round. These bullets had a small fuse and a ~4gram HE or incendiary charge. Although small, this fill quantity still has the potential to cause serious injury.



.303" Ammunition

Type: Rifle / machine gun round

Markings: Regular round – none. Tracer round – red primer

Bullet Weight: 150 – 180g

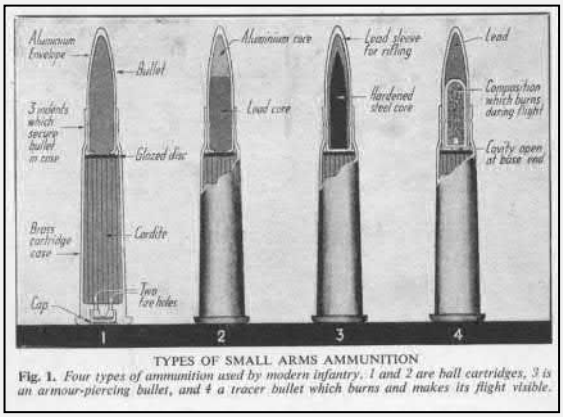
Dimensions: Total cartridge / projectile length – 182mm

Filling: Regular round – none. Tracer round – small incendiary fill

Threat: Explosive cordite within unspent cartridge

Deployment: Royal Navy, RAF and British Army Light Anti-Aircraft guns, machine guns and rifles. Standard British and Commonwealth military cartridge from 1889 until the end of the 1950s.

Remarks: Cartridges are belted or supplied loose in cartons



TYPES OF SMALL ARMS AMMUNITION

Fig. 1. *Four types of ammunition used by modern infantry. 1 and 2 are ball cartridges, 3 is an armour-piercing bullet, and 4 a tracer bullet which burns and makes its flight visible.*

9.4.3 Anti-Aircraft Shells

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) using large calibre weapons such as the 3.7" QF (Quick Firing) gun and Light Anti-Aircraft Artillery (LAA) using smaller calibre weapons such as 40mm Bofors gun which could fire up to 120 x 40mm HE shells per minute to over 1,800m. During the early war period there was a severe shortage of AAA so older WWI 3" and modified naval 4.5" guns were also deployed.

These shells are frequently mistakenly identified as small German air-delivered bombs but are differentiated by the copper driving band found in front of the base. Although the larger unexploded projectiles could enter the ground, they did not have great penetration ability and are therefore likely to be found close to WWII ground level. With a HE fill and fragmentation hazard these items of UXO also present a significant risk if encountered.

The smaller 40mm projectiles are similar in appearance and effect to small arms ammunition and, although still dangerous, present a lower risk. Details of the most commonly deployed WWII AAA projectiles are shown below:

Gun type	Calibre	Shell Dimensions	Shell Weight	HE Fill Weight
3.7 Inch	94mm	94mm x 438mm	12.7kg	1.1kg
4.5 Inch	114mm	114mm x 578mm	24.7kg	1.7kg
40mm	40mm	40mm x 311mm	0.84kg	70g

3.7" Anti-Aircraft Projectile

Weight: 12.7kg (28lb)

Dimensions: 94 x 360mm (3.7 x 14.7in)

Carriage: Mobile and static versions

Rate of Fire: 10-20 rounds per minute

Ceiling: 9,000 – 18,000m (29,000-59,000ft)

Muzzle Velocity: 72m/s

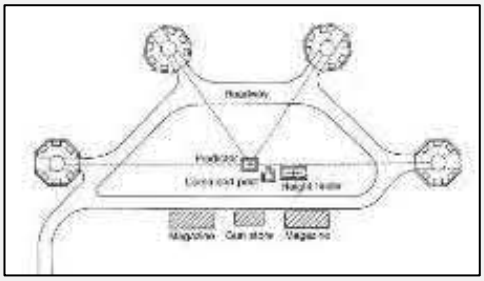
Remarks: 4.5" projectiles were also commonly utilised

Above: 3.7 inch AA Projectile, Minus Fuze.

Left: This AA shell was uncovered on a construction site in North London in February

Left: Layout plan for a typical HAA battery site.

Right: Hyde Park 1939 3.7" QF gun on mobile mounting



Home Guard soldiers load an anti-aircraft rocket at a 'Z' Battery.

Rocket Battery in action.

Rockets / Un-rotating Projectiles

Weight: (Overall) 24.5kg (54lb)

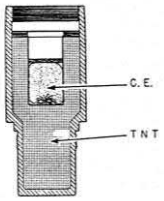
Warhead: 1.94kg (4.28lb)

Dimensions: 1930mm x 82.6mm (76 x 3.25in)

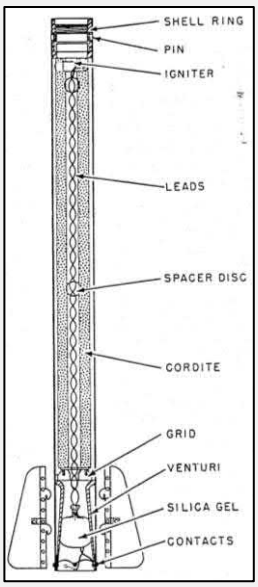
Carriage: Mobile – transported on trailers

Ceiling: 6770m (22,200ft)

Maximum Velocity: 457m/s



MK II HE Shell (3.5kg).



2" U.P AA Rocket.

40mm Bofors Gun Projectile

Weight: 0.86kg (1.96lb)

Dimensions: 40mm x 310mm (1.6in x 12.2in)

Rate of Fire: 120 rounds per minute

Ceiling: 7,000m (23,000ft)

Muzzle Velocity: 881m/s (2,890ft)

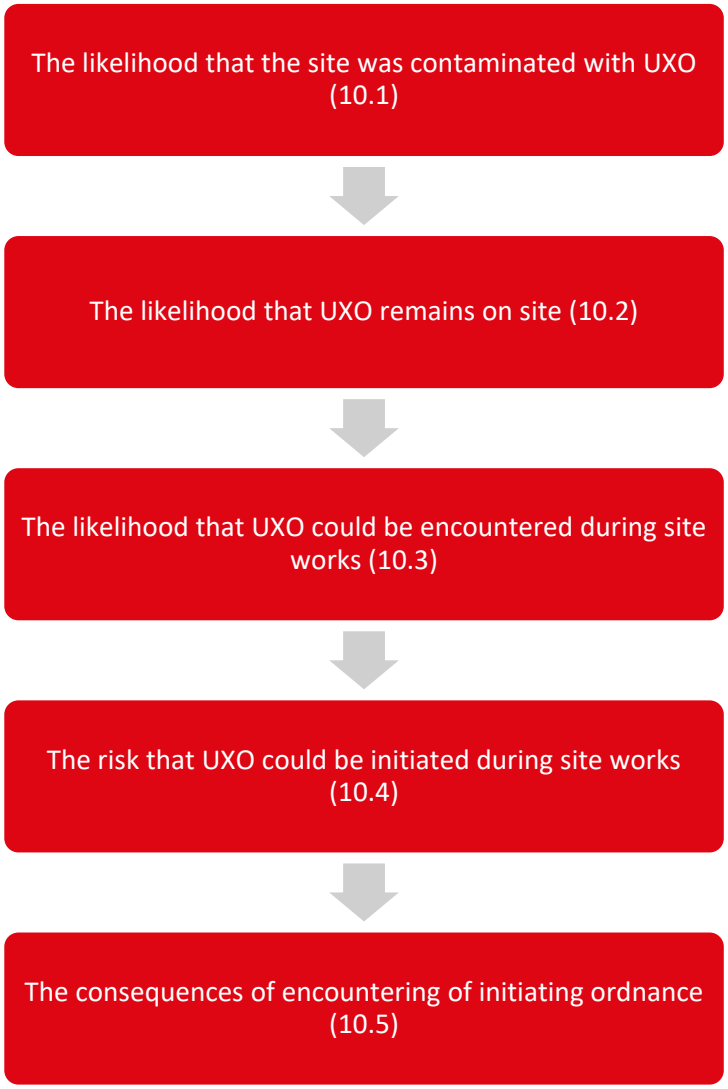
Remarks: Mobile batteries – normally few records of where these guns were located

40mm Bofors gun and crew at Stanmore in Middlesex, 28 June 1940.

Unexploded 40mm Bofors projectile

10 The Overall Unexploded Ordnance Risk Assessment Methodology

Taking into account the quality of the historical evidence, the assessment of the overall risk to any intrusive works from UXO must evaluate the following factors:



Each of these steps will be evaluated in the following sections in order to conclude the total risk from UXO to the proposed works to be undertaken within the project site.

10.1 The Likelihood that the Site was Contaminated with Unexploded Ordnance

10.1.1 General

The below is a generalised table of factors used to determine the likelihood that the site was contaminated with unexploded ordnance. Note that additional site-specific information can adjust UXO risk beyond these criteria:

Low Likelihood	Medium Likelihood	High Likelihood
German Air-Delivered Ordnance / Allied Anti-Aircraft Shells		
No evidence of bombing / bomb damage on site coupled with low local bombing density.	Moderate to High local bombing density or evidence of bombing / bomb damage on or close to the site.	High local bombing density or evidence of bombing /bomb damage on or adjacent to the site. Confirmed finds of WWII UXB.
Ground conditions that would prevent UXB penetration or lead to easily identifiable entry holes.	Ground conditions that allow for bomb penetration.	Ground conditions that would have immediately and completely obscured the existence of UXB.
Site was occupied and accessed fully throughout the bombing campaign.	Site located in an area that was infrequently observed or accessed, with a low likelihood that a UXB strike would have been noticed.	Site may be completely obscured from view or subject to very infrequent access.
British / Allied Ordnance		
No evidence of Allied military activity on or near the site. Or Military sites which have been cleared / redeveloped since their use Or Military-owned sites which have not been used for training with live munitions.	Clear evidence of military training activity on site involving live ammunition / munitions. Military sites which have not undergone clearance operations or redevelopment since use. Evidence of weapons storage on site.	Evidence of weapons testing or disposal on or adjacent to the site.
Developed areas that are unlikely to have been used for military exercises.	Open or unmaintained ground that may have been used for disposal or caching of munitions.	Evidence of UXO finds on or in the vicinity of the site.

The following sections assess the likelihood of contamination from German UXO and British / Allied UXO, based on the evidence discussed in the previous sections.

10.1.2 Likelihood of Contamination from German UXO

The following table discusses the overall likelihood of contamination from German UXO, based on the evidence discussed in Section 8.

Overview of the Potential Sources of German Air-Delivered UXO	
Bombing density	• Low regional bombing density, likely to be locally higher due to close proximity to Luftwaffe targets. • Several bombing raids over Immingham Docks. • Reports of bombs dropped on the railway sidings, potentially on site.
Bomb Damage	• No damage recorded to any buildings on site. • No evidence of bomb craters or ground disturbance on site. • Any evidence of bomb damage on site is likely to have been repaired or infilled before the 1950 aerial photograph was taken.
Ground Conditions	• The north of the site was occupied by a section of the River Humber. • Had a UXB fallen into this part of the site, it would have been immediately obscured beneath the waterline or soft tidal mud, and subsequently covered by the mobile sediment. • A large proportion of the site was occupied by soft open ground, some of which was densely vegetated and / or unmaintained. • The south of the site encompassed railway sidings across soft ground / ballast. • In these parts of the site, a UXB could have easily fallen unnoticed, with its entry hole obscured by the vegetation or unconsolidated material. • Note, the entry hole of an SC50 (the most commonly deployed German HE bomb) could be as little as 20cm in diameter and therefore easily obscured in such ground types. • Had a UXB landed directly onto any small buildings, structures or rail lines, it likely will have caused substantial damage and been noticed.
Frequency of Access	• Seasonal access to unmaintained or unoccupied land • Some heavily vegetated areas will have seen limited to no access at all. • Railway lines will have seen regular use, but the surrounding sidings and their ballast likely saw more limited maintaining works. • Northern extent of the site will have seen very limited access, especially to the riverbed / mud.

J-Curve Effect	• Had any UXB landed within the soft ground, ballast or tidal mud on site, it could have come to rest up to 15m away from its entry point, potentially beneath adjacent undamaged railway lines.
Other considerations	• Nearby naval decoy site • Bombing into the river could have resulted in UXBs migrating in or out of the site, in addition to potential burial under sediment.
Overall Likelihood of Contamination	Medium

10.1.3 Likelihood of Contamination from British / Allied UXO

The following table discusses the overall likelihood of contamination from British / Allied UXO, based on the evidence discussed in Section 9.

Overview of the Potential Sources of British / Allied UXO	
Land Service Ammunition / Small Arms Ammunition	• The surrounding Immingham Dock facility has been used extensively by the military during both WWI and WWII. • Several defensive positions, including barrage balloons, coastal batteries and pillboxes were located in the area during both WWI and WWII. • A US Army Camp was located in the vicinity of the project site during WWII. • As such, is cannot be discounted that the site, located at the periphery of the dock facilities, may have been used for training exercises, storage or disposal of munitions to an extent. • Although such a scenario cannot be entirely discounted, no specific evidence has been found of this activity type on site. • Furthermore, the camp was located adjacent to the River Humber. Often, rivers, docks and other bodies of water near to military camps offered a quick and easy unofficial method of disposal to the military personnel. Hundreds of items of small arms and land service ammunition are found across Britain's waterways every year due to this very reason. As such, the possibility that surplus, faulty or unwanted items of ammunition may have been discarded into the marine section of the site during military occupation in the area. • Had such a scenario occurred along this part of the Humber, it is also possible that items could have then migrated with the river's current into or out of the site boundary itself.
Anti-Aircraft Projectiles	• Anti-aircraft defences were present and engaged in the area during both WWI and WWII. • Nine HAA batteries were situated within a 5km radius of the site during WWII.

	• Had an unexploded AA shell landed in the parts of the site occupied by the river, it would have been immediately obscured beneath the waterline. If it had landed within the tidal mud, it is unlikely to have resulted in a persistent entry hole, and would have been quickly infilled by the soft, mobile surrounding sediment. Following such a scenario, the item could easily have been left undiscovered. • Had an unexploded AA shell landed within the parts of the site occupied by unused, soft, open ground, ballast, or vegetation, it could have been left unnoticed. • However, had such an item landed directly onto railway tracks, undamaged buildings, or any other undamaged man-made structures, it could have caused significant damage which is more likely to have been noticed and dealt with at the time.
Overall Likelihood of Contamination	Medium

10.2 The Likelihood that Unexploded Ordnance Remains on Site

10.2.1 General

The extent to which any ordnance clearance activities have taken place on site or extensive ground works have occurred is relevant since they may indicate previous ordnance contamination but also may have reduced the risk that ordnance remains undiscovered.

10.2.2 EOD Bomb Disposal and Clearance Tasks

SafeLane Global holds a number of official records of explosive ordnance disposal operations during and following WWII, obtained from the Explosive Ordnance Disposal (EOD) Archive Information Office at 33 Engineer Regiment (EOD), British Army.

Potential Source	Details
Records of Army EOD tasks having taken place on site or in the vicinity	None
Local ordnance finds	• May 2020: An undiscovered WWII bomb detonated in the Humber during dredging of Immingham's approaches. It was thought to be a small, very old device covered by silt and sand. Following this incident, a detailed survey of the area was reportedly carried out.[20] • May 2014: A WWII shell was found on the building site of the Tesco, Immingham (Kennedy Way).[21]

[20] https://www.hulldailymail.co.uk/news/hull-east-yorkshire-news/war-bomb-explodes-ve-day-4115384
[21] https://grimsby75.rssing.com/chan-4107517/all_p260.html

Local tasks undertaken by SafeLane Global	None

10.2.3 Post War Redevelopment

The nature of post-WWII ground works, redevelopment and construction has been considered. Significant structural redevelopment on site can, in some cases, provide a level of mitigation, particularly from shallow buried items. However, if a site has not undergone any extent of redevelopment, the likelihood of UXO remaining within its boundaries can remain.

The site has been redeveloped post-WWII	✖
Further Details	• OS mapping indicates that the site largely remained unchanged, while the surrounding area underwent significant redevelopment, until 1972-89. At this time, several of the railway sidings had been cleared. • The earliest available aerial photography indicates that between 2003 and the present day, the site has been subject to shallow ground works, with hardstanding laid across large portions of the project site area. • No records of large-scale, significant redevelopment on site have been found.

10.2.4 Wartime UXO in Britain's Waterways

Anecdotal and historical records give a strong indication that Britain's rivers, canals, lakes, ponds and other waterways have often presented a convenient location to easily and secretly dispose of unwanted items of UXO. This is illustrated by the significant number of items discovered in Britain's waterways ever year. A rise in the popularity of magnet fishing has presented an additional insight into the numbers of items that were dumped into these locations during and after wartime.

Furthermore, bodies of water in the UK were ideal for concealing airdropped UXBs. Often, WWII UXBs are found in rivers, docks, lakes etc, having been left unnoticed for all these years. Some lay on the bottom, but others were covered with sediment over time.

The following examples indicate the types of UXO that have recently been discovered across the UK. Note, these represent just a small number of the total items found:

Item(s) Discovered	Details
WWI-era Grenade 	July 2021 – Hand grenade found in the River Trent, near Wilford Toll Bridge, Nottingham.[22]
Unexploded Shell 	March 2021 – WWII mortar shell found by anglers in the River Avon, near Welford, Northamptonshire.[23]
WWII Mine  	December 2020 – WWII German submarine-laid, moored influence mine with 350kg of explosives found in the River Clyde.[24]

[22] https://www.bbc.co.uk/news/uk-england-nottinghamshire-57713711
[23]https://www.northamptonchron.co.uk/news/people/bomb-squad-blows-up-world-war-two-shell-found-in-northamptonshire-river-3181831
[24]https://www.glasgowtimes.co.uk/news/18915451.bomb-squad-called-river-clyde-ww2-mine-found-pristine-condition/

WWII-era Grenades 	December 2020 – 19 x grenades pulled out of the River Tame on the outskirts of Birmingham.[25]
WWII-era mortar 	July 2020 – WWII-era mortar found in the River Mole in Mickleham & Norbury in Dorking, Surrey.[26]
500kg German UXB 	In February 2018, SafeLane Global discovered an unexploded WWII bomb within King George V Dock, London. This resulted in the evacuation and closure of London City Airport.[27]

[25]https://www.independent.co.uk/news/uk/home-news/birmingham-river-grenades-found-bomb-disposal-b1777636.html
[26]https://metro.co.uk/2020/07/10/boy-6-finds-unexploded-world-war-two-bomb-magnet-fishing-12972444/
[27] https://www.safelaneglobal.com/en/case_studies/london-city-airport-bomb-clearance/

10.2.5 Site-Specific Analysis

The following table discusses the likelihood that UXO could remain on site, following any post-WWII activity.

Mitigating factors during post-WWII period	The available evidence suggests that the site has been subject only to shallow ground works since the end of WWII, inclusive of the removal of railway sidings, small buildings and vegetation. A large portion of the site has been laid to hardstanding. No records of dredging operations within the marine section of the site have been found.
Further comments	Within the footprints of the post-war redevelopment / ground works, the risk of shallow buried UXO (especially German 1kg incendiaries) remaining will have been partially mitigated since any such items could have been encountered and removed during soil stripping and levelling. Only within the volume of any post-war basement level bulk excavations and at the precise locations of any post-war pile foundations / boreholes, will the risk from deeper buried German HE UXBs have been completely mitigated. At any location on site where no bulk excavations have been carried out, the risk from deep buried UXO remains unmitigated to the maximum bomb penetration depth. Within any works taking place in the marine section of the site, there are three scenarios which could have resulted in explosive UXO remaining in the area of the proposed works: • *UXO remaining in situ* - whereby UXO remains on the seabed, in the exact location at which it was originally deposited. • *Storm Conditions* - During WWII it was observed that storms were capable of causing significant movement of objects, for example, tearing moored buoyant sea mines from their anchors. It is conceivable that any ordnance lying on the riverbed could have been moved into the study area. • *Migration* - Due to the mobile nature of some sub-marine environments, munitions can migrate across the riverbed with bottom currents, gravity flows and fishing activities. This is also the case with inshore wave action, resulting in a large quantity of munitions being washed up on beaches around the world, every year. Due to the extensive military action around the area, this is the most likely scenario for a range of difference items of ordnance, particularly SAA and LSA.

10.3 The Likelihood that Ordnance may be Encountered during the Works

The following table discusses the likelihood that UXO could be encountered on site during the proposed works.

At-Risk Scenarios	The most likely scenarios under which a UXO could be encountered during construction works is during piling, drilling operations or bulk excavations for basement levels. The overall risk will depend on the extent of the works, such as the numbers of boreholes/piles (if required) and the volume of the excavations. Since an air-dropped bomb may come to rest at any depth between just below ground level and its approximate penetration depth there is also a chance that such an item could be encountered during shallow excavations (for services or site investigations) into the original WWII ground level. If the proposed works are due to be undertaken within post war fill material / made ground, the risk of encountering WWII UXBs is low. However, if works are to be undertaken below WWII ground level this risk is significantly higher.
Likelihood of UXO being encountered during the proposed works	The proposed works are expected to consist of construction works. As such, during shallow and deeper level works, there is a likelihood that UXO could be encountered. Additionally, within the tidal section of the site, empirical evidence has shown that UXO expended onto the riverbed can subsequently become buried. The factors governing seabed burial are; sedimentation rate, presence of gravity / density flows or mega ripples, sediment type, density of UXO and water currents. A combination of these factors could result in significant burial of both small and larger items of UXO within the site boundary. With regards to post contamination burial of UXO lying on the riverbed, there is currently no overall formula incorporating these factors due to the variance of critical influences which can affect whether or not various items of UXO become buried. SafeLane Global's previous experience in the marine environment has created the basis for the assumptions made here, however as this is not considered to be an 'exact science' it would be irresponsible to make definitive statements regarding precise burial depths of UXO within soft sediment environments. In shallow water environments, where surface water wave activity, tidal currents and storm conditions have a great effect on the riverbed, burial of UXO is much more likely. In some instances, regular water movements create scour features in the sediment, around a UXO item. Over a period of time the UXO could then roll into the scour mark and subsequently become partially or completely buried just below the surface. This inference has been made with reference to a research paper on Scour and Burial of Bottom Mines in the shallow marine environment[28].

[28] Douglas L. Inman & Scott A. Jenkins Scripps - Scour and Burial of Bottom Mines - Institution of Oceanography, 2007

10.4 The Risk that Ordnance may be Initiated

Items of ordnance do not become inert or lose their effectiveness with age. Time can indeed cause items to become more sensitive and less stable. This applies equally to items submerged in water or embedded in silts, clays or similar materials. The greatest risk occurs when an item of ordnance is struck or interfered with. This is likely to occur when mechanical equipment is used or when unqualified personnel pick up munitions.

10.4.1 Initiation of Unexploded Bombs

In the case of unexploded German bombs discovered within the construction site environment, there are a number of potential initiation mechanisms:

Direct Impact onto the main body of the bomb	Unless the fuze or fuze pocket is struck, there needs to be a significant impact to initiate a buried iron bomb.
Re-starting the clock timer in the fuze	Only a small proportion of German WWII bombs employed clockwork fuzes. It is probable that significant corrosion has taken place within the fuze since the end of WWII that would prevent clockwork mechanisms from functioning, nevertheless it was reported that the fuze in a UXB dealt with by 33 EOD Regiment in Surrey in 2002 did recommence.
Induction of a static charge, causing a current in an electric fuze	The majority of German WWII bombs employed electric fuzes. It is probable that significant corrosion has taken place within the fuze mechanism since the end of WWII such that the fuze circuit could not be activated.
Friction impact initiating the (shock-sensitive) fuze explosive	This is the most likely scenario resulting in the bomb detonating.

10.4.2 Activities that may Result in the Initiation of Unexploded Ordnance

Unexploded bombs do not spontaneously explode. All high explosive requires significant energy to create the conditions for detonation to occur. The risk that UXO could be initiated if encountered will depend on its condition, how it is found and the energy with which it is struck. However certain activities pose a greater risk than others.

Percussive piling or deep mechanical excavations	The most violent activity on most construction sites is percussive piling or deep mechanical excavations. If an item is struck with a significant enough impact, be it direct or through friction/vibration, it risks detonation.
Shallow excavation	Soil levelling and shallow excavation such as trial pits can pose a similar risk to deeper excavations, since UXO can be found at any depth between ground level and the maximum bomb penetration depth. In addition to risk of initiation by violent impact or vibration, detonation can also occur if discovered items are mishandled by unqualified personnel. This is particularly common when onsite personnel are not trained in the recognition of ordnance.
Non-intrusive works	In the case of non-intrusive planned works, little risk is posed by items of UXO that are buried beneath the ground. However, risk can arise from unburied munitions, particularly items of ordnance discarded in periphery areas of military sites. These items are frequently discovered by onsite personnel and remain live and liable to activate if mishandled.

10.5 The Consequences of Encountering or Initiating Ordnance

Clearly the consequences of an inadvertent detonation of UXO during construction operations would be catastrophic with a serious risk to life, damage to plant and a total site shutdown during follow-up investigations.

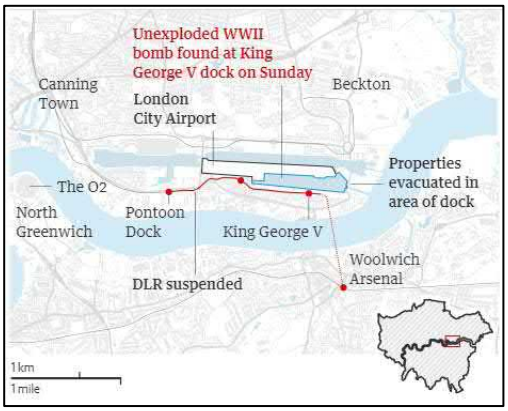
Since the risk of initiating ordnance is significantly reduced if appropriate mitigation measures are undertaken, the most important consequence of the discovery of ordnance will be economic. This would be particularly so in the case of high-profile locations and could involve the evacuation of the public.

The unexpected discovery of ordnance may require the closing of the site for any time between a few hours and a week with a potentially significant cost in lost time. Note also that the suspected find of ordnance, if handled solely through the authorities, may also involve loss of production since the first action of the Police in most cases will be to isolate the locale whilst awaiting military assistance, even if this turns out to have been unnecessary.

The following tables review a number of finds over recent years both in the UK and overseas that have seen large-scale disruptions, damage and injury/death:

UXB Incidents where intrusive works have caused detonation, resulting in death, injury and damage to plant	
 RESCUE workers search for survivors after a Second World War bomb exploded at a building site in Berlin, killing three people and injuring at least eight others. A fire brigade spokesman said he feared the final death toll could be higher. One worker was still missing, believed to be trapped under a machine. "We've **Blown up by history** found human remains 100 metres away but we can't tell if they belong to the dead already found," the spokesman said. The blast, set off by drilling work on Frankfurter Allee, one of east Berlin's busiest avenues, trapped workers under building machinery and sent huge chunks of concrete tumbling through the air. A large office block was being built on the site of the explosion which sent shoppers scrambling for shelter and paralysed dense afternoon traffic. One eyewitness said: "There was a bang, then silence, and then it started raining stones and dirt." Dozens of cars within a 250-metre radius were wrecked and the top two floors of a nearby apartment block caved in. Radio reports claimed that the total number of injured stood at 14.	A WWII bomb killed 3 and injured 8 in Berlin - 1944
	WWII bomb killed 3 in Goettingen, Germany – 2010.
	Excavator operator killed by WWII bomb in Euskirchen, Germany – 2014. A WWII bomb exploded at a construction site near a west German town, killing a man and injuring 8 others. The explosion occurred with a digger accidently struck the device during excavation works.

	A highway construction worker in Germany accidentally struck a WWII bomb, killing himself and wrecking several passing cars – 2006.
	Destroyed piling rig and dump truck after detonation of WWII UXB in Austria – 2006.
	WWII bomb injures 17 at construction site in Hattingen, Germany – 2008.
	A buried WWII-era bomb exploded during construction works in Bandar Malaysia, Kuala Lumpur – 2017.

UXB Incidents in the UK, resulting in delays, site shutdowns, evacuations, and disruptions	
	London City Airport shut: Flights cancelled after WWII bomb found in River Thames dock. London City Airport was closed after the discovery of a 250kg WWII German bomb, affecting tens of thousands of passengers. All flights into and out of the airport were stopped after the device was found by SafeLane Global in the nearby King George V dock. A 700ft exclusion zone was put in place and people living nearby were evacuated.
	Unexploded WWII bomb found in Birmingham, causing a construction site to be evacuated.
	A WWII UXB was found near to the Aston Expressway, leading to the evacuation of around 200 residents and a 500m cordon. Following the discovery, the weapon was safely detonated by the Army. However, although the M6 was reopened after the blast, the key Aston Expressway stayed shut until 6pm, extending traffic disruption. All nearby rail services and other roads were also disrupted.
	Up to 1000 homes were evacuated and a 300m exclusion zone was put in place following the discovery of a WWII UXB in Lansdown Road, Bath. The 500lb bomb was found just a meter beneath a playground at the former Royal High Junior School.

11 SafeLane Global's Risk Assessment

The Risk Assessment made by SafeLane Global for the site is based upon the likelihood that the site was contaminated, the risk of the contaminant item remaining, and the likelihood of, and potential consequences, should the item be struck during the proposed works. The following section discusses the risk that each ordnance type presents to the scope of works for the project site.

11.1 Conclusions

Taking into consideration the findings of this study, SafeLane Global considers the UXO risk at the site to be Medium.

Type of Ordnance	Likelihood of Contamination	Likelihood of UXO remaining	Likelihood of encounter	Potential Consequence	Overall Risk level
German High Explosive Bombs	Medium	Medium	Medium	Severe	**Medium**
German 1kg Incendiary Bombs	Low	Low	Low	Severe	**Low**
Allied Anti-Aircraft Shells	Medium	Medium	Medium	Minor	**Medium**
British / Allied Small Arms	Medium	Low	Low	Not Significant	**Low**
Land Service Ammunition	Medium	Low	Low	Moderate	**Low**

12 Proposed Risk Mitigation Strategy

SafeLane Global recommends the following minimum risk mitigation measures be deployed to support the proposed ground works at the site.

12.1 Summary

Based on the findings of the report, the following mitigation measures have been recommended for the proposed works on the site. Further detail on each method is presented in **Section 12.2.**

Risk Level	Environment	Planned Site Activity	Recommendations
Medium	Land-based	Shallow Intrusive Works e.g. excavations	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Non-Intrusive (NI) Magnetometer Survey (Greenfield areas only) • Target Investigation (Required as a follow-on from NI magnetometer survey) • Search & Clear • Explosive Ordnance Disposal (EOD) Engineer Watching Brief (for brownfield areas unsuitable for NI magnetometer survey)
		Deep intrusive works (e.g. piling)	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Intrusive Magnetometer Survey of pile/borehole positions
	Marine based	Shallow Intrusive Works e.g. excavations	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Non-Intrusive Magnetometer UXO Survey • Non-Intrusive 3D Seismic Investigation from the 2m contour
		Deep intrusive works (e.g. piling)	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Seismic Investigation: Further Non-Intrusive Survey over exact locations to identify and mitigate risk and geological assessment for further risk management.

12.2 Additional Notes

Risk Mitigation Measures – Further Detail	
Site Specific Explosive Ordnance Safety and Awareness Briefings (UXO Toolbox Briefing) to all personnel conducting intrusive works	These briefings are intended to make site operatives aware of the nature of explosive ordnance that may be encountered on their project site. • Delivered by a specialist Explosive Ordnance Disposal Engineer. • Provides information on the site-specific explosive ordnance risk • Basic ordnance identification. • What to do in the event of an encounter with a suspicious object. Provide UXO response procedures.
Site Specific Safety Instruction (SSSI)	For longer term projects that require Explosive Ordnance Safety and Awareness Briefings as part of the Explosive Ordnance Risk Mitigation measures for the project, SSSIs can be provided to allow nominated site representatives to deliver these briefings after initial training. • 2/3-hour presentation and training course. • Delivered by a fully qualified senior EOD Engineer. • Suitable for Project Site Manager HSE representative and supervisors. • Includes briefing pack. This provides a cost-effective solution to ensure that the Explosive Ordnance Safety and Awareness Briefings can be delivered effectively and efficiently to the required standard.
Explosive Ordnance Disposal (EOD) Engineer On-Site Support	In areas where the risk posed by the potential presence of explosive ordnance is low or where the conditions are not suitable for pro-active survey, EOD On-Site Support can provide a reactive response to any suspicious object that may be encountered during open excavation works. The presence of the EOD Engineer (sometimes referred to as 'high risk dig wardens') on-site in support of shallow intrusive work allows for a direct monitoring of works using visual recognition and instrumentation and provides an immediate response to reports of suspicious objects or suspected items of ordnance that have been recovered by ground workers. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings (UXO TBB) to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential incident management which would involve liaison with the local authorities and police should ordnance that presents an explosive hazard be identified. • Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all excavations. • Provides safety and awareness briefings to construction personnel as required.

	• Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO.
Explosive Ordnance Disposal (EOD) Engineer to support site investigation works	For cost effective Explosive Ordnance Risk Mitigation for site investigation work, the EOD Engineer can survey ahead of trial pits, monitor excavations when the ground conditions are not suitable for a pro-active survey and conduct intrusive surveys for borehole and window sample locations working in conjunction with the site investigation team. The On-Site Support will also provide a reactive response to any suspicious object that may be encountered during open excavation works. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential Incident Management which would involve liaison with the local authorities and police should ordnance be identified and present an explosive hazard. • Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all trial pit excavations. • Provides safety and awareness briefings to construction personnel as required. • Works in conjunction with the drilling team to survey all borehole and window sample locations in real-time using a staged drilling and magnetometer survey procedure. • Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. • Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO. *Technical Information* 1. In optimum ground conditions each survey using the borehole technique will have a 1 metre look ahead capability. 2. Any steel casing used for borehole surveys will need to be retracted by 3 metres to allow the magnetometer survey to be conducted. Non-ferrous pipe will be required to support the borehole during the survey minimum diameter 60mm (to be supplied by the client).
Search & Clear	Where a non-intrusive magnetometer survey is not possible (e.g. wooded areas) SafeLane Global can deploy a two-man Explosive Ordnance Disposal Engineer team using handheld magnetometer equipment who will proactively survey either in search lanes or boxes, investigating each reading with the support of

	an operated excavator. The survey is suited to detecting suspicious ferro-magnetic buried objects that may be munitions and/or explosive ordnance related. All SafeLane Global personnel involved with the Search and Clearance Works will be former military personnel who have gained formal NATO Military Explosive Ordnance Disposal Qualifications, having completed training at the Defence Explosive Ordnance Disposal School (DEODS) Chattenden, Kent or similar establishment throughout their military service. The client will be responsible for: • Demarcating the areas to be searched. • Providing services clearance and permit to dig. • Providing operated excavator to access deeper targets if required (SafeLane Global can provide this service at additional cost). • Providing coordinates of positions where debris have been identified (if information required in report). • Providing storage for recovered debris. Output will depend upon terrain and contamination (number of readings to be investigated).
Non-Intrusive Magnetometer Survey and Target Investigation (greenfield land only)	**Non-Intrusive Survey** This survey type is designed for use on magnetically 'clean' land commonly referred to as 'greenfield'. Brownfield land is often described as that which has had previous industrial or commercial use. In this context it specifically encompasses sites with are underlain by 'made ground' which may contain metallic contamination. Non-intrusive magnetometry or electromagnetic equipment which is used in the search for buried UXO relies upon the detection of small changes between clear ground and that containing UXO. The technique operates very successfully in environments where there is minimal ground contamination from other sources such as fired bricks, reinforced concrete, discarded scrap metal and buried services. There are also man-made ambient effects on magnetic and electromagnetic non-intrusive survey systems which include moving plant vehicles, power cables, electric trains etc. Non-Intrusive survey is carried out using either total-field or gradiometer magnetometry, dependent upon site conditions. Data is recorded and then interpreted using advanced AGSPRoc software in order to map magnetic fields and model discrete magnetic anomalies (variations in the Earth's magnetic field caused by ferro-magnetic objects electrical fields or geology). The location of such anomalies is determined, and mathematical modelling used to estimate their mass and depth. The survey will also locate any buried services with a magnetic signature and indicate any areas of gross magnetic "contamination" which may indicate the presence of unknown obstructions. Additionally, the survey can provide information on archaeological features. The system can detect the magnetic field from a 50kg WWII air-dropped bomb at a depth of 4m and smaller items such as Land Service Ammunition to depths of up to 1.5m in ground with a low ambient magnetic field. In the case of soft geology, it should be noted that a 50kg high explosive bomb may be buried greater than 4 metres below ground level and therefore may not be detected by the survey. In this instance intrusive surveys may be required.

	The non-intrusive survey system will be deployed utilising the pedestrian survey frame. The output for the pedestrian frame is estimated at up to 2Ha per day. *Technical information:* • Client to clearly demarcate area to be surveyed prior to start and highlight any known services/underground obstructions. • Ground must be level, free of obstacles / obstructions and clear of undergrowth. Height of any crops should be no more than 400mm and where crops are present SafeLane Global would require written approval from the landowner or client to walk over the site area. • When working adjacent to existing infrastructure the survey may be ineffective due to the ferro magnetic interference caused by passing vehicles and the presence of underground buried services. A site visit may be recommended prior to commencement. • Note: the survey will be ineffective on Brownfield sites due to the magnetic nature of building rubble, which typically masks the weaker magnetic signatures of buried objects. If parts of the site are contaminated, then alternative risk mitigation measures may need to be considered. **Target Investigation** If a buried anomaly is detected that cannot be discounted as a potential UXO / UXB then the object will need to be investigated to positively identify the item. The process will include; • Specialist two-man Explosive Ordnance Disposal Team. • Combination of manual and mechanical excavation techniques. • Excavator shafting, shoring and dewatering equipment can be provided by SafeLane Global if required. • Excavation techniques will be defined and agreed prior to the commence. **A factual report with clearance certificate will be issued on completion of the investigation.**
Intrusive Magnetometer Survey of all pile locations down to the maximum bomb penetration depth	SafeLane Global can deploy a range of intrusive magnetometry techniques to clear ahead of all the pile locations. The appropriate technique is governed by a number of factors, but most importantly the site's ground conditions. The appropriate survey methodology would be confirmed once the enabling works have been completed. A site meeting would be required between SafeLane Global and the client to determine the methodology suitable for this site. Target investigation or avoidance will be recommended as appropriate.
Marine: **Non-Intrusive Magnetometer and Side Scan UXO Survey**	A Magnetometer and high-resolution Side Scan Survey should be conducted over the proposed works area to identify any ferrous anomalies (potential UXO), This will also identify areas clear of ferrous anomalies that may be used for the placement of piled foundations. The Side Scan Survey also allows for the identification of non-ferrous surface obstructions which may hamper the proposed works, to aid planning and design.

Marine: **Intrusive Magnetometer Survey - Down-hole Vallon Probing ahead of Marine Boreholes**	A down-hole Vallon magnetometer is lowered to the riverbed first to scan a radius for ferrous anomalies. Provided the riverbed is clear, boreholing is conducted to 1m. Nonferrous sleeving must be used with the Vallon lowered down the sleeve to clear the next metre ahead of the borehole. This sequence is repeated until bomb penetration depth is reached, then boreholing can continue unrestricted. Sleeving would be expected to extend from the JU Barge deck to riverbed to ensure drill bit relocates the borehole each time it is withdrawn.
Marine: **Barge-Mounted Intrusive Magnetometer Survey**	Magnetometer surveys of discrete pile locations are accomplished by the use of a TFG drill rig mounted on a jack up barge with a moon pool over each pile position. Where the use of a moon pool is not feasible due to the proximity of the pile location to other structures, a gantry can be constructed over the side of the barge to allow for drilling and safe access to the rig. A TFG survey can then be conducted to depth to prove whether a position is clear of ferrous anomalies.
Marine: **Seismic Investigation: Further Non-Intrusive Survey over exact locations to identify and mitigate risk (as an alternative to above two measures).**	This method will enable the gathering of detailed target information on individual targets giving the ability to produce true 3D seismic volumes of the upper tens of metres of sediment and imaging buried structures and objects with 3D decametric resolution allowing accurate UXO risk decision making to be made. This process is quick and requires no intrusive works unless an item of UXO is identified. In addition, this process would provide details of any other obstructions that may affect piling operations. In recent projects, SafeLane has reduced potential obstructions affecting piling works from an anticipated 10% to 0.01%.

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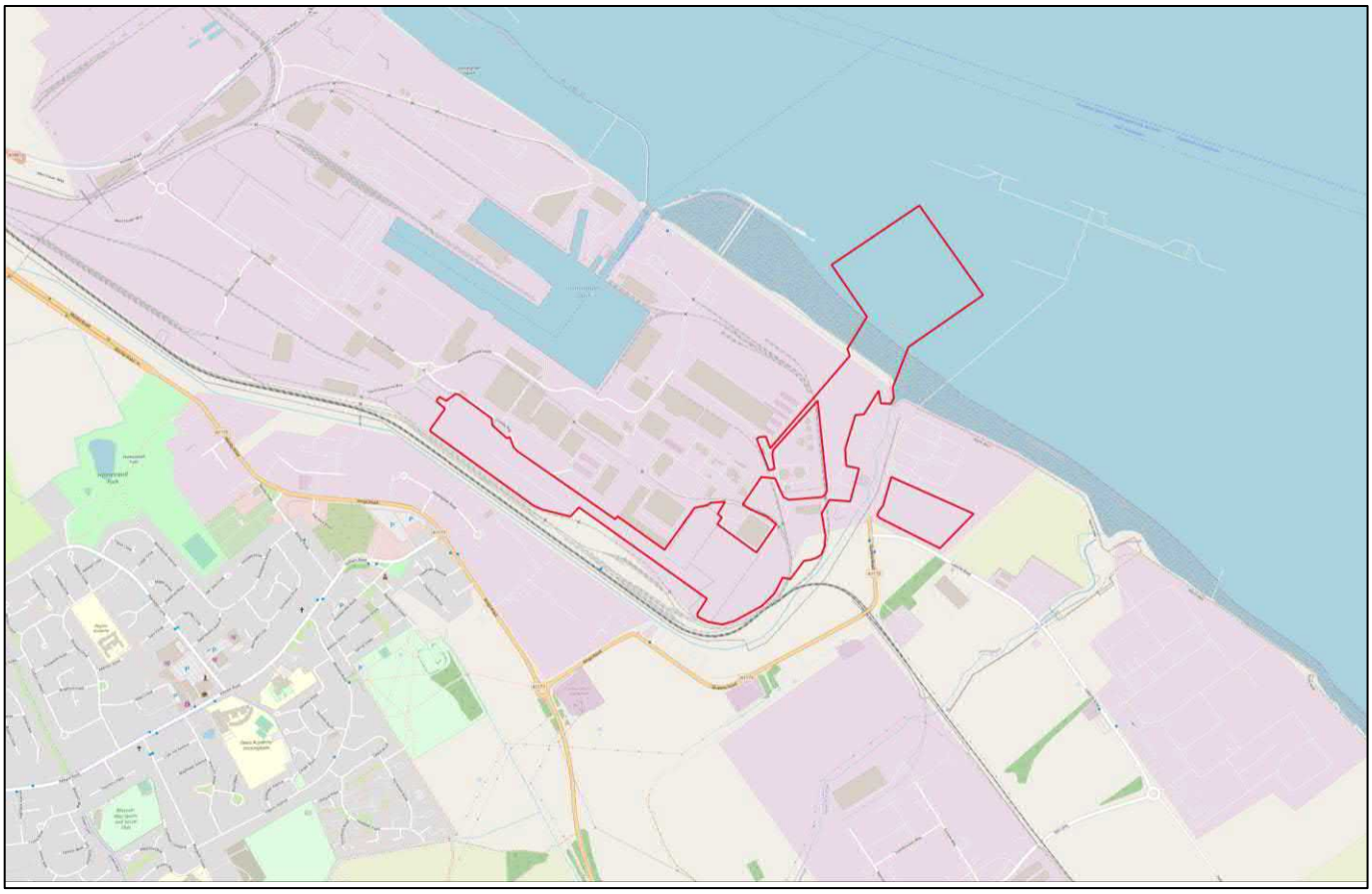

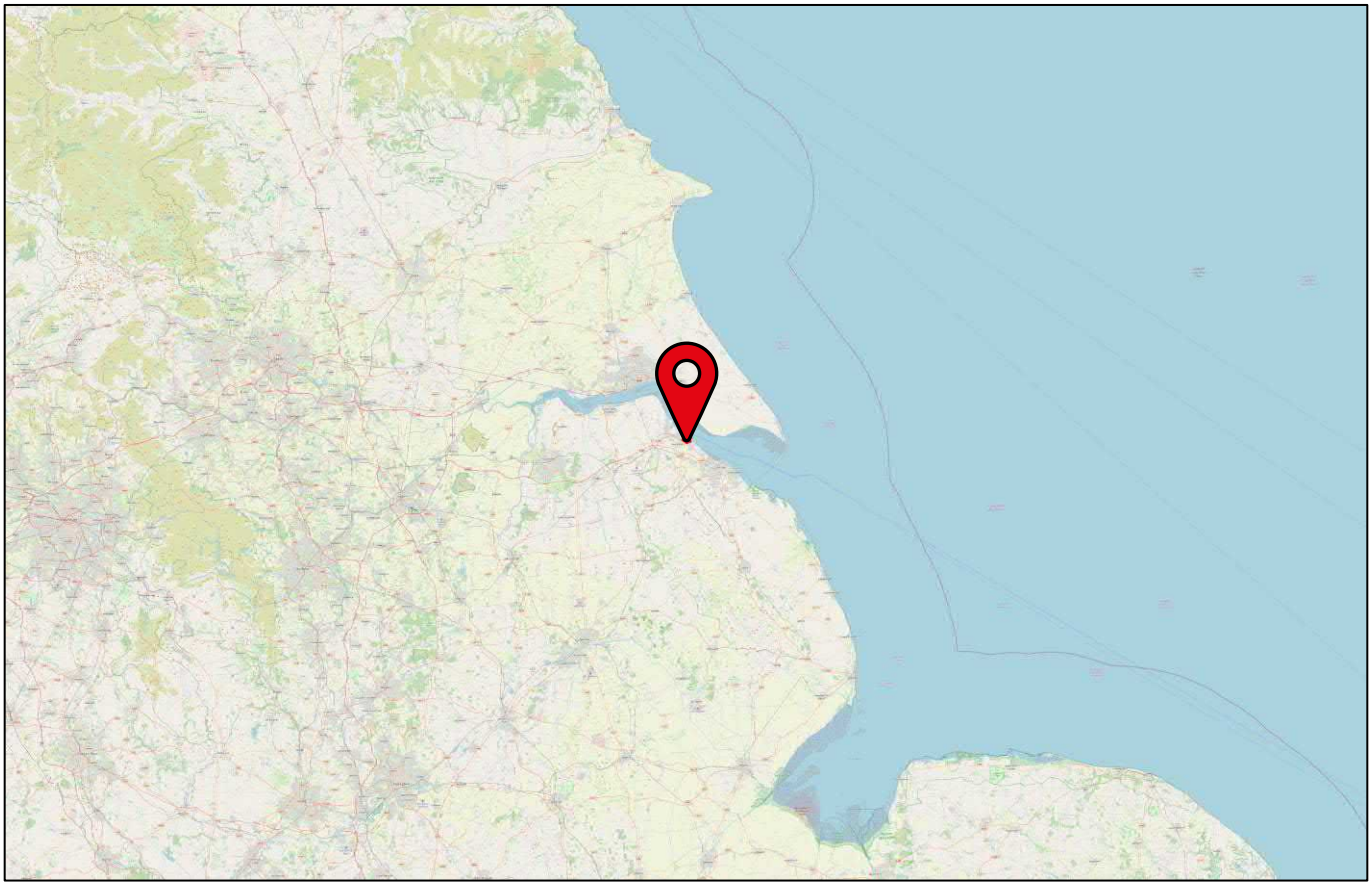

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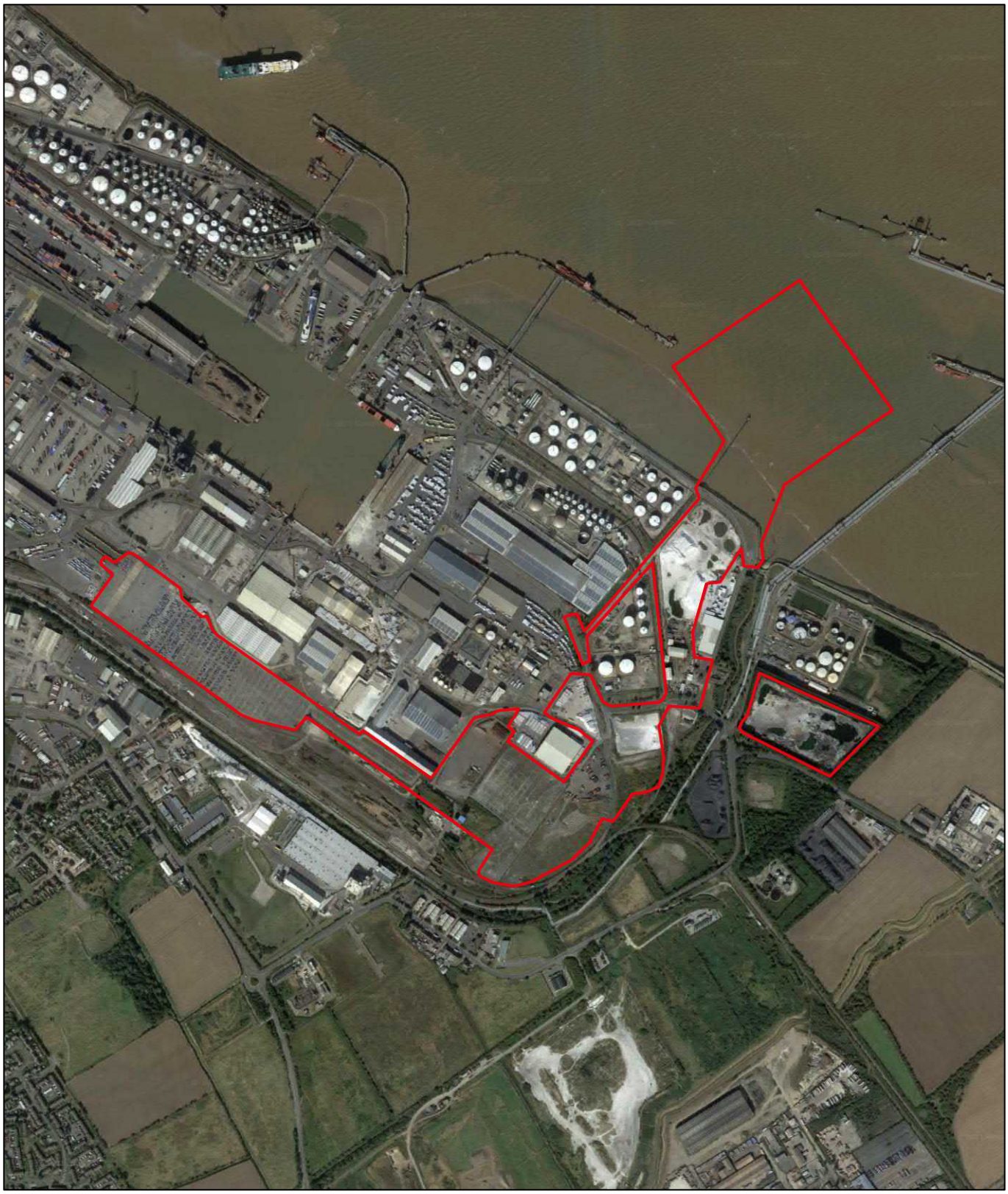

Approximate site boundary

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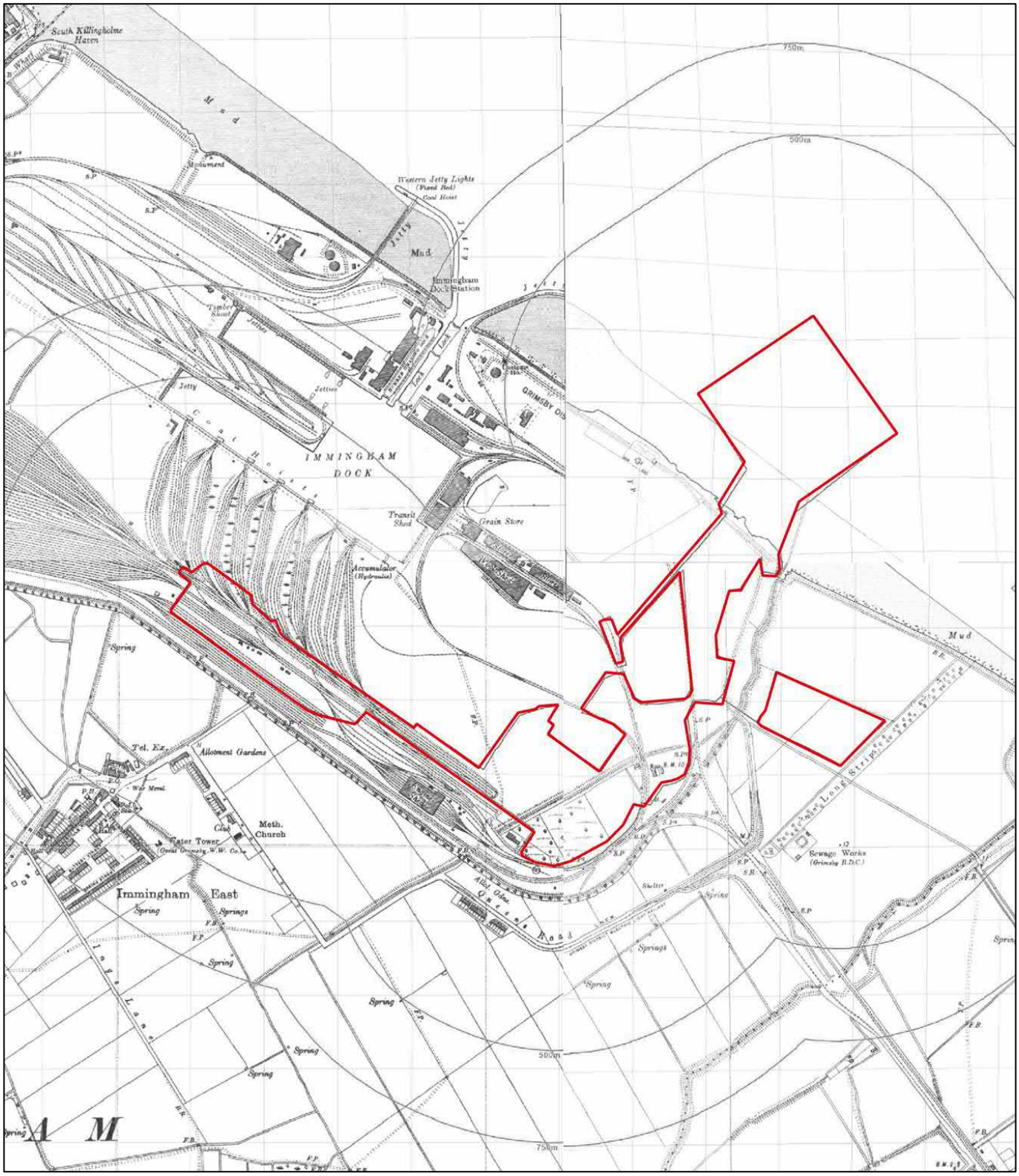

Approximate site boundary

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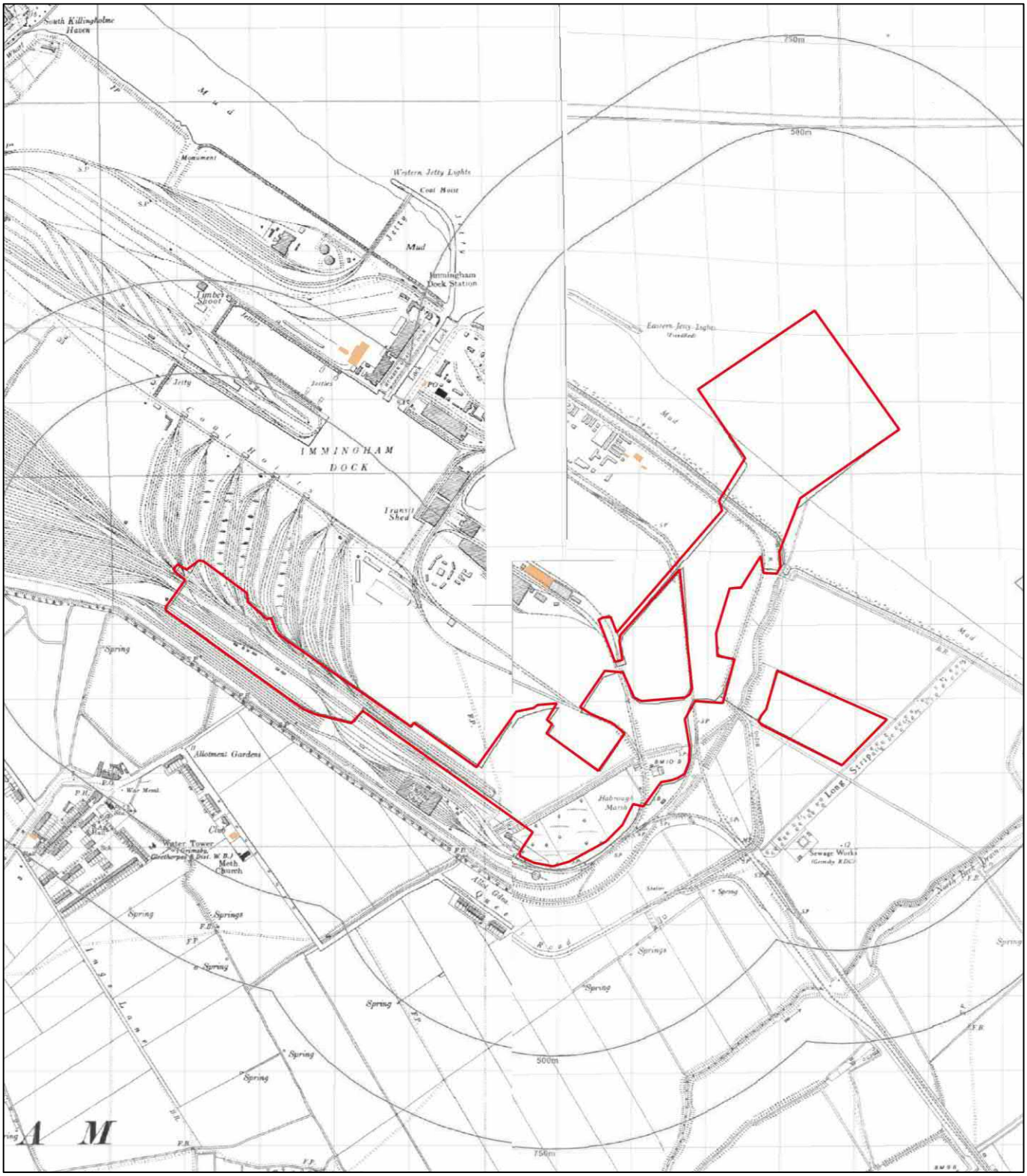
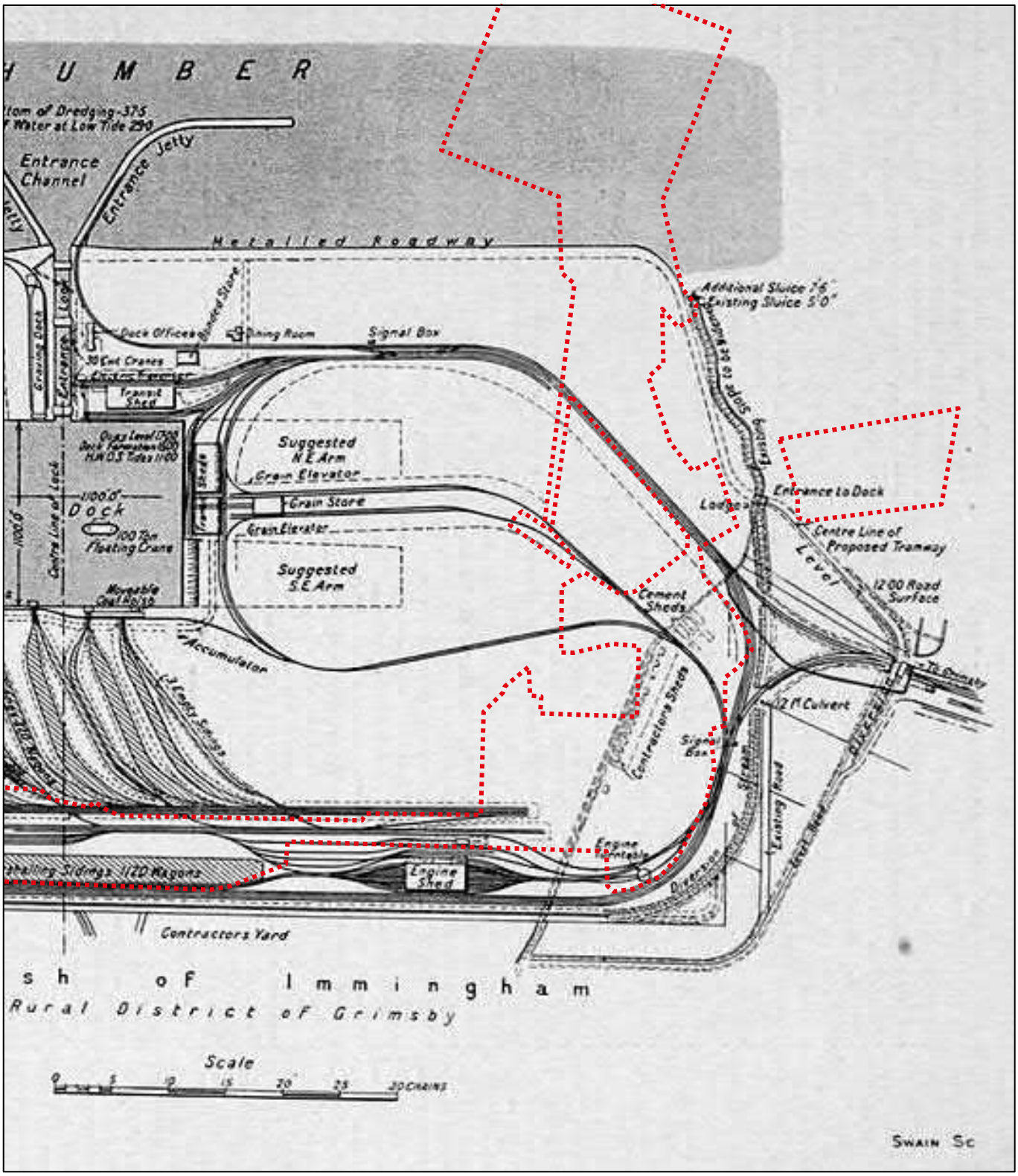


Approximate site boundary Clearance



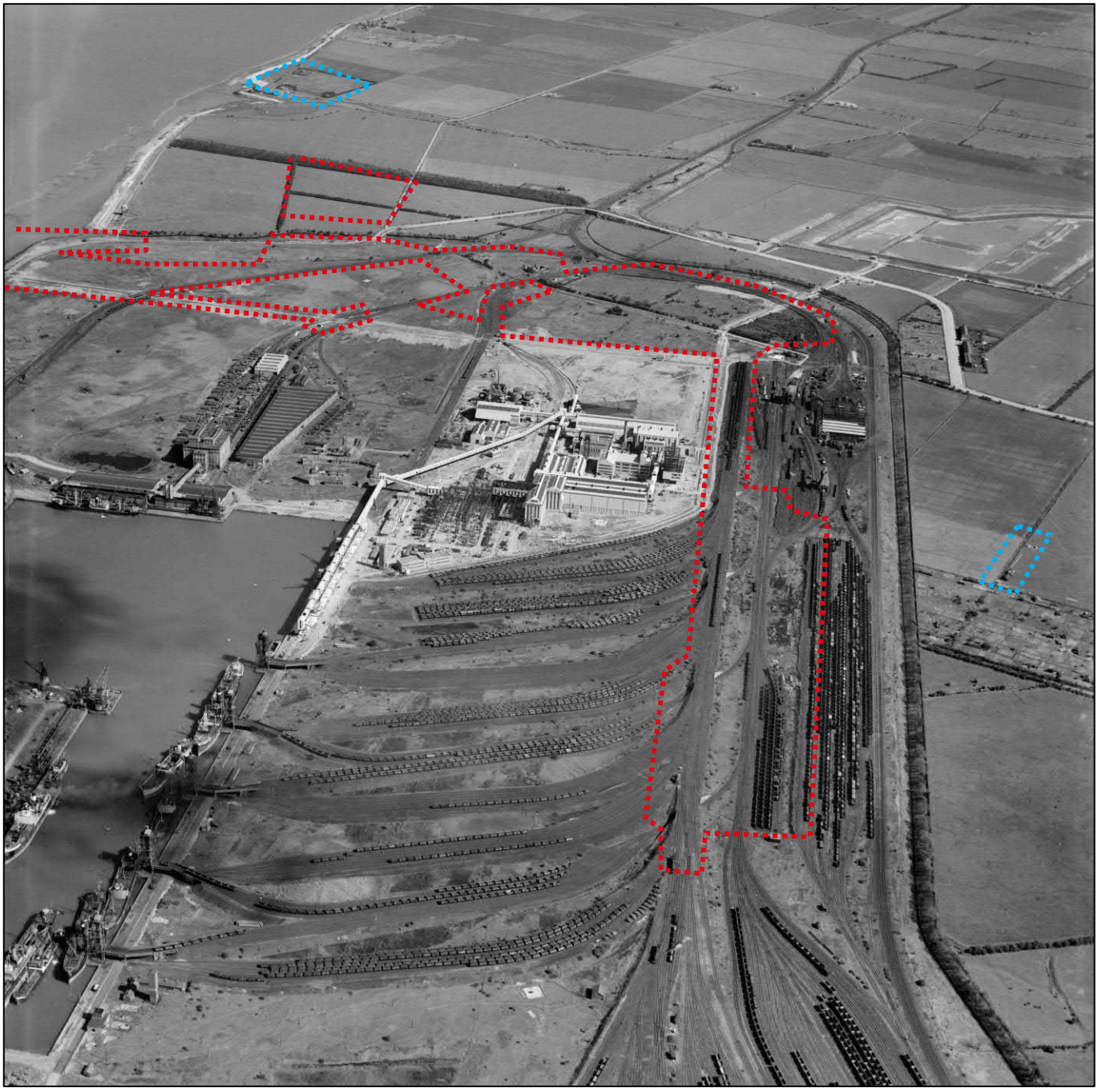
Approximate site boundary

SAFELANE® GLOBAL

WWII-era RAF Aerial Photography – 4th May 1950

Annex E
9048 RA

N



Approximate site boundary Gun battery site

Britain From Above

Anti-aircraft gunnery training, c.1940s

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