Appendix D

Detailed Unexploded Ordnance (UXO) Risk Assessment Report

1ST LINE DEFENCE

Detailed Unexploded Ordnance (UXO) Risk Assessment

Project Name	Northfleet, Gravesend, Kent
Client	GVR Geoservices Ltd
Site Address	Northfleet, Gravesend, Kent, DA11 9AD
Report Reference	DA11104a-00
Date	19/05/23
Authored by	CJ
Revised by	HJ
Final Check	AT

Executive Summary

Site Location and Description

The site is located in Northfleet, in the borough of Gresham, Kent.

The site comprises a large section of an industrial and commercial wharf area, located on the south side of the Thames estuary. Within the southern section is several large industrial and commercial warehouse structures of the former Kimberley-Clark Factory and associated hard ground. The northern section of the site comprises partially of a large warehouse structure, various smaller industrial structures, associated hard-ground, and wharf structures adjacent to the Thames River.

The site is bordered to the north by the remainder of a wharf adjacent to the Thames River, to the east by a combination of commercial structures, warehouses and hard-ground, including roadways and car parking space. To the south the site is bound by foliage and hard standing car parking space adjacent to London Road, and to the west by Granby Road and associated foliage and shrubbery.

The site is approximately centred on the OS grid reference: **TQ 62680 74392**.

Proposed Works

The client is undertaking a Phase 1 Geoenvironmental Desk Study to ascertain the historical and current land use history of the Northfleet Kimberley Clark Papermill site and the potential for ground and groundwater contamination at the site. The desk study is a non-intrusive geoenvironmental assessment not requiring site works.

Geology and Bomb Penetration Depth

The British Geological Survey (BGS) map shows the bedrock geology of the site to comprise Lewes Nodular Chalk Formation, Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated) - Chalk. Sedimentary Bedrock formed approximately 72 to 94 million years ago in the Cretaceous Period.

Site-specific geotechnical information was not available to 1st Line Defence at the time of the production of this report. An assessment of maximum bomb penetration depth can be made once such data becomes available, or by a UXO specialist during on-site support.

It should be noted that the maximum depth that a bomb could reach may vary across a site and will be largely dependent on the specific underlying geological strata and its density.

UXO Risk Assessment

1st Line Defence has assessed that there is a **Low-Medium Risk** from items of German air delivered UXO across the site. This assessment is based on the following factors:

- During WWII the site was located within the Urban District of Northfleet, which sustained an overall high density of bombing with an average of 103.2 items of ordnance falling per 1,000 acres according to official Home Office bombing statistics. This was mainly due to the industrial capacity of the town and its position on the River Thames, with numerous factories and commercial ports located along the harbour area
- Kent Daily Bomb Mapping records numerous bomb incidents within the Northfleet area, although the mapping was recorded on small scale maps and thus it is not possible to determine the exact locations of individual bomb strikes, beyond establishing the approximate locality of the incidents.
- Northfleet and Medway Group War Diary written records record several bomb incidents within the vicinity of the site, most notably at the location of the Paper Mills directly north-east of the site.. No bomb incidents are recorded directly within the site boundary, although there are no major structures within the site boundary from which to identify the location of a bomb strike.
- Anecdotal evidence corroborates these written records, confirming Bowater Paper Mill did indeed suffer several bomb strikes.
- WWII-era aerial photography of the site from 1944 shows no obvious indications of bomb damage such as craters, or ground disturbances in the undeveloped portions of the site. The housing, situated in the south-eastern section of the site, also appears externally intact and undamaged. There is evidence of bomb damage in the vicinity of the site, and roofing repairs can be observed on the Paper Mills factory to the north-east of the site- see **Annex M2**.

UXO Risk Assessment

- The south of the site is not considered to have had ground cover conducive to the detection of UXO as it was occupied by predominantly undeveloped ground. UXO entry holes, which could be as small as 20cm in diameter and could have easily been obscured by the vegetation present within the site and its surrounds. The ground cover in the north of the site is considered to have been more conducive to the detection of UXO. This is because the site comprised of more developed land, including landscaped allotments, small structures and roadways
- The access frequency of access to the site is not considered to have been homogenous. The southern section of the site, comprising of predominantly undeveloped ground, is considered to have experienced a low degree of access, owing to the lack of structures. The northern section of the site is considered to have experienced a higher degree of access, due to the presence of on-site structures and roadways, and the proximity of the nearby Paper Mills factory. How often the allotment gardens in this area were accessed is wholly dependent upon how often each owner visited their allotment garden. The south-eastern section of the site was occupied by residential housing. It appears that the housing survived the war structurally intact. Therefore, it is thought likely that residents would have continued to live there and therefore conduct post-raid checks, for evidence of UXO. Generally, more frequent access increases the likelihood UXO could go noticed and reported
- To summarise, no positive evidence of on-site bomb strikes or bomb damage could be found. However, there is evidence of bomb strikes and bomb damage to roads and structures within the wider vicinity of the site, particularly in relation to the nearby former Bowater Paper Mill factory. Subsequently, although the evidence available does not indicate the UXO risk on site to be significantly elevated above the 'background level' of risk for Gravesend, the risk from UXO cannot be entirely discounted and has been designed as **Low-Medium**. As a result of this risk level, it is recommended that a UXO risk management plan is in place prior to intrusive works taking place and that any staff undertaking such works receive UXO awareness briefings.
-

The Risk from Allied UXO

- Anecdotal evidence sourced online suggests that the Bowater Paper Mills, situated immediately east of the northern section of the site, may have been requisitioned during the war for the production of weaponry. It has not been possible to completely verify the information, but is it considered likely that this would have involved the large-scale use and storage of explosives, as the available evidence indicates that the factory was used to build the components of weapons. The factory was also outside the site boundary. This factor is thus not considered to have any significant impact on the risk of Allied UXO contamination on-site.
- There is no evidence that the site formerly had any military occupation or usage that could have led to contamination with items of Allied ordnance, such as LSA and SAA. The conditions in which HAA or LAA projectiles may have fallen unnoticed within the site boundary are however analogous to those regarding aerial delivered ordnance.

Post-WWII Redevelopment

- The site has been significantly redeveloped post-war. Historical OS mapping and current satellite imagery indicates that a large area of industrial structures and associated hard-ground has been developed on the previously mostly undeveloped land within the site boundary, which has subsequently been redeveloped. 1st Line Defence has found no evidence to suggest that any items of UXO were encountered during these prior post-war works on site.
- The risk of UXO remaining is considered to be mitigated at the location of and down to the depth of any post-war redevelopment on site. For example, the risk from deep buried UXO will only have been mitigated within the volumes of any post-war pile foundations or deep excavations for basement levels. The risk will however remain within virgin geology below and amongst these post-war works, down to the maximum bomb penetration depth.

Recommended Risk Mitigation Measures

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

All Works

- UXO Risk Management Plan
- Site Specific UXO Awareness Briefings to all personnel conducting intrusive works.

Glossary

Abbreviation	Definition
AA	Anti-Aircraft
AFS	Auxiliary Fire Service
AP	Anti-Personnel
ARP	Air Raid Precautions
DA	Delay-action
EOC	Explosive Ordnance Clearance
EOD	Explosive Ordnance Disposal
FP	Fire Pot
GM	G Mine (Parachute mine)
HAA	Heavy Anti-Aircraft
HE	High Explosive
IB	Incendiary Bomb
JSEODOC	Joint Services Explosive Ordnance Disposal Operation Centre
LAA	Light Anti-Aircraft
LCC	London County Council
LRRB	Long Range Rocket Bomb (V-2)
LSA	Land Service Ammunition
NFF	National Filling Factory
OB	Oil Bomb
PAC	Pilotless Aircraft (V-1)
PB	Phosphorous Bomb
PM	Parachute Mine
POW	Prisoner Of War
RAF	Royal Air Force
RCAF	Royal Canadian Air Force
RFC	Royal Flying Corps
RNAS	Royal Naval Air Service
ROF	Royal Ordnance Factory
SA	Small Arms
SAA	Small Arms Ammunition
SD2	Anti-personnel “Butterfly Bomb”
SIP	Self-Igniting Phosphorous
U/C	Unclassified bomb
UP	Unrotated Projectile (rocket)
USAAF	United States Army Air Force
UX	Unexploded
UXAA	Unexploded Anti-Aircraft
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V-1	Flying Bomb (Doodlebug)
V-2	Long Range Rocket
WAAF	Women’s Auxiliary Air Force
X	Exploded

Contents

Annexes

List of Report Annexes	
Annex A	Site Location Maps
Annex B	Recent Aerial Photography
Annex C	Client Provided Site Plan
Annex D	Pre and Post-WWII Historical Maps
Annex E	Pre-WWII Oblique Aerial Photography
Annex F	Example of UXO Entry Hole / The 'J-curve' Effect Principle
Annex G	Examples of UXO Incidents
Annex H	WWI Map of Air Raids and Naval Bombardments
Annex I	Luftwaffe Target / Reconnaissance Photography
Annex J	Kent Daily Bomb Mapping
Annex K	V-1 and Shells Daily Bomb Census Map
Annex L	Northfleet and Medway Group War Diary
Annex M	WWII-era RAF Aerial Photography of the Site & Damage Overlay

Appendices

List of Report Appendices	
Appendix i-iii	Examples of German Air-Delivered Ordnance
Appendix iv	Examples of Anti-Aircraft Projectiles

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

Site: Northfleet, Gravesend, Kent
Client: GVR Geoservices Ltd

1. Introduction

1.1. Background

1st Line Defence has been commissioned by GVR Geoservices Ltd to conduct a Detailed Unexploded Ordnance (UXO) Risk Assessment for the works proposed at Northfleet, Gravesend, Kent.

Buried UXO can present a significant risk to construction works and development projects. The discovery of a suspect device during works can cause considerable disruption to operations as well as cause unwanted delays and expense.

UXO in the UK can originate from three principal sources:

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

This report will assess the potential factors that may contribute to the risk of UXO contamination. If an elevated risk is identified at the site, this report will recommend appropriate mitigation measures, in order to reduce the risk to as low as is reasonably practicable. Detailed analysis and evidence will be provided to ensure an understanding of the basis for the assessed risk level and any recommendations.

This report complies with the guidelines outlined in *CIRIA C681*, 'Unexploded Ordnance (UXO) A Guide for the Construction Industry.'

2. Method Statement

2.1. Report Objectives

The aim of this report is to conduct a comprehensive assessment of the potential risk from UXO at Northfleet, Gravesend, Kent. The report will also recommend appropriate site and work-specific risk mitigation measures to reduce the risk from explosive ordnance during the envisaged works to a level that is as low as reasonably practicable.

2.2. Risk Assessment Process

1st Line Defence has undertaken a five-step process for assessing the risk of UXO contamination:

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

In order to address the above, 1st Line Defence has taken into consideration the following factors:

- Evidence of WWI and WWII German air delivered bombing as well as the legacy of Allied occupation.
- The nature and conditions of the site during WWII.
- The extent of post-war development and UXO clearance operations on site.
- The scope and nature of the proposed works and the maximum assessed bomb penetration depth.
- The nature of ordnance that may have contaminated the proposed site area.

2.3. Sources of Information

Every reasonable effort has been made to ensure that relevant evidence has been consulted and presented in order to produce a thorough and comprehensible report for the client. To achieve this the following, which includes military records and archive material held in the public domain, have been accessed:

- The National Archives and Kent History and Library Centre.
- Historical mapping datasets.
- Historic England National Monuments Record.
- Relevant information supplied GVR Geoservices Ltd.
- Available material from 33 Engineer Regiment (EOD) Archive (part of 29 Explosive Ordnance and Disposal and Search Group).
- 1st Line Defence's extensive historical archives, library and UXO geo-datasets.
- Open sources such as published books and internet resources.

3. Background to Bombing Records

3.1. General Considerations of Historical Research

This desktop assessment is based largely upon analysis of historical evidence. Every reasonable effort has been made to locate and present significant and pertinent information. 1st Line Defence cannot be held accountable for any changes to the assessed risk level or risk mitigation measures, based on documentation or other data that may come to light at a later date, or which was not available to 1st Line Defence during the production of this report.

It is often problematic and sometimes impossible to verify the completeness and accuracy of WWII-era records. As a consequence, conclusions as to the exact location and nature of a UXO risk can rarely be quantified and are, to a degree, subjective. To counter this, a range of sources have been consulted, presented and analysed. The same methodology is applied to each report during the risk assessment process. 1st Line Defence cannot be held responsible for any inaccuracies or the incompleteness in available historical information.

3.2. German Bombing Records

During WWII, bombing records were generally gathered locally by the police, Air Raid Precaution (ARP) wardens and military personnel. These records typically contained information such as the date, the location, the amount of damage caused and the types of bombs that had fallen during an air raid. This information was made either through direct observation or post-raid surveys. The Ministry of Home Security Bomb Census Organisation would then receive this information, which was plotted onto maps, charts, and tracing sheets by regional technical officers. The collective record set (regional bomb census mapping and locally gathered incidents records) would then be processed and summarised into reports by the Ministry of Home Security Research and Experiments Branch. The latter were tasked with providing the government 'a complete picture of air raid patterns, types of weapons used and damage caused- in particular to strategic services and installations such as railways, shipyards, factories and public utilities.'[1]

The quality, detail and nature of record keeping could vary considerably between provincial towns, boroughs and cities. No two areas identically collated or recorded data. While some local authorities maintained records with a methodical approach, sources in certain areas can be considerably more vague, dispersed, and narrower in scope. In addition, the immediate priority was mostly focused on assisting casualties and minimising damage at the time. As a result, some records can be incomplete and contradictory. Furthermore, many records were even damaged or destroyed in subsequent air raids. Records of raids that took place on sparsely or uninhabited areas were often based upon third party or hearsay information and are therefore not always reliable. Whereas records of attacks on military or strategic targets were often maintained separately and have not always survived.

3.3. Allied Records

During WWII, considerable areas of land were requisitioned by the War Office for the purpose of defence, training, munitions production and the construction of airfields. Records relating to military features vary and some may remain censored. Within urban environments datasets will be consulted detailing the location of munition production as well as wartime air and land defences. In rural locations it may be possible to obtain plans of military establishments, such as airfields, as well as training logs, record books, plans and personal memoirs. As with bombing records, every reasonable effort will be made to access records of, and ascertain any evidence of, military land use. However, there are occasions where such evidence is not available, as records may not be accessible, have been lost/destroyed, or simply were not kept in the first place.

[1] http://www.nationalarchives.gov.uk/help-with-your-research/research-guides/bomb-census-survey-records-1940-1945/.

4. UK Regulatory Environment and Guidelines

4.1. General

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

4.2. CDM Regulations 2015

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

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

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

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

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

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

4.4. CIRIA C681

In 2009, the Construction Industry Research and Information Association (CIRIA) produced a guide to the risk posed by UXO to the UK construction industry (CIRIA C681). CIRIA is a neutral, independent and not-for-profit body, linking organisations with common interests and facilitating a range of collaborative activities that help improve the industry.

The publication provides the UK construction industry with a defined process for the management of risks associated with UXO from WWI and WWII air bombardment. It is also broadly applicable to the risks from other forms of UXO that might be encountered. It focuses on construction professionals' needs, particularly if there is a suspected item of UXO on site, and covers issues such as what to expect from a UXO specialist. The guidance also helps clients to fulfil their legal duty under CDM 2015 to provide designers and contractors with project specific health and safety information needed to identify hazards and risks associated with the design and construction work. This report conforms to this CIRIA guidance and to the various recommendations for good practice referenced therein. It is recommended that this document is acquired and studied where possible to allow a better understanding of the background to both the risk assessment process and the UXO issue in the UK in general.

4.5. Additional Legislation

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

5. The Role of Commercial UXO Contractors and The Authorities

5.1. Commercial UXO Specialists

The role of a UXO Specialist (often referred to as UXO Consultant or UXO Contractor) such as 1st Line Defence, is defined in CIRIA C681 as the provision of expert knowledge and guidance to the client on the most appropriate and cost-effective approach to UXO risk management at a site.

The principal role of UXO Specialists is to provide the client with an appropriate assessment of the risk posed by UXO for a specific project, and identify and carry out suitable methodology for the mitigation of any identified risks to reduce them to an acceptable level.

The requirement for a UXO Specialist should ideally be identified in the initial stages of a project, and it is recommended that this occur prior to the start of any detailed design. This will enable the client to budget for expenditure that may be required to address the risks from UXO, and may enable the project team to identify appropriate techniques to eliminate or reduce potential risks through considered design, without the need for UXO specific mitigation measures. The UXO Specialist should have suitable qualifications, levels of competency and insurances.

Please note 1st Line Defence has the capability to provide a complete range of required UXO risk mitigation services, in order to reduce a risk to as low as reasonably practicable. This can involve the provision of both ground investigation, and where appropriate, UXO clearance services.

5.2. The Authorities

The police have a responsibility to co-ordinate the emergency services in the event of an ordnance-related incident at a construction site. Upon inspection they may impose a safety cordon, order an evacuation, and call the military authorities Joint Services Explosive Ordnance Disposal Operation Centre (JSEODOC) to arrange for investigation and/or disposal. Within the Metropolitan Police Operational Area, SO15 EOD will be tasked to any discovery of suspected UXO. The request for Explosive Officer (Expo) support is well understood and practiced by all Metropolitan Boroughs. The requirement for any additional assets will then be coordinated by the Expo if required.

In the absence of a UXO specialist, police officers will usually employ such precautionary safety measures, thereby causing works to cease, and possibly requiring the evacuation of neighbouring businesses and properties.

The priority given to the police request will depend on the EOD teams' judgement of the nature of the UXO risk, the location, people and assets at risk, as well as the availability of resources. The speed of response varies; authorities may respond immediately or in some cases it may take several days for the item of ordnance to be dealt with. Depending on the on-site risk assessment the item of ordnance may be removed from the site and/or destroyed by a controlled explosion.

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

6. The Site

6.1. Site Location

The site is located in Northfleet, in the borough of Gresham, Kent.

The site is bordered to the north by the remainder of a wharf adjacent to the Thames River, to the east by a combination of commercial structures, warehouses and hard-ground, including roadways and car parking space. To the south the site is bound by foliage and hard standing car parking space adjacent to London Road, and to the west by Granby Road and associated foliage and shrubbery.

The site is approximately centred on the OS grid reference: **TQ 62680 74392**.

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

6.2. Site Description

The site comprises a large section of an industrial and commercial wharf area, located on the south side of the Thames estuary. Within the southern section is several large industrial and commercial warehouse structures of the former Kimberley-Clark Factory and associated hard ground. The northern section of the site comprises partially of a large warehouse structure, various smaller industrial structures, associated hard-ground, and wharf structures adjacent to the Thames River.

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

7. Scope of the Proposed Works

7.1. General

The client is undertaking a Phase 1 Geoenvironmental Desk Study to ascertain the historical and current land use history of the Northfleet Kimberley Clark Papermill site and the potential for ground and groundwater contamination at the site. The desk study is a non-intrusive geoenvironmental assessment not requiring site works.

8. Ground Conditions

8.1. General Geology

The British Geological Survey (BGS) map shows the bedrock geology of the site to comprise Lewes Nodular Chalk Formation, Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated) - Chalk. Sedimentary Bedrock formed approximately 72 to 94 million years ago in the Cretaceous Period.

8.2. Site-Specific Geology

Whilst geotechnical data was provided by GVR Geoservices Ltd, owing to this information relating to an area beyond the site boundary, it is not considered relevant for an assessment of the precise conditions on site.

9. Site History

9.1. Introduction

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

9.2. Ordnance Survey Historical Maps

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

Pre-WWII		
Date	**Scale**	**Description**
1939	1:2,500	Pre-WWII OS mapping indicates the south of the site is occupied mainly by a large area of undeveloped land, labelled as Callybank. Individual rectangular plots of land are situated in the western part of this section, whilst a row of terraced houses is partially included within the eastern boundary. A Tramway line also intersects this section along the eastern and southern boundaries. The northern section of the site comprises more landscaped land, labelled as allotment gardens, and various small structures associated with the docklands area. Several small roadways and paths intersect this section, whilst the very northern section of the site comprises sediment adjacent to the Thames River. To the immediate north-east of the site boundary is a large industrial Paper Mill, structure. According to historical sources this stricture, known as The Bowater Paper Mill, was established in 1914 and then expanded to include the site boundary by 1960. The Paper Mill was closed down in 1972. To the south lies London Road, to the west Granby Road, and to the north the Thames River.

Post-WWII		
Date	**Scale**	**Description**
1946	1:10,560	Post-WWII OS mapping of a slightly lower quality shows no major structural developments occurred within the site boundary or its immediate vicinity during the war.
1967	1:2,500	Post-WWII OS mapping from a later date shows major structural developments have occurred on-site. The Paper Mill factory to the north-east of the site has expanded to include the land encompassing the site. Various industrial structures are now included within the site boundary and its vicinity.

9.3. Pre-WWII Photography of the Site

Pre-WWII aerial photography has been obtained from the Aerofilms collection available from *Britain From Above*. This imagery is presented in **Annex E**. See below for a description:

Title of Photograph	Comments
August 1932	The oblique image partially covering the site corroborates the layout of the site presents in historical OS mapping. The northern section can clearly been seen to comprise landscaped allotments, whilst the southern section of the site appears entirely undeveloped. The large Bowater Paper Mill can be observed immediately west of the site.
12th May 1939	This oblique covering the entire site from a later date again corroborates the layout of the site presented in historical OS mapping.

10. Introduction to German Air Delivered Ordnance

10.1. General

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

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

The main focus of research for this section of the report will concern German air delivered ordnance dropped during WWII, although WWI bombing will also be considered.

10.2. Generic Types of WWII German Air Delivered Ordnance

To provide an informed assessment of the hazards posed by any items of unexploded ordnance that may remain in situ on site, the table below provides information on the types of German air delivered ordnance most commonly used by the Luftwaffe during WWII. Images and brief summaries of the characteristics of these items of ordnance are listed in **Appendices i-iii**.

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

10.3. Failure Rate of German Air Delivered Ordnance

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

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

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

10.4. UXB Ground Penetration

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

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

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

10.4.1. The J-Curve Effect Principle

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

10.4.2. WWII UXB Ground Penetration Studies

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

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

10.4.3. Site Specific Bomb Penetration Considerations

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

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

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

10.5. V-Weapons

Hitler's 'V-weapon' campaign began from mid-1944. It used newly developed unmanned cruise missiles and rockets. The V-1, known as the flying bomb or pilotless aircraft, and the V-2, a long range rocket, were launched from bases in Germany and occupied Europe. A total of 9,251 V-1s and 1,115 V-2s were recorded in the United Kingdom.

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

11. The Likelihood of Contamination from German Air Delivered UXBs

11.1. World War I

During WWI Britain was targeted and bombed by Zeppelin Airships, as well as Gotha and Giant fixed-wing aircraft. A WWI map of air raids and naval bombardments across England is presented in **Annex H**. Although several WWI bombs were recorded in the general area, this source does not record any WWI bombing incidents to have affected the site.

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

11.2. World War II Bombing of the Urban District of Northfleet

The Luftwaffe's main objective for the attacks on Britain was to inhibit the country's economic and military capability. To achieve this they targeted airfields, depots, docks, warehouses, wharves, railway lines, factories, and power stations. As the war progressed the Luftwaffe bombing campaign expanded to include the indiscriminate bombing of civilian areas in an attempt to subvert public morale.

During WWII the site was located within the Urban District of Northfleet, which sustained an overall high density of bombing with an average of 103.2 items of ordnance falling per 1,000 acres according to official Home Office bombing statistics, as represented in the table below. This was mainly due to the industrial capacity of the town and its position on the River Thames, with numerous factories and commercial ports located along the harbour area. The town was thus a prominent target for Luftwaffe attacks, with prominent industrial entities such as the Bowater Paper Mill attracting bombing raids, which were just east of the site (Luftwaffe target photography presented in **Annex I**).

The town's position on the Thames Estuary, in close proximity to London, made it an ideal target for German bomber aircraft returning from a raid on the capital and to undertake 'tip and run' style attacks prior to returning across the channel.

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

Records of bombing incidents are presented in the following sections.

11.3. WWII Home Office Bombing Statistics

The following table summarises the quantity of German air delivered bombs (excluding 1kg incendiaries and anti-personnel bombs) dropped on the Urban District of Northfleet between 1940 and 1945.

Record of German Ordnance Dropped on the Urban District of Northfleet		
Area Acreage		**3,770**
Weapons	High Explosive bombs (all types)	364
	Parachute mines	3
	Oil bombs	7
	Phosphorus bombs	0
	Fire pots	9
	Pilotless aircraft (V-1)	5
	Long range rocket bombs (V-2)	1
Total		**389**
Number of Items per 1,000 acres		**103.2**

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

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

11.4. Kent Daily Bomb Maps

To understand the density of bombing in the region of the site areas, bomb maps covering the entirety of Kent were obtained from the Kent History and Library Centre for the purposes of this assessment. Whilst the mapping is a useful resource for understanding the general locations of incidents across individual districts on a daily basis, the mapping was recorded on small scale maps that depicted the whole county. Consequently, it is not possible to determine the exact locations of individual strikes, beyond establishing the approximate locality of the incident.

Furthermore, it is typical that single plotted strikes may represent numerous incidents of bombing. This is especially likely in cases of incendiary bombing, as incendiary bombs were frequently deployed in high numbers. As a result, this mapping has been used largely as an initial reference tool, which has subsequently been cross-referenced with other resources to fully appreciate the risk to the site area.

Examples of the Kent daily bomb maps are presented in **Annex J**. Unfortunately, due to the small-scale of the mapping it has not been possibly to precisely overlay the site areas onto the mapping. Map editions plotting incidents on or close to the approximate site area are discussed in the table below.

Kent Daily Bomb Maps	
Date Range	**Comments**
28th August 1940	**Incendiary bombing** recorded in the vicinity of the site.
8th September 1940	**Incendiary bombing** recorded to the east of the site.
14th September 1940	**Two HE bomb incidents** recorded in the wider vicinity east of the site, on the Thames River
5th October 1940	**Incendiary bombing** recorded in the vicinity of the site.
23rd October 1940	**One HE bomb incident** recorded in the vicinity of the site.
14th September 1940	**One HE bomb incident** and **incendiary bombing** recorded in the wider vicinity west of the site.
17th March 1941	**One HE bomb incident** recorded in the vicinity of the site.
23rd March 1941	**One HE bomb incident** recorded in the vicinity of the site.

11.5. V-1 and Shells Daily Bomb Census Map

Bomb plot maps showing the location of all the V-1 and shell incidents in the County of Kent was compiled by the Kent Messenger in 1944. Due to the large scale of the maps, only the incidents wherein the radius of the incident overlapped with the site have been listed below. The sections covering the area of the site were checked and are presented in **Annex K**.

V-1 and Shells Daily Bomb Census Maps	
Date Range	**Comments**
19th July 1944	**One V-1 Bomb Strike** recorded to the south-west of the site.

11.6. Northfleet and Medway Group War Diary

War diaries covering the Urban District of Northfleet and the wider Medway group area were obtained from the Kent History and Library Centre. These diaries were likely compiled by local Air Raid Precaution (ARP) personnel and volunteers during the war and provide the location, time, type of bomb and damage caused by bombing incidents across numerous areas in the Urban District of Northfleet. This record set is not believed to be comprehensive and does not appear to cover certain periods of the war. .

A transcription of the associated written records for bombs which fell in the site area is presented in the table below. The relevant records are presented in **Annex L**.

Northfleet and Medway Group War Diary			
Date	**Location**	**Type of Bomb (s)**	**Comments**
14th September 1940	Northfleet 083/932	4 HE Bombs and Incendiary Bomb	Minor bombing. 4 HE's in pulp yard of **Bowater Paper Mills** and Incendiary Bombs found in vicinity
12th December 1940	Northfleet 074/930	2 HE Bombs and 1 Oil Bomb	**Bowater Paper Mills.** I.Bs exploded in Boiler Room. 1 HE UXB in fitters shop. Production suspended
23rd October 1940	Northfleet 074/930	500kg HE Bomb	One large HE exploded in Cretehall Road
11th February 1944	Northfleet 063/931	2 HE bombs	Factory Road

11.7. Anecdotal Accounts of Bombing in Northfleet

Sourced from the BBC's 'WW2 People's War', an online archive of anecdotal accounts of air raids drawn from the experiences of British citizens alive during the War. In this extract, a Peter Rowdan details an air raid in Northfleet:

> *"In 1943 I left school at the age of 14 and he went to work at Bowater's making munitions they manufactured Bofor guns and Triple oerlican guns which were mounted in coal railway wagons. The factory was bombed twice during the war… Bowater's yard had a massive shower of what look like leaves falling from the sky but it was actually pieces of aluminium shrapnel from the V2 rocket."*[2]

This anecdote confirms that the Bowater factory complex, immediately west of the site, did indeed suffer multiple bomb strikes, including from a V-2 weapon.

11.8. WWII-Era Aerial Photography

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

WWII-Era Aerial Photography	
Date	**Description**
18th April 1944	This aerial image taken during the later stages of the war covers most of the site boundary, albeit not a small section of the southern part of the site. As with pre-war photography, the site appears to be predominantly undeveloped ground. No obvious indications of bomb damage, such as craters, or areas of disturbed ground, are evident within this image. The residential housing situated in the south-eastern section of the site appears externally intact, with no indications of bomb damage such as clearance or missing roofs. It appears that the Paper Mills factories, just east of the site, have been damaged. Some of the roofing is white – white tiled roofing is often indicative of repair work resulting from bomb damage. A visual overlay highlighting the damage to the Paper Mill factories is presented in **Annex M2.**

[2] *https://www.bbc.co.uk/history/ww2peopleswar/stories/82/a4401082.shtml*

11.9. Abandoned Bombs

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

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

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

11.10. Bomb Disposal Tasks

The information service from the Explosive Ordnance Disposal (EOD) Archive Information Office at 33 Engineer Regiment (now part of 29 EOD & Search Group) no longer processes commercial requests for information. It has therefore not been possible to include any updated official information regarding bomb disposal/clearance tasks with regards to this site. A database of known disposal/clearance tasks has been referred to which does not make reference to such instances occurring within the site of proposed works. If any relevant information is received at a later date, GVR Geoservices Ltd will be advised.

11.11. Evaluation of German Air Delivered UXO Records

Factors	Conclusion
Density of Bombing *It is important to consider the bombing density when assessing the possibility that UXBs remain in an area. High bombing density could allow for error in record keeping due to extreme damage caused to the area.*	During WWII the site was located within the Urban District of Northfleet, which sustained an overall high density of bombing with an average of 103.2 items of ordnance falling per 1,000 acres according to official Home Office bombing statistics. This was mainly due to the industrial capacity of the town and its position on the River Thames, with numerous factories and commercial ports located along the harbour area. Kent Daily Bomb Mapping records numerous bomb incidents within the Northfleet area, although the mapping was recorded on small scale maps and thus it is not possible to determine the exact locations of individual bomb strikes, beyond establishing the approximate locality of the incidents. Northfleet and Medway Group War Diary written records record several bomb incidents within the vicinity of the site, most notably at the location of the Paper Mills directly north-east of the site.. No bomb incidents are recorded directly within the site boundary, although there are no major structures within the site boundary from which to identify the location of a bomb strike. Anecdotal evidence corroborates these written records, confirming Bowater Paper Mill did indeed suffer several bomb strikes.

Damage *If buildings or structures on a site sustained bomb or fire damage, any resulting rubble and debris could have obscured the entry holes of unexploded bombs dropped during the same or later raids. Similarly, a high explosive bomb strike in an area of open agricultural land will have caused soil disturbance, increasing the risk that a UXB entry hole would be overlooked.*	WWII-era aerial photography of the site from 1944 shows no obvious indications of bomb damage such as craters, or ground disturbances in the undeveloped portions of the site. The housing, situated in the south-eastern section of the site, also appears externally intact and undamaged. There is evidence of bomb damage in the vicinity of the site, and roofing repairs can be observed on the Paper Mills factory to the north-east of the site- see **Annex M2**. This damage to the Paper Mills complex is also recorded in written records, matching with the observable damage on WWII-era aerial photography.
Ground Cover *The nature of the ground cover present during WWII would have a substantial influence on any visual indication that may indicate UXO being present.*	The ground cover is not considered to be homogenous across the site boundary. The south of the site is not considered to have had ground cover conducive to the detection of UXO as it was occupied by predominantly undeveloped ground. UXO entry holes, which could be as small as 20cm in diameter and could have easily been obscured by the vegetation present within the site and its surrounds. The ground cover in the north of the site is considered to have been more conducive to the detection of UXO. This is because the site comprised of more developed land, including landscaped allotments, small structures and roadways.
Access Frequency *UXO in locations where access was irregular would have a greater chance of passing unnoticed than at those that were regularly occupied. The importance of a site to the war effort is also an important consideration as such sites are likely to have been both frequently visited and subject to post- raid checks for evidence of UXO.*	The access frequency of access to the site is not considered to have been homogenous. The southern section of the site, comprising of predominantly undeveloped ground, is considered to have experienced a low degree of access, owing to the lack of structures. The northern section of the site is considered to have experienced a higher degree of access, due to the presence of on-site structures and roadways, and the proximity of the nearby Paper Mills factory. How often the allotment gardens in this area were accessed is wholly dependent upon how often each owner visited their allotment garden. The south-eastern section of the site was occupied by residential housing. It appears that the housing survived the war structurally intact. Therefore, it is thought likely that residents would have continued to live there and therefore conduct post-raid checks, for evidence of UXO. Generally, more frequent access increases the likelihood UXO could go noticed and reported.
Bomb Failure Rate	There is no evidence to suggest that the bomb failure rate in the locality of the site would have been dissimilar to the 10% normally used.
Abandoned Bombs	1st Line Defence holds no records of abandoned bombs at or within the site vicinity.
Bombing Decoy sites	1st Line Defence could find no evidence of bombing decoy sites within the site vicinity.
Bomb Disposal Tasks	1st Line Defence could find no evidence of bomb disposal tasks within the site boundary and immediate area.

12. Introduction to Allied Ordnance

12.1. General

Many areas across the UK may be at risk from Allied UXO because of both wartime and peacetime military use. Typical military activities and uses that may have led to a legacy of military UXO at a site include former minefields, home guard positions, anti-aircraft emplacements, training and firing ranges, military camps, as well as weapons manufacture and storage areas.

Although land formerly used by the military was usually subject to clearance before returned to civilian use, items of UXO are sometimes discovered and can present a potential risk to construction projects.

12.2. Defending the UK From Aerial Attack

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

Active Defences	Passive Defences
• Anti-aircraft gun emplacements to engage enemy aircraft. • Fighter aircraft to act as interceptors. • Rockets and missiles were used later during WWII.	• Blackouts and camouflaging to hinder the identification of Luftwaffe targets. • Decoy sites were located away from targets and used dummy buildings and lighting to replicate urban, military, or industrial areas. • Barrage balloons forced enemy aircraft to greater altitudes. • Searchlights were often used to track and divert adversary bomber crews during night raids.

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

12.2.1. Anti-Aircraft Artillery (AAA)

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

Anti-Aircraft Artillery				
Item	**Description**			
HAA	These large calibre guns such as the 3.7" QF (Quick Firing) were used to engage high flying enemy bombers. They often fired large HE projectiles, which were usually initiated by integral fuzes, triggered by impact, area, time delay or a combination of aforementioned mechanisms.			
LAA	These mobile guns were intended to engage fast, low flying aircraft. They were typically rotated between locations on the perimeters of towns and strategically important industrial works. As they could be moved to new positions with relative ease when required, records of their locations are limited. The most numerous of these were the 40mm Bofors gun which could fire up to 120 x 40mm HE projectiles per minute to over 1,800m.			
Variations in HAA and LAA Ammunition	**Gun type**	**Calibre**	**Shell Weight**	**Shell Dimensions**
	3.0 Inch	76mm	7.3kg	76mm x 356mm
	3.7 Inch	94mm	12.7kg	94mm x 438mm
	4.5 Inch	114mm	24.7kg	114mm x 578mm
	40mm	40mm	0.9kg	40mm x 311mm
Z-AA	The three inch unrotated rocket/projectile known as the UP-3 had initially been developed for the Royal Navy. The UP-3 was also used in ground-based single and 128-round launchers known as ''Z'' batteries. The rocket, containing a high explosive warhead was often propelled by cordite.			

The conditions in which anti-aircraft projectiles may have fallen unnoticed within a site area are analogous to those regarding air delivered ordnance. Unexploded anti-aircraft projectiles could essentially have fallen indiscriminately anywhere within range of the guns. The chance of such items being observed, reported and removed during the war depends on factors such as land use, ground cover, damage and frequency of access – the same factors that govern whether evidence of a UXB is likely to have been noted. More information about these factors with regards to this particular site can be found in the German Air Delivered Ordnance section of this report.

Illustrations of Anti-Aircraft artillery, projectiles and rockets are presented at **Appendix iv**.

13. The Likelihood of Contamination from Allied Ordnance

13.1. Introduction

There are several factors that may serve to either affirm, increase, or decrease the level of risk within a site with a history of military usage. Such factors are typically dependent upon the proximity of the proposed area of works to training activities, munition productions and storage, as well as its function across the years.

This section will examine the history of the proposed site and assess to what degree, if any, the site could have become contaminated as a result of the military use of the surrounding area.

13.2. Military History of the Site of Proposed Works

Anecdotal evidence sourced online suggests that the Bowater Paper Mills, situated immediately east of the northern section of the site, may have been requisitioned during the war for the production of weaponry. It has not been possible to completely verify the information, but it is not considered likely that this would have involved the large-scale use and storage of explosives. Instead anecdotal accounts suggest that the factory was used to produce gun components. The factory was also outside the site boundary. Thus the factory is not considered to have any significant impact on the risk of Allied UXO contamination on-site.

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

13.3. Evaluation of Contamination Risk from Allied UXO

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

Sources of Allied UXO Contamination	Conclusion
Military Camps *Military camps present an elevated risk from ordnance simply due to the large military presence and likelihood of associated live ordnance training.*	1st Line Defence could find no evidence of a military camp within the site.
Anti-Aircraft Defences *Anti-Aircraft defences were employed across the country. Proximity to anti-aircraft defences increases the chance of encountering AA projectiles.*	1st Line Defence could find no evidence of Anti-Aircraft defences such as a HAA or LAA gun emplacement occupying or bordering the site. The closest HAA was located approximately 3.5km east of the site, however the range of a projectile can be up to 15km. The conditions in which HAA or LAA projectiles may have fallen unnoticed within a site footprint are analogous to those regarding German aerial delivered ordnance.
Home Guard Activity *The Home Guard regularly undertook training and ordnance practice in open areas, as well as burying ordnance as part of anti-invasion defences.*	Evidence of Home Guard activity is often difficult to locate, owing to the ad-hoc nature of Home Guard activity within each local area. Such training was often conducted on a small scale at the discretion of individual commanders and as such was seldom recorded officially. As such, no positive evidence could be found to confirm the presence of HG units within proximity to the site.

Defensive Positions *Defensive positions suggest the presence of military activity, which is often indicative of ordnance storage, usage or disposal.*	There is no evidence of any pillbox, emplacement or other defensive features formerly located on or bordering the site footprint.
Training or firing ranges *Areas of ordnance training saw historical ordnance usage in large numbers, often with inadequate disposal of expended and live items. The presence of these ranges significantly impact on the risk of encountering items of ordnance in their vicinity.*	No evidence of training or firing ranges could be found within the site or surrounding area.
Defensive Minefields *Minefields were placed in strategic areas to defend the country in the event of a German invasion. Minefields were not always cleared with an appropriate level of vigilance.*	There is no evidence of defensive minefields affecting the site.
Ordnance Manufacture *Ordnance manufacture indicates an increased chance that items of ordnance were stored, or disposed of, within a location.*	No information of ordnance being stored, produced, or disposed of within the proposed site could be found.
Military Related Airfields *Military airfields present an elevated risk from ordnance simply due to the large military presence and likelihood of associated live ordnance training or bombing practice.*	The site was not situated within the perimeters or vicinity of a military airfield.

14. The Likelihood of UXO Contamination Summary

The following table assesses the likelihood that the site was contaminated by items of German air delivered and Allied ordnance. Factors such as the risk of UXO initiation, remaining, and encountering will be discussed later in the report.

UXO Contamination Summary	
Quality of the Historical Record	The research has evaluated pre- and post-WWII Ordnance Survey maps, Luftwaffe reconnaissance imagery, post-war aerial imagery, Kent Daily Bomb Census Mapping, Medway Group War Diaries, WWII-era aerial imagery, in-house data and online sources The record set is of generally satisfactory quality. Although some incidents and evidence of damage are corroborated across the record-set, there are many discrepancies owing to the uncomprehensive nature of many sources.
German Aerial Delivered Ordnance	• During WWII the site was located within the Urban District of Northfleet, which sustained an overall high density of bombing with an average of 103.2 items of ordnance falling per 1,000 acres according to official Home Office bombing statistics. This was mainly due to the industrial capacity of the town and its position on the River Thames, with numerous factories and commercial ports located along the harbour area • Kent Daily Bomb Mapping records numerous bomb incidents within the Northfleet area, although the mapping was recorded on small scale maps and thus it is not possible to determine the exact locations of individual bomb strikes, beyond establishing the approximate locality of the incidents. • Northfleet and Medway Group War Diary written records record several bomb incidents within the vicinity of the site, most notably at the location of the Paper Mills directly north-east of the site.. No bomb incidents are recorded directly within the site boundary, although there are no major structures within the site boundary from which to identify the location of a bomb strike. • Anecdotal evidence corroborates these written records, confirming Bowater Paper Mill did indeed suffer several bomb strikes. • WWII-era aerial photography of the site from 1944 shows no obvious indications of bomb damage such as craters, or ground disturbances in the undeveloped portions of the site. The housing, situated in the south-eastern section of the site, also appears externally intact and undamaged. There is evidence of bomb damage in the vicinity of the site, and roofing repairs can be observed on the Paper Mills factory to the north-east of the site- see **Annex M2**. • The south of the site is not considered to have had ground cover conducive to the detection of UXO as it was occupied by predominantly undeveloped ground. UXO entry holes, which could be as small as 20cm in diameter and could have easily been obscured by the vegetation present within the site and its surrounds. The ground cover in the north of the site is considered to have been more conducive to the detection of UXO. This is because the site comprised of more developed land, including landscaped allotments, small structures and roadways • The access frequency of access to the site is not considered to have been homogenous. The southern section of the site, comprising of predominantly undeveloped ground, is considered to have experienced a low degree of access, owing to the lack of structures. The northern section of the site is considered to have experienced a higher degree of access, due to the presence of on-site structures and roadways, and the proximity of the nearby Paper Mills factory. How often the allotment gardens in this area were accessed is wholly dependent upon how often each owner visited their allotment garden. The south-eastern section of the site was occupied by residential housing. It appears that the housing survived the war structurally intact. Therefore, it is thought likely that residents would have continued to live there and therefore conduct post-raid checks, for evidence of UXO. Generally, more frequent access increases the likelihood UXO could go noticed and reported.

	• To summarise, no positive evidence of on-site bomb strikes or bomb damage could be found. However, there is evidence of bomb strikes and bomb damage to roads and structures within the wider vicinity of the site, particularly in relation to the nearby former Bowater Paper Mill factory. Subsequently, although the evidence available does not indicate the UXO risk on site to be significantly elevated above the 'background level' of risk for Gravesend, the risk from UXO cannot be entirely discounted and has been designed as **Low-Medium**. As a result of this risk level, it is recommended that a UXO risk management plan is in place prior to intrusive works taking place and that any staff undertaking such works receive UXO awareness briefings.
Allied Ordnance	• Anecdotal evidence sourced online suggests that the Bowater Paper Mills, situated immediately east of the northern section of the site, may have been requisitioned during the war for the production of weaponry. It has not been possible to completely verify the information, but is it considered likely that this would have involved the large-scale use and storage of explosives, as the available evidence indicates that the factory was used to build the components of weapons. The factory was also outside the site boundary. This factor is thus not considered to have any significant impact on the risk of Allied UXO contamination on-site. • There is no evidence that the site formerly had any military occupation or usage that could have led to contamination with items of Allied ordnance, such as LSA and SAA. The conditions in which HAA or LAA projectiles may have fallen unnoticed within the site boundary are however analogous to those regarding aerial delivered ordnance.

15. The Likelihood that UXO Remains

15.1. Introduction

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

15.2. UXO Clearance

1st Line Defence has found no evidence in the public domain or within internal records that any official ordnance clearance operations have taken place on site. Note however that we have not received confirmation of this fact from the 33 EOD Regiment Archive (now part of 29 EOD & Search Group). It should also be noted that in addition to 29 EOD & Search Group archival information, 1st Line Defence also do not currently have access to data that may be relevant including 5131(BD)SQN Archive, SD Training Technical Advisory Section (TAS) and MACA Records (bomb disposal callouts).

If such information is available at a later date, it is recommended that it be reviewed as it will assist with understanding both levels and types of contamination likely to be present, and may indicate risk reduction in certain areas.

15.3. Post-War Redevelopment

The site has been significantly redeveloped post-war. Historical OS mapping and current satellite imagery indicates that a large area of industrial structures and associated hard-ground has been developed on the previously mostly undeveloped land within the site boundary, which has subsequently been redeveloped. 1st Line Defence has found no evidence to suggest that any items of UXO were encountered during these prior post-war works on site.

The risk of UXO remaining is considered to be mitigated at the location of and down to the depth of any post-war redevelopment on site. For example, the risk from deep buried UXO will only have been mitigated within the volumes of any post-war pile foundations or deep excavations for basement levels. The risk will however remain within virgin geology below and amongst these post-war works, down to the maximum bomb penetration depth.

16. The Likelihood of UXO Encounter

16.1. Introduction

For UXO to pose a risk at a site, there should be a means by which any potential UXO might be encountered on that site.

The likelihood of encountering UXO on the site of proposed works would depend on various factors, such as the type of UXO that might be present and the intrusive works planned on site. In most cases, UXO is more likely to be present below surface (buried) than on surface.

In general, the greater the extent and depth of intrusive works, the greater the risk of encountering. The most likely scenarios under which items of UXO could be encountered during construction works is during piling, drilling operations or bulk excavations for basement levels. The 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.

Generally speaking, the risk of encountering any type of UXO will be minimal for any works planned within the footprint and down to the depth of post-war foundations and excavations.

16.2. Encountering Air Delivered Ordnance

Since an air delivered bomb may come to rest at any depth between just below ground level and its maximum penetration depth, there is a chance that such an item (if present) could be encountered during shallow excavations (for services or site investigations) into the original WWII ground level as well as at depth.

17. The Likelihood of UXO Initiation

17.1. Introduction

UXO does not spontaneously explode. Older UXO devices will require an external event/energy to create the conditions for detonation to occur. The likelihood that a device will function can depend on a number of factors including the type of weaponry, its age and the amount of energy it is struck with.

17.2. Initiating Air Delivered Ordnance

Unexploded bombs do not spontaneously explode. All high explosive filling requires significant energy to create the conditions for detonation to occur.

In recent decades, there have been a number of incidents in Europe where Allied UXBs have detonated, and incidents where fatalities have resulted. There have been several hypotheses as to the reason why the issue is more prevalent in mainland Europe – reasons could include the significantly greater number of bombs dropped by the Allied forces on occupied Europe, the preferred use by the Allies of mechanical rather than electrical fuzes, and perhaps just good fortune. The risk from UXO in the UK is also being treated very seriously in many sectors of the construction industry, and proactive risk mitigation efforts will also have affected the lack of detonations in the UK.

There are certain construction activities which make initiation more likely, and several potential initiation mechanisms must be considered:

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

18. Consequences of Initiation/Encounter

18.1. Introduction

The repercussions of the inadvertent detonation of UXO during intrusive ground works, or if an item or ordnance is interfered with or disturbed, are potentially profound, both in terms of human and financial cost. A serious risk to life and limb, damage to plant and total site shutdown during follow-up investigations are potential outcomes. However, if appropriate risk mitigation measures are put in place, the chances of initiating an item of UXO during ground works is comparatively low.

The consequences of encountering UXO can be particularly notable in the case of high-profile sites (such as airports and train stations) where it is necessary to evacuate the public from the surrounding area. A site may be closed for anything from a few hours to a week with potentially significant cost in lost time. It should be noted that even the discovery of suspected or possible item of UXO during intrusive works (if handled solely through the authorities), may also involve significant loss of production.

18.2. Consequences of Detonation

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

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

19. 1st Line Defence Risk Assessment

19.1. Risk Assessment Stages

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

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

19.2. Assessed Risk Level

1st Line Defence has assessed that there is an overall **Low-Medium Risk** from German and anti-aircraft unexploded ordnance at the site of proposed works. There is also an assessed **Low Risk** from Allied ordnance.

Ordnance Type	Risk Level			
	Negligible	Low	Medium	High
German Unexploded HE Bombs		✓		
German 1kg Incendiary Bombs		✓		
Allied Anti-Aircraft Artillery Projectiles		✓		
Allied Land Service and Small Arms Ammunition		✓		

Please note – although the risk from unexploded ordnance on this site has been assessed as 'Low', this does not mean there is 'no' risk of encountering UXO. This report has been undertaken with due diligence, and all reasonable care has been taken to access and analyse relevant historical information. By necessity, when dealing historical evidence, and when making assessments of UXO risk, various assumptions have to be made which we have discussed and justified throughout this report. Our reports take a common-sense and practical approach to the assessment of risk, and we strive to be reasonable and pragmatic in our conclusions.

It should however be stressed that if any suspect items are encountered during the proposed works, 1st Line Defence should be contacted for advice/assistance, and to re-assess the risk where necessary. The mitigation measures outlined in the next section are recommended as a minimum precaution to alert ground personnel to the history of the site, what to look out for, and what measures to take in the event that a suspect item is encountered. It should also be noted that the conclusions of this report are based on the scope of works outlined in the 'Proposed Works' section of this report. Should the scope of works change or additional works be proposed, 1st Line Defence should be contacted to re-evaluate the risk.

20. Proposed Risk Mitigation Methodology

20.1. General

The following risk mitigation measures are recommended to support the proposed works at Northfleet, Gravesend, Kent:

Type of Work	Recommended Mitigation Measure
All Works	• **UXO Risk Management Plan** It is recommended that a site-specific plan for the management of UXO risk be written for this site. This plan should be kept on site and be referred to in the event that a suspect item of UXO is encountered at any stage of the project. It should detail the steps to be taken in the event of such a discovery, considering elements such as communication, raising the alarm, nominated responsible persons etc. Contact 1st Line Defence for help/more information. • **Site Specific UXO Awareness Briefings to all personnel conducting intrusive works.** As a minimum precaution, all personnel working on the site should be briefed on the basic identification of UXO and what to do in the event of encountering a suspect item. This should in the first instance be undertaken by a UXO Specialist. Posters and information on the risk of UXO can be held in the site office for reference.

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

1st Line Defence Limited **19/05/23**

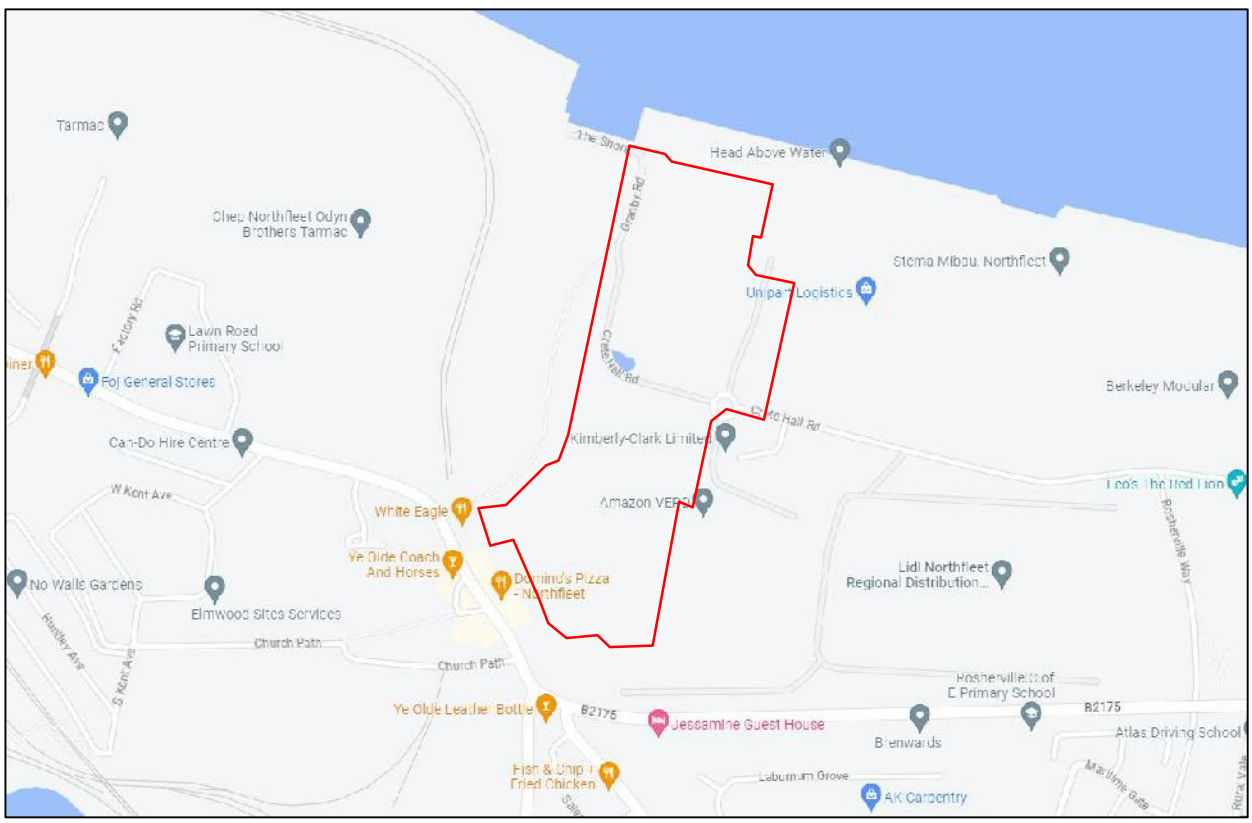
This Report has been produced in compliance with the Construction Industry Research and Information Association (CIRIA) C681 guidelines for the writing of Detailed UXO Risk Assessments.

Bibliography

- Bates, H. E., *Flying Bombs over England*, Frogletts Publications Ltd., 1994
- Dobinson, C., *AA Command: Britain's Anti-Aircraft Defences of the Second World War*, Methuen., 2001
- Fegan, T., *The 'Baby Killers': German Air raids on Britain in the First World War*, Leo Cooper Ltd., 2002
- Fleischer, W., *German Air-Dropped Weapons to 1945,* Midland Publishing., 2004
- Jappy, M. J., *Danger UXB: The Remarkable Story of the Disposal of Unexploded Bombs during the Second World War*, Channel 4 Books., 2001
- Price, A., *Blitz on Britain, The Bomber Attacks on the United Kingdom 1939 – 1945*, Purnell Book Services Ltd., 1977
- Ramsey, W., *The Blitz Then and Now, Volumes 1,2 & 3*, Battle of Britain Prints International Ltd., 1987, 1988 & 1990
- Scofield, J., *Modern Military Matters*., Council for British Archaeology., 2004
- Stone, K., et al., *Unexploded Ordnance (UXO) A Guide For The Construction Industry (C681)*., CIRIA, 2009
- Whiting, C., *Britain Under Fire: The Bombing of Britain's Cities 1940-1945*, Pen & Sword Books Ltd., 1999

Site Location Maps

Annex: **A**



1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client:	**GVR Geoservices Ltd**	**Approximate site boundary**	N
Project:	**Northfleet, Gravesend, Kent**		
Ref:	**DA11104a-00**	Source: Google Maps	

Recent Aerial Photography

Annex: **B**

1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00**

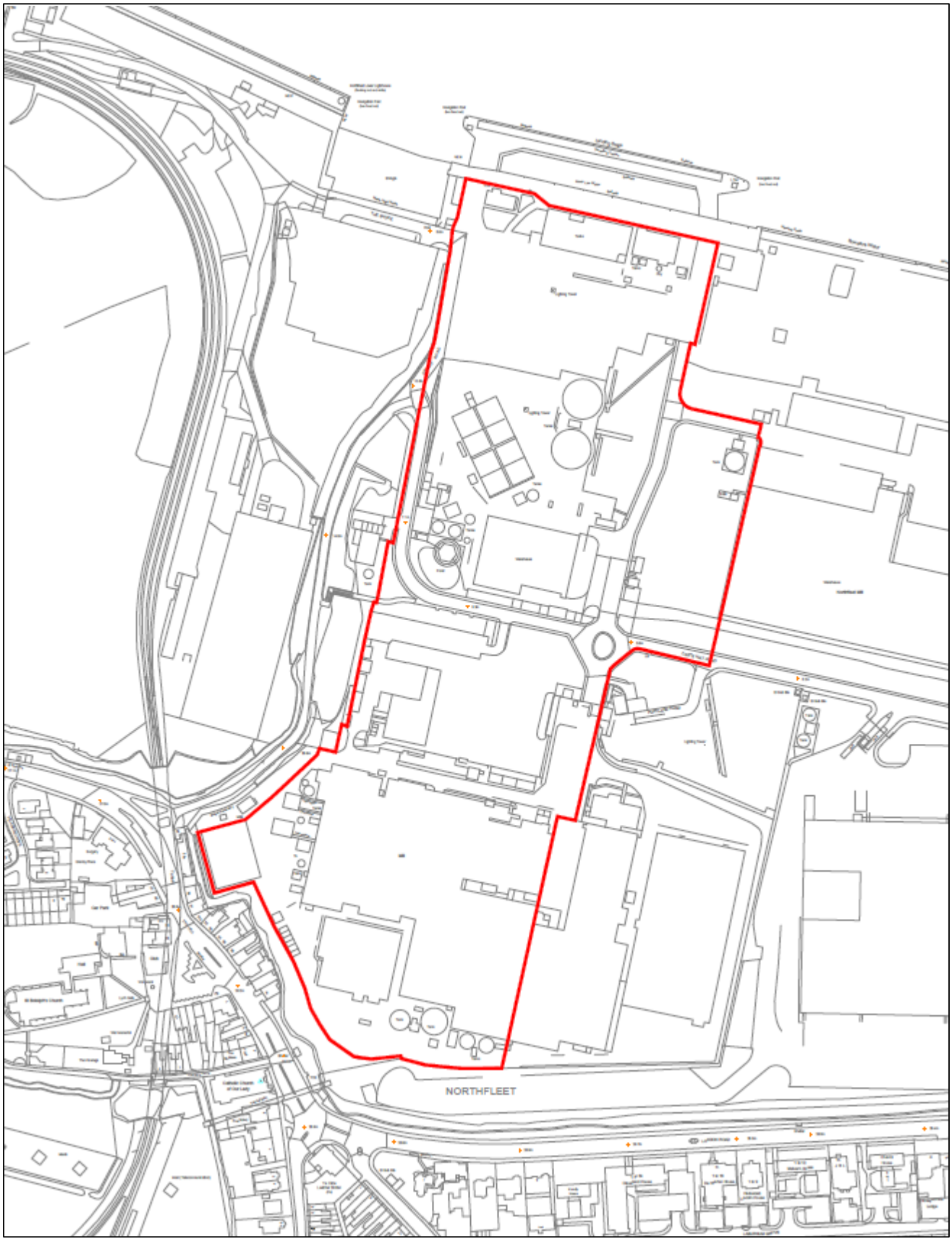
Source: Google Earth ™ Mapping Services

Approximate site boundary

N

Client Provided Site Plan

Annex: C



1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Approximate site boundary

N

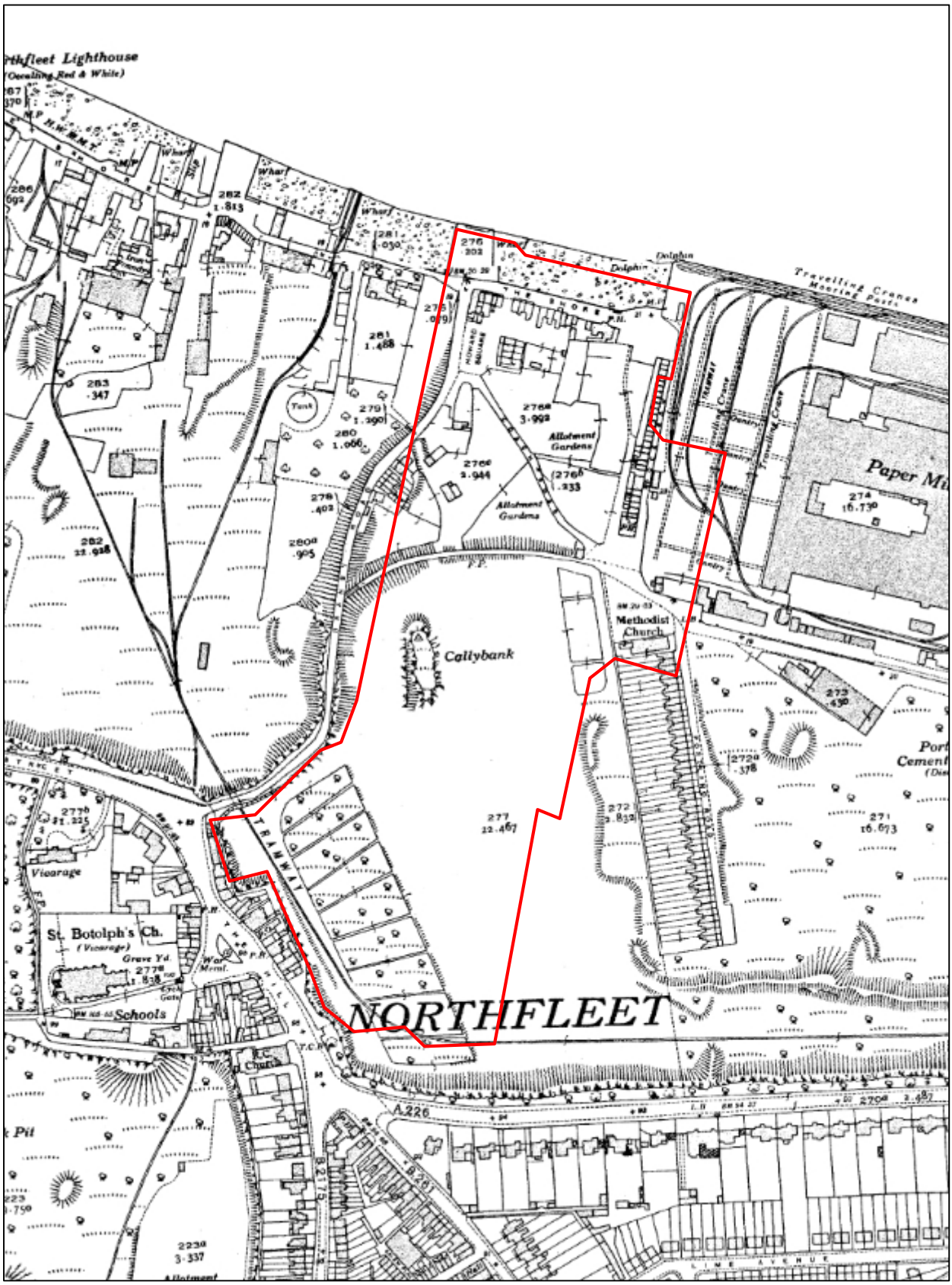
Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00**

Source: GVR Geoservices Ltd

Pre-WWII Historical Map, 1939

Annex: **D1**



1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00**

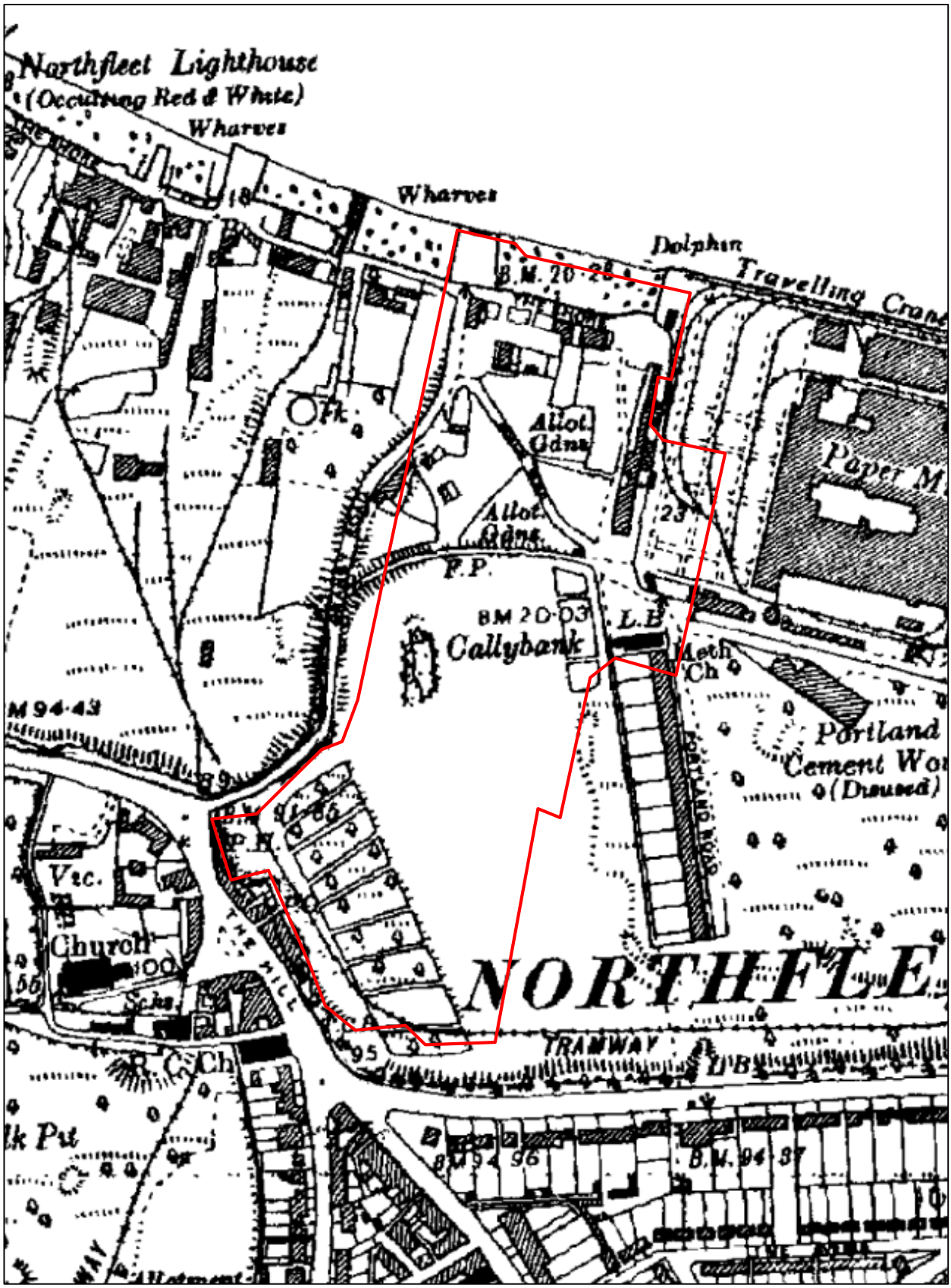
Source: Landmark Maps

Approximate site boundary

N

Post-WWII Historical Map, 1946

Annex: D2



1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00**

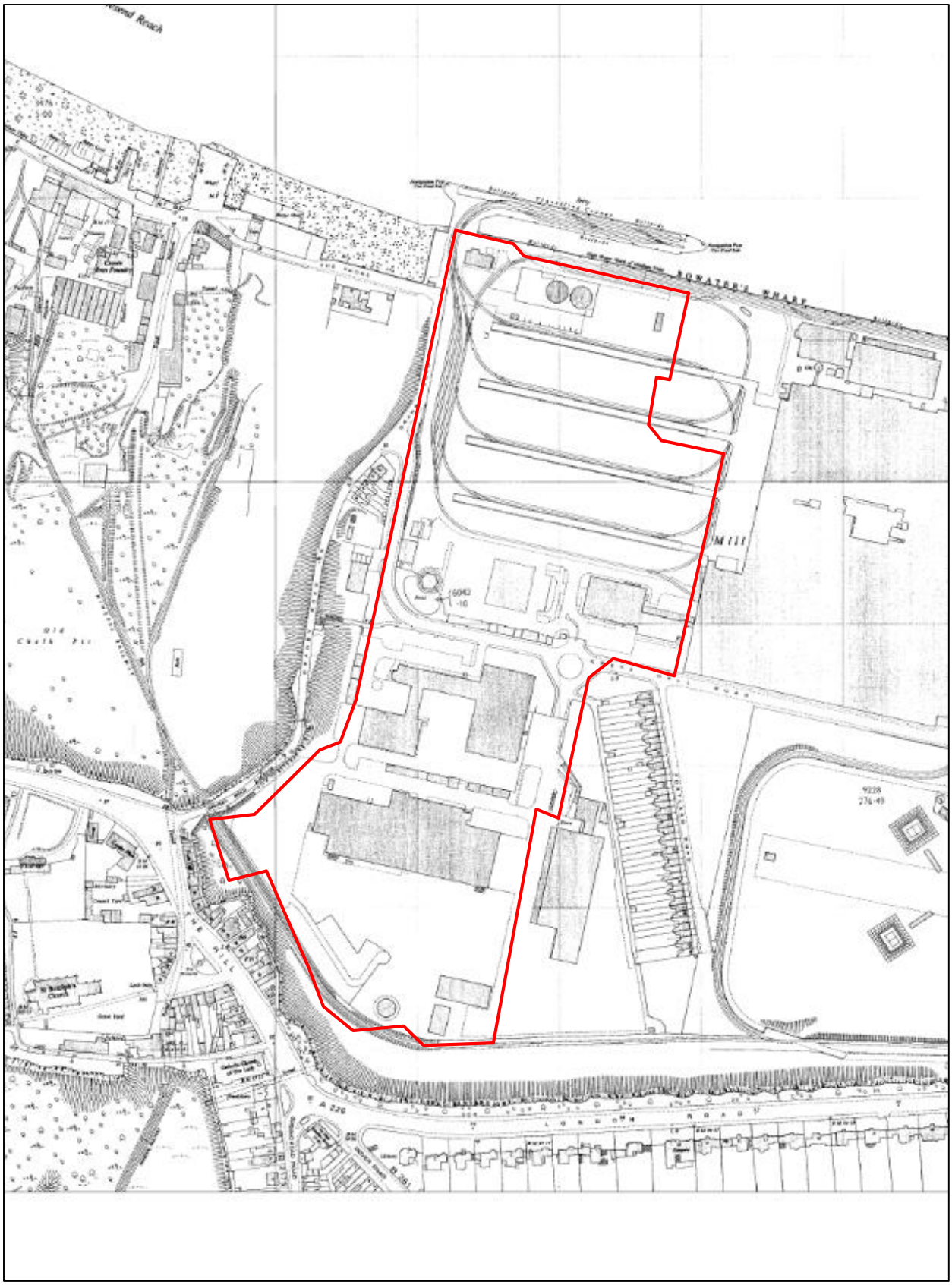
Source: Landmark Maps

Approximate site boundary

N

Post-WWII Historical Map, 1967

Annex: D3



1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00**

Source: Landmark Maps

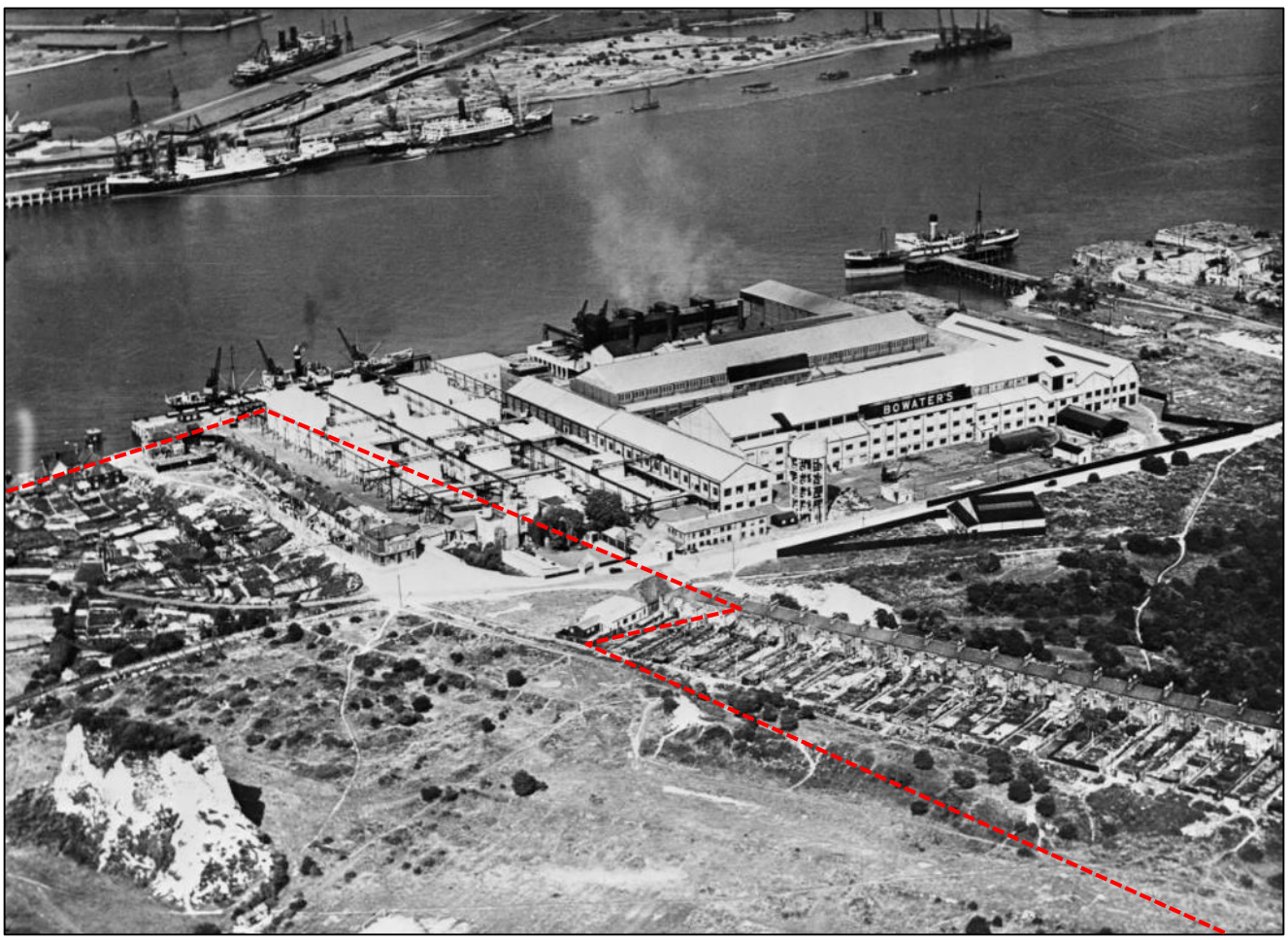
Approximate site boundary

N

Oblique Aerial Photography August 1932

Annex: **E1**

Approximate Partial Site Area.



1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Approximate site boundary

Project: **Northfleet, Gravesend, Kent**

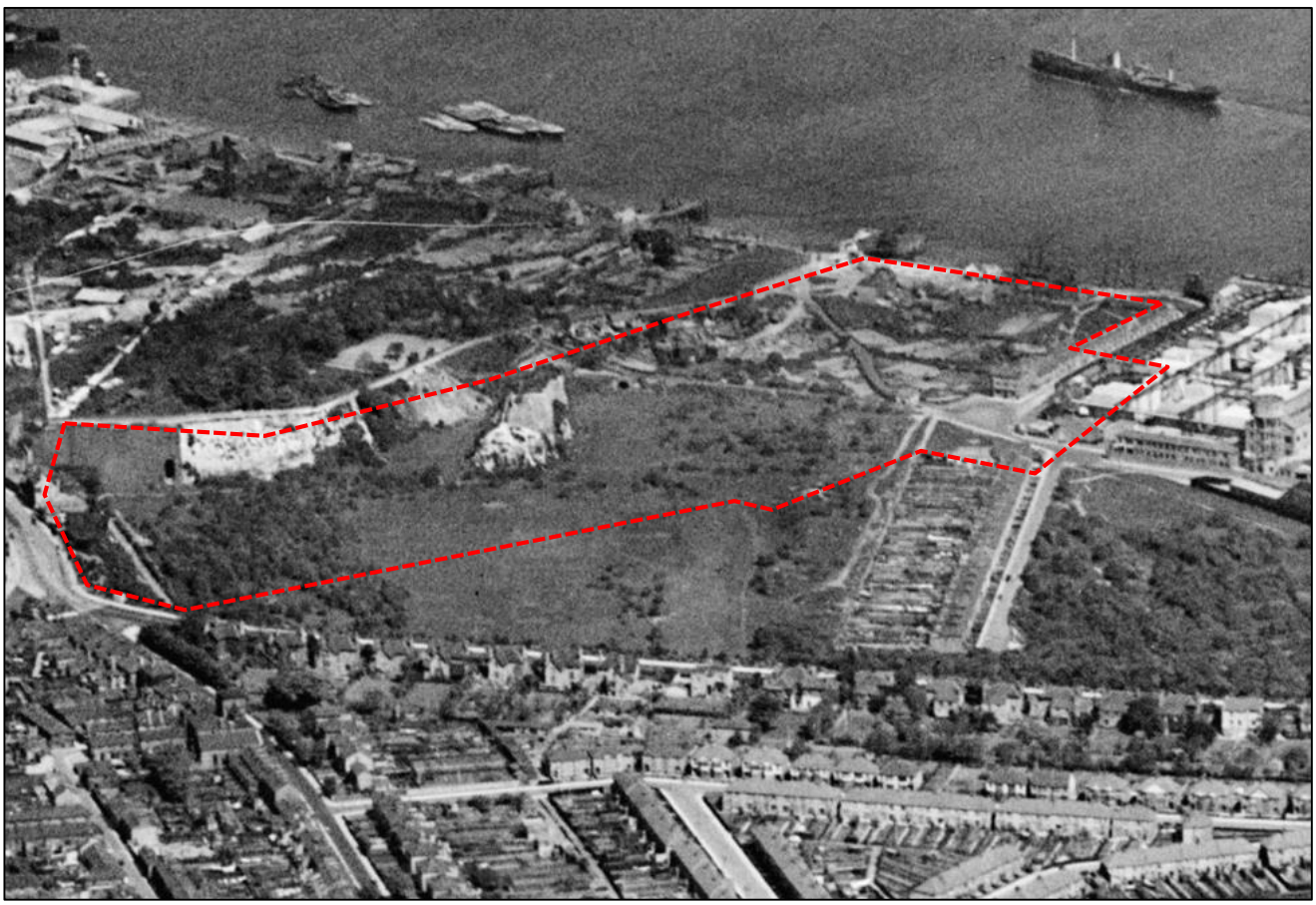
Ref: **DA11104a-00**

Source: Britain From Above

Oblique Aerial Photography 12th May 1939

Annex: **E2**

Approximate Site Area.



1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Approximate site boundary

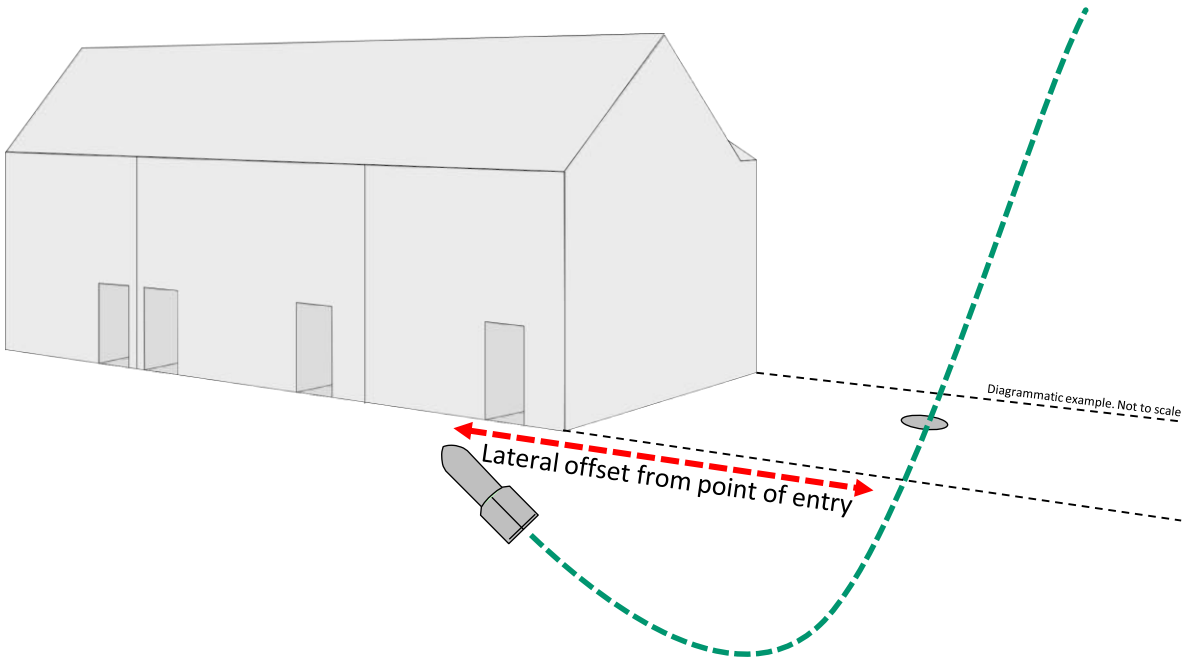
Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00**

Source: Britain From Above

Example of UXO Entry Hole / The 'J-curve' Effect Principle

Annex: **F**



Top: J-curve Effect - Due to angle of entry, unexploded bombs would often end their trajectory at a lateral offset from point of entry, often ending up beneath adjacent extant structures/sites. The photograph above shows a 250kg unexploded bomb found in Bermondsey in 2015, pointing upwards, demonstrating 'J-curve'.

One of the most common scenarios for UXO going unnoticed was when a UXB fell into a 'bomb site' (such as the area shown **Top Left**), the entry hole of the bomb obscured by any debris and rubble present. Note that the entry hole of a 50kg UXB could be as little as 20cm in diameter (**Left**).

1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00**

Source: Various sources

BBC NEWS

Bermondsey bomb: World War Two device safely removed

An unexploded World War Two bomb found in south London has been driven away safely under police and Army escort.

The 500lb (250kg) device was found on a building site in Grange Walk, Bermondsey on Monday.

Two primary schools were closed and hundreds of homes were evacuated as a precaution.

A cordon and 656ft (200m) exclusion zone was lifted at about 18:15 GMT as the bomb was removed to a quarry in Kent to be detonated, police said.

The Metropolitan Police force said the device was a 'SA' 250kg WWII German air-dropped bomb, known to the Army's Royal Logistic Corps bomb disposal experts.

250kg German HE Bomb, March 2015

BBC NEWS

WW2 bomb found near London City Airport blown up

An unexploded World War Two bomb found near London City Airport has been detonated.

The 500kg device was discovered at the King George V Dock on Sunday during planned work at the airport.

It was closed and all flights were cancelled on Monday after an exclusion zone was put in place.

The detonation, which took take place off Shoeburyness, Essex, was postponed on Tuesday because of high winds and dangerous conditions for divers.

The 1.5m-long German bomb - which was found in a bed of silt, 15m underwater - was carefully removed from the Thames and placed in a secure location a mile away from the coast of Essex.

500kg German HE Bomb, February 2018

BBC NEWS

Exeter WW2 bomb is detonated after homes evacuated

More than 2,600 households and 12 university halls of residence were cleared before the 2,200lb (1,000kg) device **was destroyed** on Saturday.

Police said the blast left a crater about the size of a double-decker bus.

Police have reported large pieces of metal debris hitting buildings and said some properties in the 100m (330ft) exclusion zone had sustained "structural damage".

1000kg German HE bomb, February 2021

BBC NEWS

Great Yarmouth: Huge blast after unplanned WW2 bomb detonation

A World War Two bomb found in Great Yarmouth has detonated while work was being done to defuse it, causing a huge blast that was heard for miles.

Army specialists were attempting to disarm it when there was an unplanned detonation at about 17:00 GMT.

People on social media said they heard a loud bang and felt buildings shake 15 miles (24km) away.

There have been no reports of injuries among the Army, emergency services or the public, Norfolk Police said.

Cordons were put in place when the bomb was first discovered close to two gas pipes on Tuesday, and work began to make it safe.

250kg German HE Bomb, February 2023

1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00** Source: BBC News

Examples of Unexpected Detonation of WWII Bombs in Europe

Annex: **G2**

BASF has confirmed that an explosive device, most likely a World War II-era bomb, caused the blast that left one person injured Tuesday at a plant construction site in Germany.

The explosion was reported at BASF's Ludwigshafen toluene diisocyanate (TDI) plant, which recently broke ground for a 300,000 metric tons per year TDI production plant and other construction to expand its facilities.

BASF Provides Some Details

Responding to a request from *PaintSquare News* for more information on Wednesday (Feb. 27), BASF's manager of media relations and corporate communications Europe, Ursula von Stetten, wrote in an email, "So here [are] the facts: The detonation took place at 10:00 a.m. One person was injured; the injury is not serious. He will be kept in the hospital for some days.

"Cause of the detonation was an explosive device, presumably a bomb deriving from the Second World War. The device detonated when grounding work was done. No details on [a] delay [are] available. At the moment, the exact circumstances of the incident are [being] evaluated."

1st March 2013

SPIEGEL ONLINE

Blast Kills One

World War II Bomb Explodes on German Motorway

A highway construction worker in Germany accidentally struck an unexploded World War II bomb, causing an explosion which killed him and wrecked several passing cars.

A World War II bomb has exploded during construction work on a German highway, killing one worker and injuring several motorists who were driving past, police said.

The worker had been cutting through the road surface near the south-western town of Aschaffenburg when his machine struck the bomb and triggered it. Police said they weren't sure yet what type of bomb it was. "The explosion seems to have been too small for it to have been an aircraft bomb," a police spokesman said.

23rd October 2006

WWII bomb injures 17 at Hattingen construction site

Seventeen people were injured on Friday when a construction crew unwittingly detonated a buried World War II-era bomb in Hattingen.

An excavator apparently drove over a 250-kilogramme (550 pound) American bomb, damaging surrounding buildings. Most of the injured suffered auditory trauma from the blast, and the excavator operator suffered injuries to his hands, police in the German state of North Rhine-Westphalia said.

"The hole was astoundingly small for such a large bomb full of so many explosives," Armin Gebhard, head of the Arnsberg department for military ordnance removal, told The Local. "But of course it damaged all the surrounding buildings too. We are really happy it wasn't worse."

19th September 2013

BBC NEWS

World War II bomb kills three in Germany

A special commission is investigating the causes of the explosion, while prosecutors are considering whether the team leader should face charges of manslaughter through culpable negligence, the BBC's Oana Lungescu reports from Berlin.

The blast happened an hour before the defusing operation was due to start.

Officials said the three men who died were experienced sappers, or combat engineers, who over 20 years had defused up to 700 bombs.

More than 7,000 people were immediately evacuated when the 500kg bomb was found. Several schools, a kindergarten and local companies remain closed.

2nd June 2010

June 2006

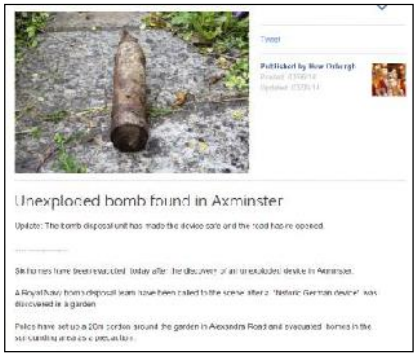
1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client:	**GVR Geoservices Ltd**		
Project:	**Northfleet, Gravesend, Kent**		
Ref:	**DA11104a-00**	Source:	Various news sources

Examples of Land Service Ammunition finds in the UK

Annex: G3



Land Service Ammunition (LSA) resulting from historic military activity is commonly encountered across the UK by the public and construction industry alike. Such finds are much more common in rural areas than in urban environments, and can often be anticipated in areas such as former RAF stations or ranges. However, such items are also encountered entirely by surprise where the landowner or developer has no knowledge of any previous military use of the land.

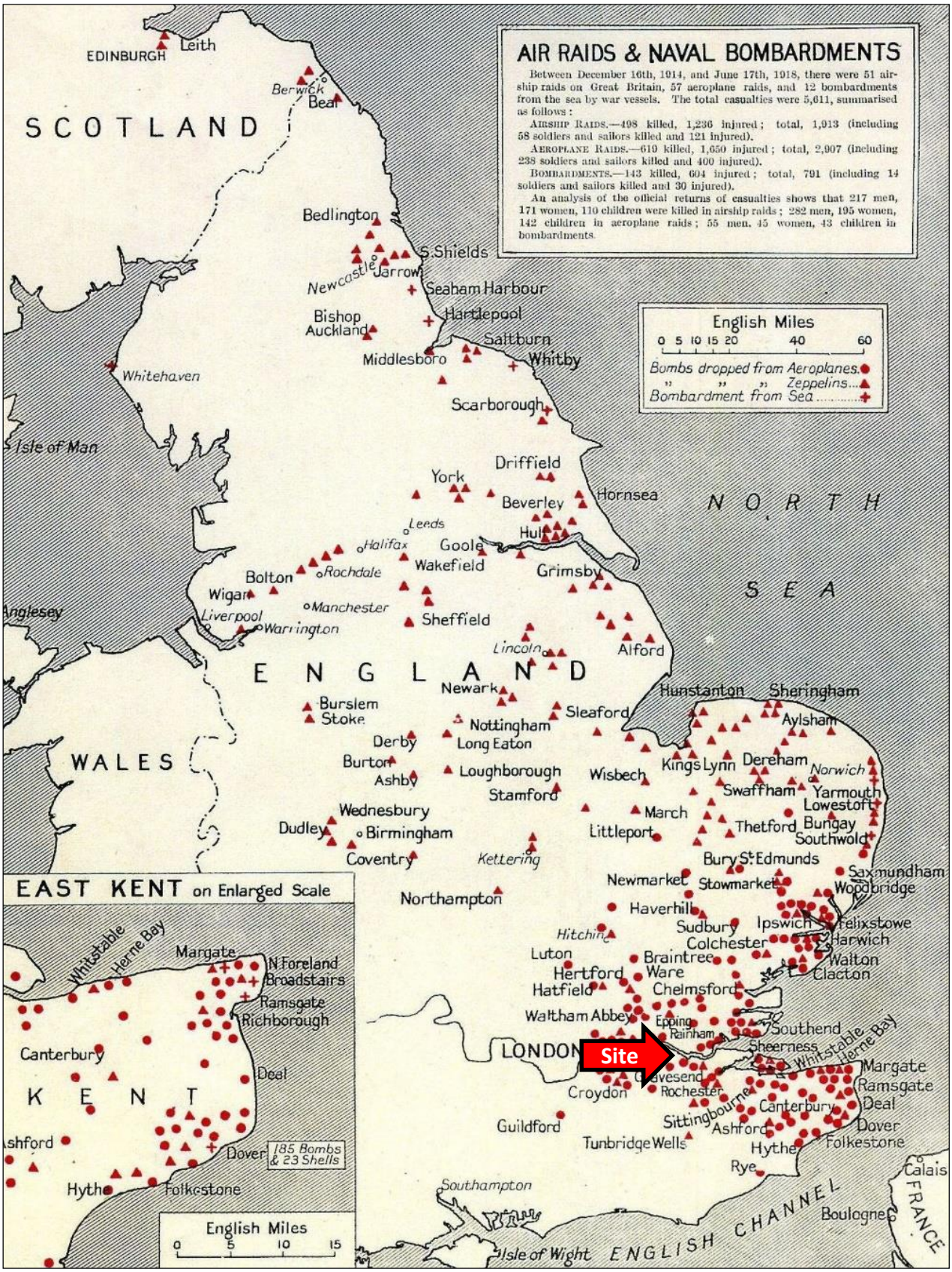
1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client:	**GVR Geoservices Ltd**		
Project:	**Northfleet, Gravesend, Kent**		
Ref:	**DA11104a-00**	Source:	Various news sources

WWI Map of Air Raids and Naval Bombardments

Annex: H



1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00**

Source: J. Morris, *German Air Raids on Britain*

N

Luftwaffe Photograph, 4th June 1939

Kent – Gravesend
A) 'Kraftwerk' (Power station)– Designated Luftwaffe target

The site located immediately west of target A

1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00**

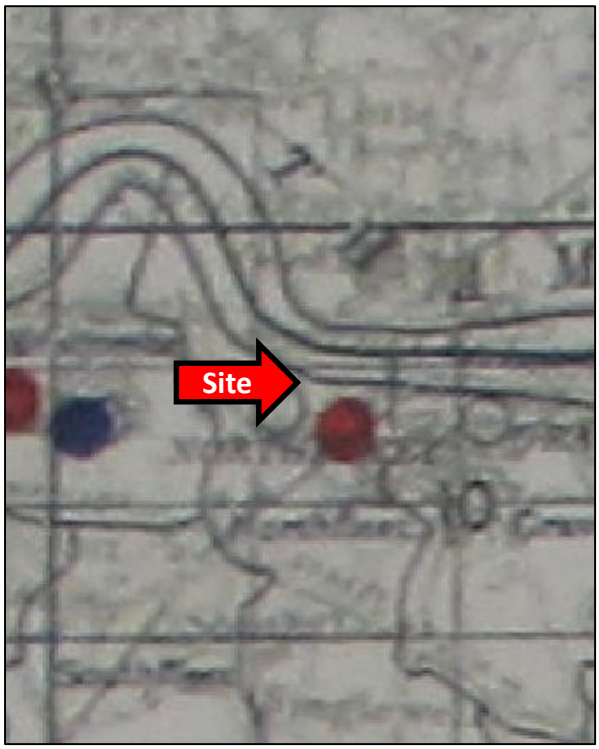
Source: Nigel J. Clarke, "Adolf Hitler's Home Counties Holiday Snaps"

Kent Daily Bomb Mapping

Annex: **J1**

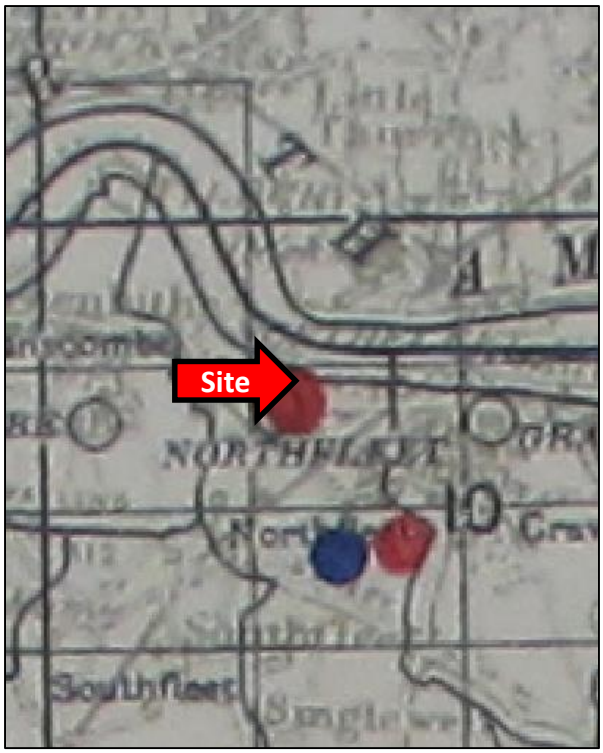
28th August 1940

8th September 1940



14th September 1940

5th October 1940



Recorded bomb strike Incendiary bomb strike

1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00**

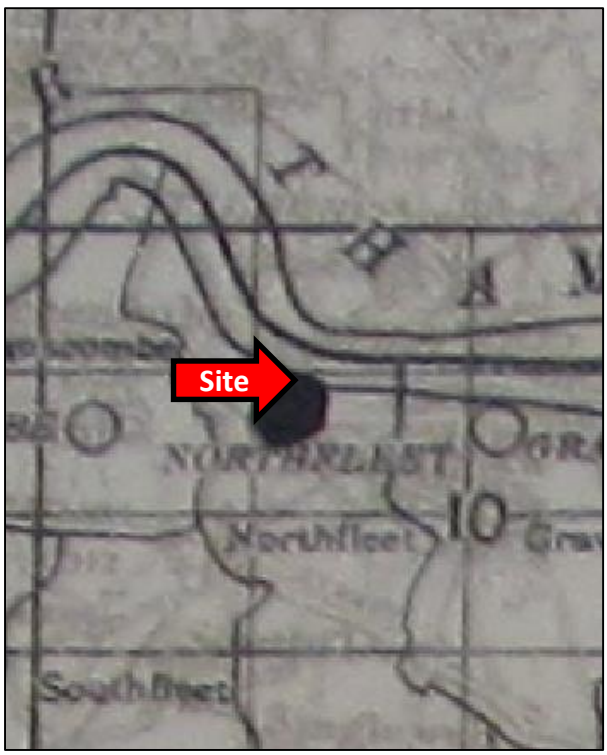
Source: Kent History and Library Centre

N

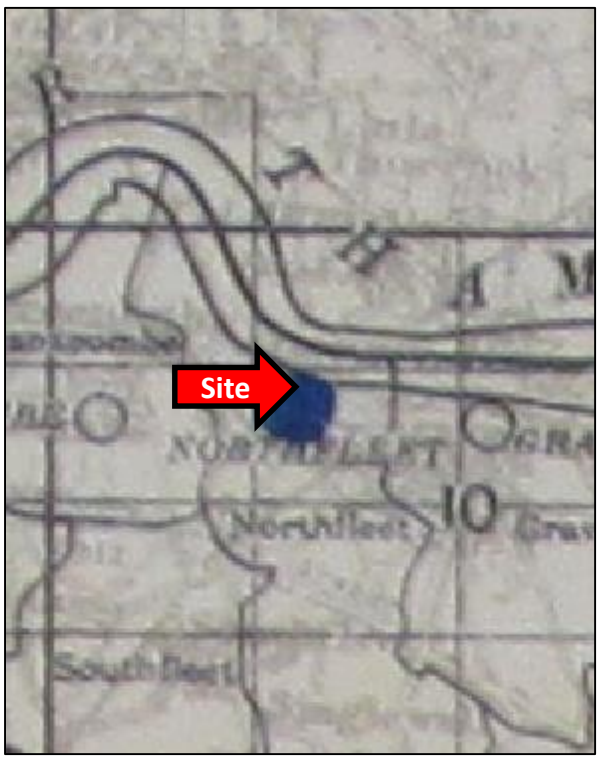
23rd October 1940

14 September 1940

17th March 1941



March 23rd 1941



Recorded bomb strike Incendiary bomb strike

1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00**

Source: Kent History and Library Centre

N

V-1 and Shells Daily Bomb Census Map

Annex: **K**

19th July 1944

Recorded V-1 bomb strike

1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

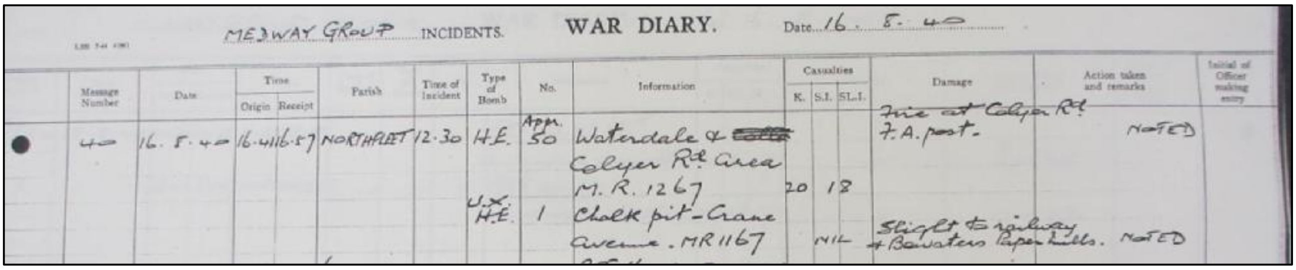
Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00**

Source: Kent History and Library Centre

N

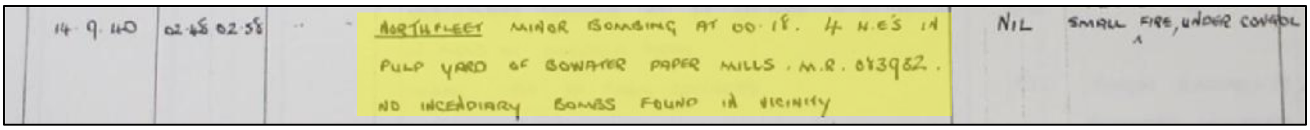
16th August 1940



MEDWAY GROUP INCIDENTS. WAR DIARY. Date 16. 8. 40

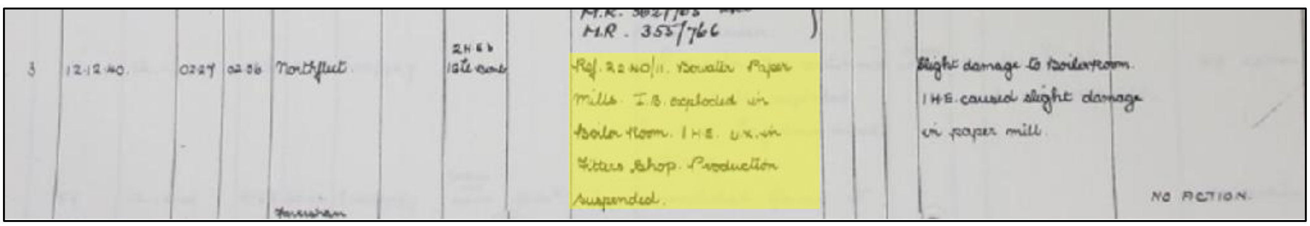
Message Number	Date	Time Origin	Time Receipt	Parish	Time of Incident	Type of Bomb	No.	Information	Casualties K.	Casualties S.I.	Casualties SL.I.	Damage	Action taken and remarks	Initial of Officer making entry
40	16. 8. 40	16.41	16.57	NORTHFLEET	12-30	H.E.	Appr. 50	Waterdale & Colyer Rd Area M.R. 1267	20	18		Fire at Colyer Rd F.A. post.	NOTED	
						U.X. H.E.	1	Chalk pit - Crane avenue. MR 1167	NIL			Slight to railway & Bowaters Paper Mills.	NOTED	

4th September 1940



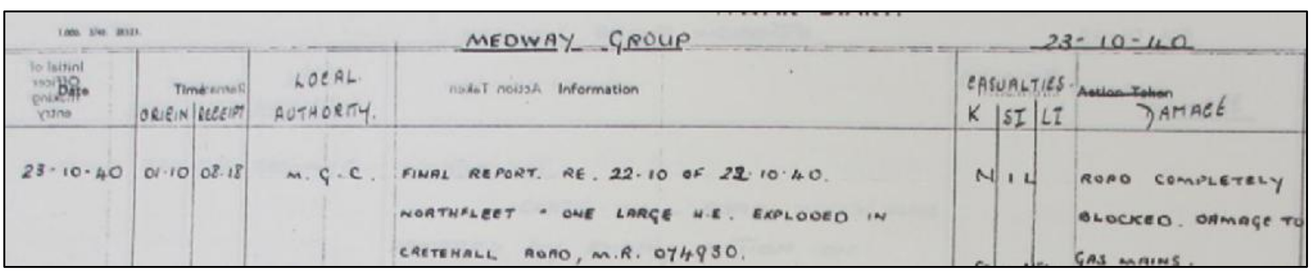
4. 9. 40	02.48	02.58	NORTHFLEET	MINOR BOMBING AT 00.18. 4 H.E'S IN PULP YARD OF BOWATER PAPER MILLS. M.R. 073982. NO INCENDIARY BOMBS FOUND IN VICINITY	NIL	SMALL FIRE, UNDER CONTROL	

12th December 1940



3	12.12.40	0227	0256	Northfleet	2 H.E.s 1 U.X. bomb	Ref. 22.40/11. Bowater Paper Mills. I.B. exploded in Boiler Room. 1 H.E. U.X. in Fitters Shop. Production suspended.	Slight damage to Boiler room. 1 H.E. caused slight damage in paper mill	NO ACTION.

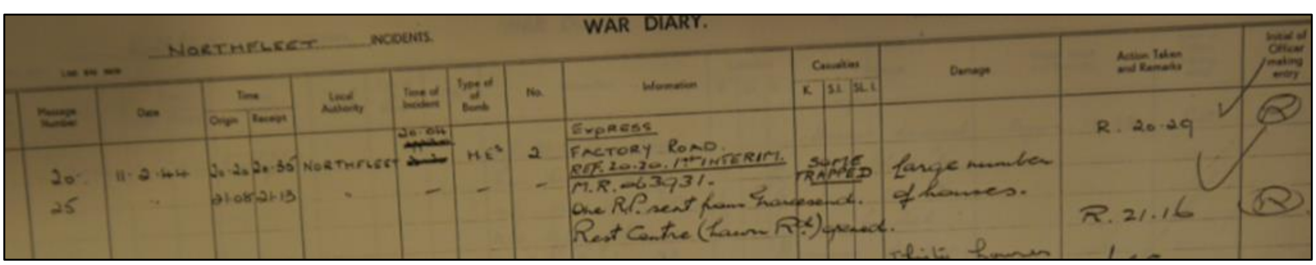
23rd October 1940



MEDWAY GROUP 23-10-40

Date	Time Origin	Time Receipt	LOCAL AUTHORITY.	Information	CASUALTIES K	SI	LI	DAMAGE
23-10-40	01.10	08.18	M.G.C.	FINAL REPORT. RE. 22.10 OF 22.10.40. NORTHFLEET - ONE LARGE H.E. EXPLODED IN CRETEHALL ROAD, M.R. 074930.	N	I	L	ROAD COMPLETELY BLOCKED. DAMAGE TO GAS MAINS.

11th February 1944



NORTHFLEET INCIDENTS. WAR DIARY.

Message Number	Date	Time Origin	Time Receipt	Local Authority	Time of Incident	Type of Bomb	No.	Information	Casualties K.	S.I.	SL.I.	Damage	Action Taken and Remarks	Initial of Officer making entry
20 25	11.2.44	20.20 21.08	20.36 21.13	NORTHFLEET	20.04	H.E.s	2	Express Factory Road. REF. 20.20. 1st INTERIM. M.R. 063731. One R.P. sent from Gravesend. Rest Centre (Lawn Rd) opened.	SOME TRAPPED			Large number of houses.	R. 20.29 R. 21.16	

RAF Aerial Photography 18th April 1944

Annex: **M1**

1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Approximate site boundary

N

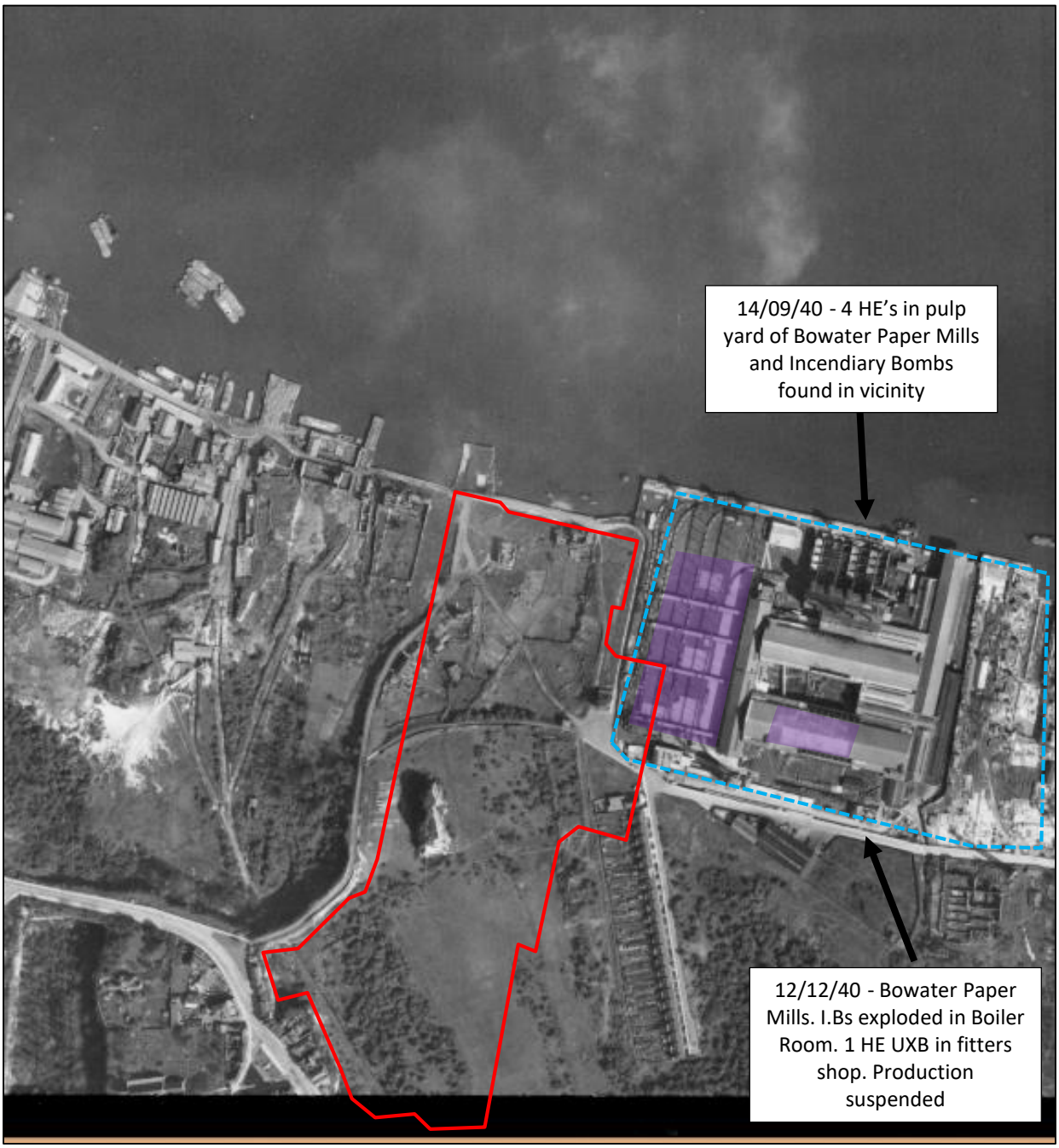
Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00**

Source: National Monuments Record Office (Historic England)

RAF Aerial Photography 18th April 1944 – Damage Overlay

Annex: **M2**



Visible Repairs to Damaged Roofing.

1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Approximate site boundary

N

Project: **Northfleet, Gravesend, Kent**

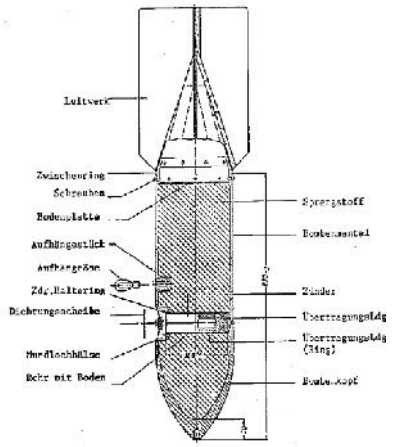
Ref: **DA11104a-00**

Source: National Monuments Record Office (Historic England)

Examples of German Aerial-Delivered Ordnance

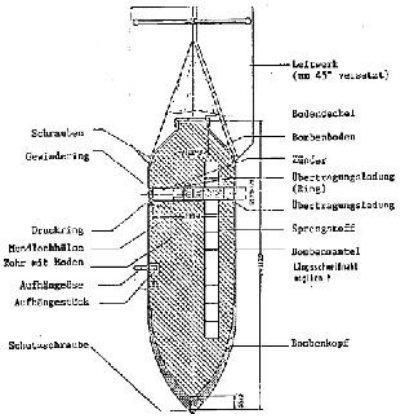
SC 50kg High Explosive Bomb

Bomb Weight	40-54kg (88-119lb)
Explosive Weight	25kg (55lb)
Fuze Type	Impact fuze/electro-mechanical time delay fuze
Bomb Dimensions	1,090 x 280mm (42.9 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 stories.
Remarks	The smallest and most common conventional German bomb. Nearly 70% of bombs dropped on the UK were 50kg.



SC 250kg High Explosive Bomb

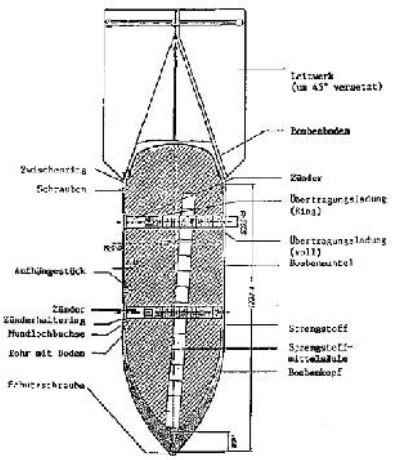
Bomb Weight	245-256kg (540-564lb)
Explosive Weight	125-130kg (276-287lb)
Fuze Type	Electrical impact/mechanical time delay fuze
Bomb Dimensions	1640 x 512mm (64.57 x 20.16in)
Body Diameter	368mm (14.5in)
Use	Against railway installations, embankments, flyovers, underpasses, large buildings and below-ground installations.
Remarks	It could be carried by almost all German bomber aircraft and was used to notable effect by the Junkers Ju-87 Stuka (*Sturzkampfflugzeug*, or dive-bomber).

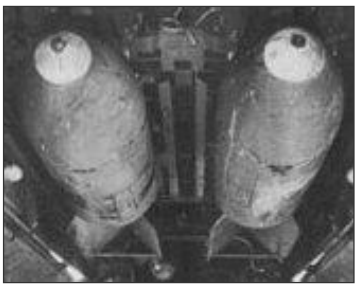


SC250 bomb being loaded onto German bomber

SC 500kg High Explosive Bomb

Bomb Weight	480-520kg (1,058-1,146lb)
Explosive Weight	250-260kg (551-573lb)
Fuze Type	Electrical impact/mechanical time delay fuze
Bomb Dimensions	1957 x 640mm (77 x 25.2in)
Body Diameter	470mm (18.5in)
Use	Against fixed airfield installations, hangars, assembly halls, flyovers, underpasses, high-rise buildings and below-ground installations.
Remarks	40/60 or 50/50 Amatol TNT, Trialene. Bombs recovered with Trialen filling have cylindrical paper-wrapped pellets, 1-15/16in. in length and diameter.





1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

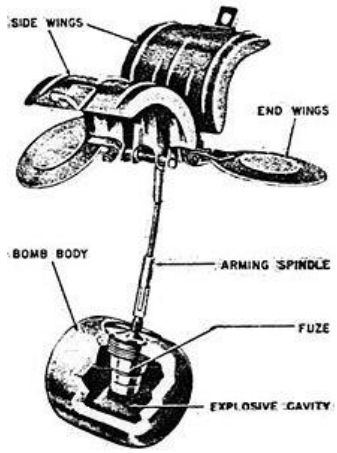
Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00**

Source: Various sources

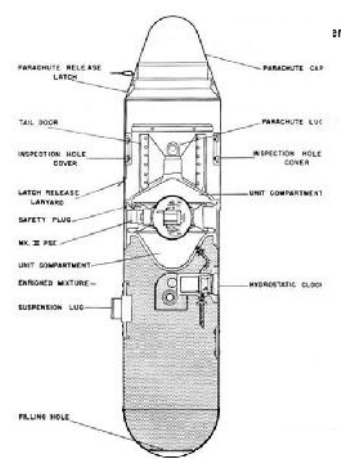
SD2 Anti-Personnel 'Butterfly Bomb'

Bomb Weight	Approx. 2kg (4.41lb)
Explosive Weight	Approx. 7.5oz (225 grams) of Amatol surrounded by a layer of bituminous composition.
Fuze Type	41 fuze (time) , 67 fuze (clockwork time delay) or 70 fuze (anti-handling device)
Body Diameter	3in (7.62 cm) diameter, 3.1in (7.874) long
Use	Designed as an anti-personnel/fragmentation weapon. They were delivered by air, being dropped in containers of 23-144 sub-munitions that opened at a predetermined height, thus scattering the bombs.
Remarks	Quite rare. First used against Ipswich in 1940, but were also dropped on Kingston upon Hull, Grimsby and Cleethorpes in June 1943, amongst various other targets in UK. As the bombs fell the outer case flicked open via springs which caused four light metal drogues with a protruding 5 inch steel cable to deploy in the form of a parachute & wind vane, which armed the device as it span.



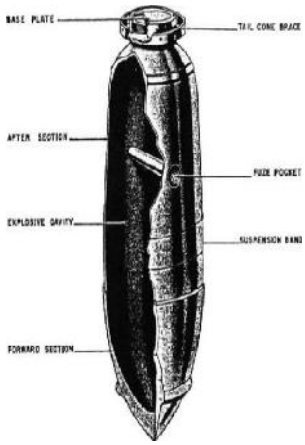
Parachute Mine (Luftmine B / LMB)

Bomb Weight	Approx. 990kg (2176lb)
Explosive Weight	Approx. 705kg (1,554lb)
Fuze Type	Impact/time delay/hydrostatic pressure fuze
Dimensions	2.64m x 0.64m (3.04m with parachute housing)
Use	Against civilian, military and industrial targets. Used as blast bombs and designed to detonate above ground level to maximise damage to a wider area.
Remarks	Deployed a parachute when dropped in order to control its descent. Had the potential to cause extensive damage within a 100m radius.



SC 1000kg

Bomb Weight	Approx. 993-1027kg (2,189-2,264lb)
Explosive Weight	Approx. 530-620kg (1168-1367lb)
Fuze Type	Electrical impact/mechanical time delay fuze.
Filling	Mixture of 40% amatol and 60% TNT, but when used as an anti-shipping bomb it was filled with Trialen 105, a mixture of 15% RDX, 70% TNT and 15% aluminium powder.
Bomb Dimensions	2800 x 654mm (110 x 25.8in)
Body Diameter	654mm (18.5in)
Use	SC-type bombs were General Purpose Bombs used primarily for general demolition work. Constructed of parallel walls with comparatively heavy noses, they are usually of three-piece welded construction.



1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Project: **Northfleet, Gravesend, Kent**

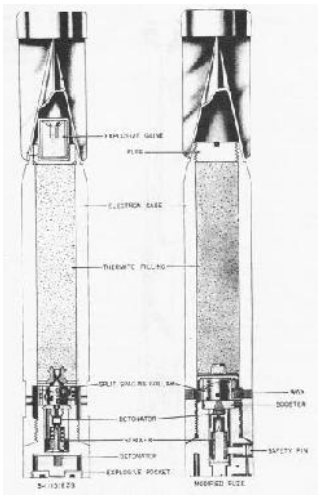
Ref: **DA11104a-00**

Source: Various sources

Examples of German Incendiary Bombs

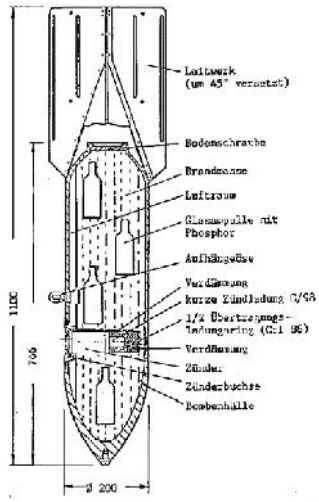
1kg Incendiary Bomb

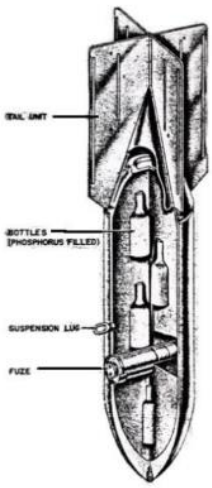
Bomb Weight	Approx. 1.0 - 1.3kg (2.2 and 2.9lb)
Explosive Weight	Approx. 680g (1.5lb) Thermite 8-15gm Explosive Nitropenta
Fuze Type	Impact fuze
Bomb Dimensions	350 x 50mm (13.8 x 1.97in)
Body Diameter	50mm (1.97in)
Use	As incendiary – dropped in clusters on towns and industrial complexes.
Remarks	Magnesium alloy case. Sometimes fitted with high explosive charge. The body is a cylindrical alloy casting threaded internally at the nose to receive the fuze holder and fuze.



C50 A Incendiary Bomb

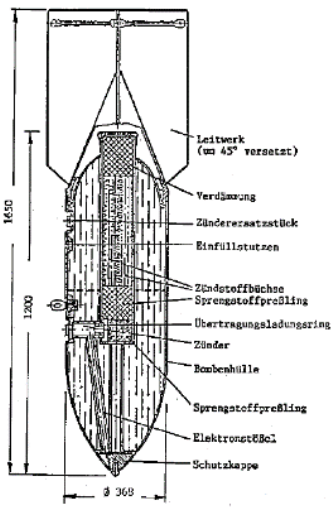
Bomb Weight	Approx. 41kg (90.4lb)
Explosive Weight	Approx. 0.03kg (0.066lb)
Incendiary Filling	12kg (25.5lb) liquid filling with phosphor igniters in glass phials. Benzine 85%; Phosphorus 4%; Pure Rubber 10%
Fuze Type	Electrical impact fuze
Bomb Dimensions	1,100 x 280mm (43.2 x 8in)
Use	Against any targets where an incendiary effect is required.
Remarks	Early fill was a phosphorous/carbon disulphide incendiary mixture.





Flam C-250 Oil Bomb

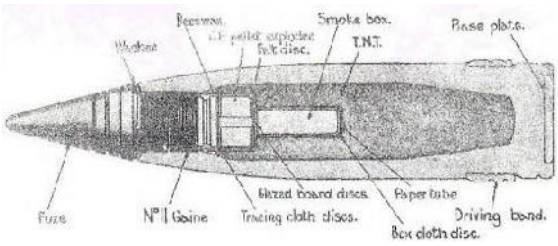
Bomb Weight	Approx. 125kg (276lb)
Explosive Weight	Approx. 1kg (2.2lb)
Fuze Type	Super-fast electrical impact fuze
Filling	Mixture of 30% petrol and 70% crude oil
Bomb Dimensions	1,650 x 512.2mm (65 x 20.2in)
Body Diameter	368mm (14.5in)
Use	Often used for surprise attacks on ground troops, against troop barracks and industrial installations. Thin casing – not designed for ground penetration.



Examples of Anti-Aircraft Projectiles

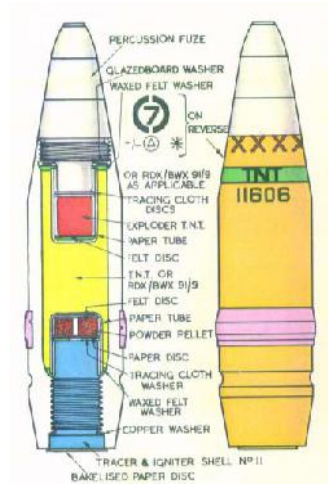
3.7 Inch QF Anti-Aircraft Projectile

Projectile Weight	28lb (12.6 kg)
Explosive Weight	2.52lbs
Fuze Type	Mechanical Time Fuze
Dimensions	3.7in x 14.7in (94mm x 360mm)
Rate of Fire	10 to 20 rounds per minute
Use	The 3.7in AA Mks 1-3 were the standard Heavy Anti-Aircraft guns of the British Army and were commonly used on the Home Front.
Ceiling	30,000ft to 59,000ft



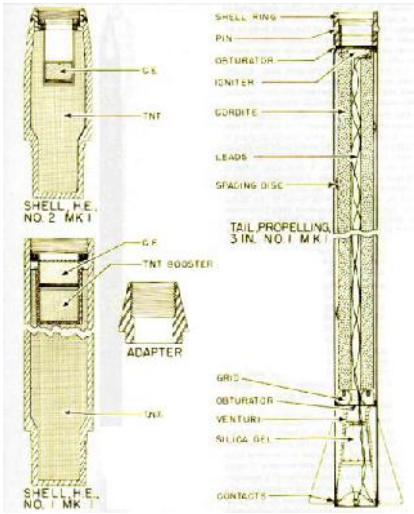
40mm Bofors Projectile

Projectile Weight	1.96lb (0.86kg)
Explosive Weight	300g (0.6lb)
Fuze Type	Impact Fuze
Rate of Fire	120 rounds per minute
Projectile Dimensions	40 x 180mm
Ceiling	23,000ft (7000m)
Remarks	Light quick fire high explosive anti-aircraft projectile. Each projectile fitted with small tracer element. If no target hit, shell would explode when tracer burnt out. Designed to engage aircraft flying below 2,000ft.



3in Unrotated Projectile (UP) Anti-Aircraft Rocket ("Z" Battery)

HE Projectile Weight	3.4kg (7.6lb)
Explosive Weight	0.96kg (2.13lb)
Filling	High Explosive – TNT. Fitted with aerial burst fuzing
Dimensions of projectile	236 x 83mm (9.29 x 3.25in)
Remarks	As a short range rocket-firing anti-aircraft weapon developed for the Royal Navy. It was used extensively by British ships during the early days of World War II. The UP was also used in ground-based single and 128-round launchers known as Z Batteries. Shell consists of a steel cylinder reduced in diameter at the base and threaded externally to screw into the shell ring of the rocket motor.



1ST LINE DEFENCE
Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **GVR Geoservices Ltd**

Project: **Northfleet, Gravesend, Kent**

Ref: **DA11104a-00** Source: Various sources

1ST LINE DEFENCE

Unit 3, Maple Park
Essex Road
Hoddesdon
Hertfordshire
EN11 0EX
Tel: 01992 245020

www.1stlinedefence.co.uk

1ST LINE DEFENCE