Georgiana Street, London NW1 0QS

Bangor Wharf

Report to accompany planning application:

Ground Investigation Report
GEA

February 2017

ONE HOUSING
LIVING BETTER

GROUND INVESTIGATION REPORT

Bangor Wharf
Georgiana Street
London NW1

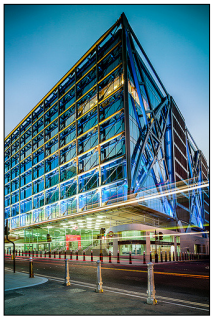
Client: One Housing Group

Engineer: Conisbee

J15227A

February 2016



GEA Geotechnical & Environmental Associates

Document Control

Project title	Bangor Wharf, Georgiana Street, Camden, NW1 0QS	**Project ref**	J15227A
Report prepared by	Matthew Penfold MSci MSc DIC CGeol FGS		
Report checked and approved for issue by	Steve Branch BSc MSc CGeol FGS FRGS MIEnvSc		
Issue No	**Status**	**Date**	**Approved for Issue**
1	Draft	9 February 2016	
2	Final	19 February 2016	

This report has been issued by the GEA office indicated below. Any enquiries regarding the report should be directed to the office indicated or to Steve Branch in our Herts office.

✓	Hertfordshire	tel 01727 824666	mail@gea-ltd.co.uk
☐	Nottinghamshire	tel 01509 674888	midlands@gea-ltd.co.uk

CONTENTS

EXECUTIVE SUMMARY

This executive summary contains an overview of the key findings and conclusions. No reliance should be placed on any part of the executive summary until the whole of the report has been read. Other sections of the report may contain information that puts into context the findings that are summarised in the executive summary.

BRIEF

This report describes the findings of a ground investigation carried out by Geotechnical and Environmental Associates Limited (GEA) on the instructions of Conisbee, on behalf of One Housing Group, with respect to the construction of a number of new mixed commercial and residential buildings of up to six storeys. The purpose of the investigation has been to determine the ground conditions, to provide additional information with respect to the presence of contamination and to provide information to assist with the design of suitable foundations.

A desk study did not form part of the project brief, as a Phase I Environmental Assessment (report ref UK11-20589, dated September 2014) and Environmental Site Investigation (report ref RC7994 Phase II, dated July 2004), have previously been completed by Environ.

SITE DESCRIPTION

The site is located roughly 200 m to the southeast of Camden Road railway station. It is bounded by the Grand Union Canal to the northeast, Gray's Inn Bridge to the east, Georgiana Street to the south and southeast, adjoining two-storey residential properties fronting onto Royal College Street to the west and an adjoining three-storey commercial property to the north. The western part of the site is occupied by a two-storey office block, with associated single storey storage buildings that extend across the northern part of the site and a number of single storey outbuildings adjacent to the Grand Union Canal. The central part of the site comprises an area of open hardstanding used for parking and accessed from Georgiana Street via a set of security barriers. It is understood that the Fleet Trunk Sewer is situated beneath the south-eastern part of the site.

GROUND CONDITIONS

The investigation has generally confirmed the expected ground conditions in that, below a moderate thickness of made ground, London Clay has been encountered and proved to the maximum depth of the investigation, of 25.0 m (-0.7 m OD). The made ground comprises brown silty sandy clay with gravel, brick, concrete and ash and was generally found to extend to depths of between 0.6 m (23.65 m OD) and 1.6 m (23.05 m OD). A more significant thickness was encountered on the eastern part of the site, where the made ground was found to extend to the full depth of the trial pits of 2.0 m, whilst the previous investigation carried out by Environ also encountered a significant thickness of made ground of up to 2.8 m in the north-western part of the site, within the extent of the former canal wharf. The underlying London Clay comprises an upper layer of firm becoming stiff fissured medium strength becoming high strength brown silty clay, with occasional grey markings, which extends to depths of between 8.70 m (15.60 m OD) and 9.10 m (15.55 m OD). This is underlain by stiff becoming very stiff fissured high strength becoming very high strength dark grey silty clay with occasional partings of silt and sand, which was proved to the full depth of the investigation.

Groundwater was not encountered during the investigation, although shallow seepages were recorded during the previous investigation within the made ground in the north-western part of the site.

RECOMMENDATIONS

Piled foundations, extending into the London Clay, are likely to provide the most suitable solution, particularly given the likely loads of the proposed new six-storey buildings and the presence of the Fleet Trunk Sewer beneath part of the site. Alternatively, for any lightly loaded or ancillary structures, it should be feasible to adopt light to moderately loaded spread or pad foundations bearing within the London Clay outside of the Thames Water exclusion zone. All foundations would need to bypass the made ground and may need to be deepened in accordance with NHBC guidelines if they are to be located in the vicinity of existing trees.

End users will be effectively isolated from any potential contaminants within the near surface soils as a result of the extent of the existing and proposed buildings and through the provision of imported soils to form the area of proposed amenity space, such that no specific remediation measures should be required.

Part 1: INVESTIGATION REPORT

This section of the report details the objectives of the investigation, the work that has been carried out to meet these objectives and the results of the investigation. Interpretation of the findings is presented in Part 2.

1.0 INTRODUCTION

Geotechnical and Environmental Associates Limited (GEA) has been commissioned by Conisbee, on behalf of One Housing Group, to carry out a ground investigation at Bangor Wharf, Georgiana Street, Camden, NW1 0QS, within the London Borough of Camden.

A Phase I Environmental Assessment (report ref UK11-20589, dated September 2014) and Environmental Site Investigation (report ref RC7994 Phase II, dated July 2004), have previously been completed by Environ; copies of these reports were provided by the consulting engineer and are included in the appendix. Additional desk study research has not formed part of the project brief.

A trunk sewer structural impact assessment has also been completed by Conisbee, the consulting structural engineers (report ref 150032/N, dated August 2015), which as well as the above reports, also includes an impact assessment undertaken by Geotechnical Consulting Group (GCG; report ref 0011/10055, dated July 2015).

Additional site investigation work is proposed following demolition works to confirm the boundary wall conditions and check for contamination beneath the footprint of the existing buildings. This work will be undertaken in due course and the findings issued as an addendum to this report.

1.1 Proposed Development

It is proposed to develop the site for a mixed commercial and residential end use through the construction of a number of new buildings of up to a maximum of six storeys, with a communal courtyard which will be generally hard-covered, with nominal soft landscaping.

The development will also include construction of a new canal wall, either in the form of bored piles with a concrete capping beam or a traditional concrete retaining wall.

This report is specific to the proposed development and the advice herein should be reviewed once the development proposals are finalised.

1.2 Purpose of Work

The principal technical objectives of the work carried out were as follows:

- to determine the ground conditions and their engineering properties;
- to identify the configuration of existing foundations and boundary wall conditions;
- to assess the possible impact of the proposed development on the local hydrogeology and surrounding structures;

- to provide advice with respect to the design of suitable foundations;
- to provide an indication of the degree of soil contamination present; and
- to assess the risk that any such contamination may pose to the proposed development, its users or the wider environment.

1.3 Scope of Work

In order to meet the above objectives, following a review of the previous desk study and site investigation carried out by Environ, as well as the Structural Impact Assessment provided by the consulting engineer, a ground investigation was carried out which comprised, in summary, the following activities:

- two cable percussion boreholes, advanced to a depth of 25.0 m (-0.7 m OD);
- standard penetration tests (SPTs), carried out at regular intervals in the cable percussion borehole, to provide quantitative data on the strength of the soils;
- a total of six shallow trial pits, excavated by hand to expose the existing foundations and confirm the boundary wall conditions;
- laboratory testing of selected soil samples for geotechnical purposes;
- additional contamination testing to supplement the findings of the previous investigation completed by Environ; and
- provision of a report presenting and interpreting the above data, together with our advice and recommendations with respect to the proposed development.

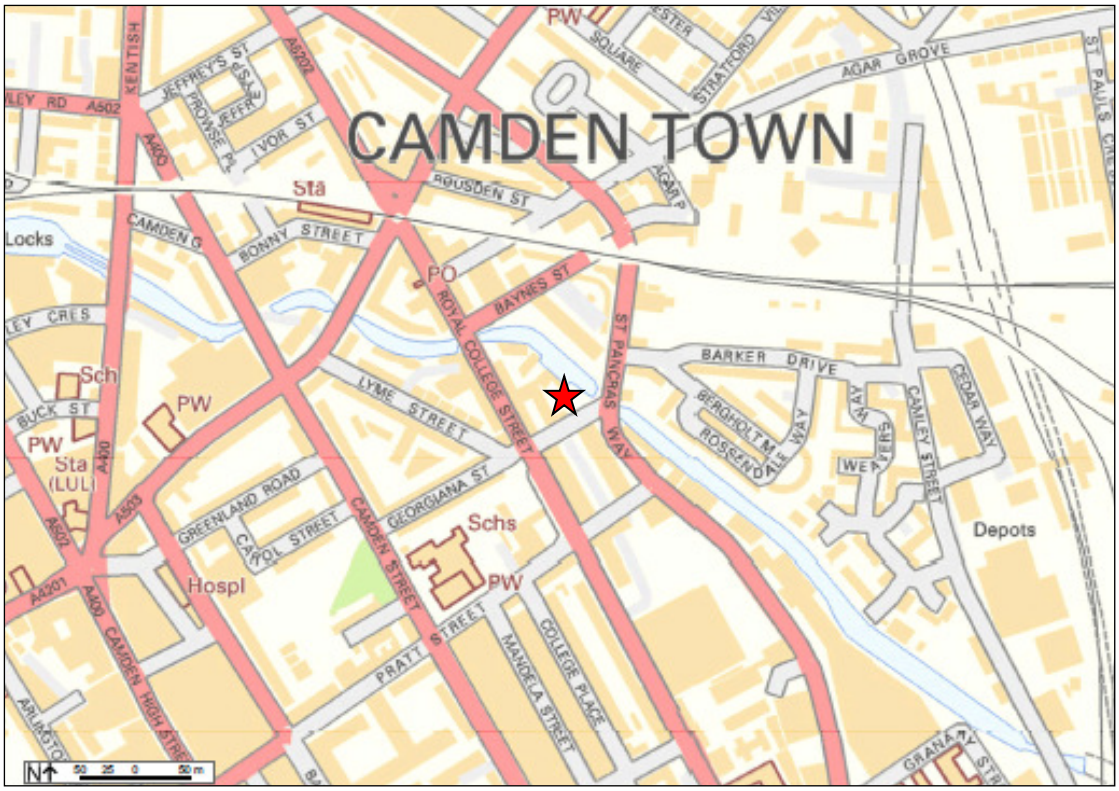
1.4 Limitations

The conclusions and recommendations made in this report are limited to those that can be made on the basis of the investigation. The results of the work should be viewed in the context of the range of data sources consulted and the number of locations where the ground was sampled. No liability can be accepted for information in other data sources or conditions not revealed by the sampling or testing. Any comments made on the basis of information obtained from the client or other third parties are given in good faith on the assumption that the information is accurate; no independent validation of such information has been made by GEA.

2.0 THE SITE

2.1 Site Description

The site is located roughly 200 m to the southeast of Camden Road railway station. It is bounded by the Grand Union Canal to the northeast, Gray's Inn Bridge to the east, Georgiana Street to the south and southeast, a row of two to three-storey residential properties fronting onto Royal College Street to the west and an adjoining three-storey commercial property to the north. The site may be additionally located by National Grid Reference 529340, 184030 and is shown on the map overleaf.



The site forms an irregular shaped area, measuring approximately 60 m northwest-southeast by 45 m northeast-southwest and is occupied by a former depot that until recently was owned and operated by EDF.

The western part of the site is occupied by a two-storey office block, with associated single storey storage buildings that extend across the northern part of the site and a number of single storey outbuildings adjacent to the Grand Union Canal. The central part of the site comprises an area of open hardstanding used for parking accessed from Georgiana Street via a set of security barriers.

A concrete plinth, with separate gated access onto Georgiana Street, occupies the south-eastern part of the site, behind which a cobbled ramp leads down to an enclosed vault that extends beneath the southern end of the Gray's Inn Bridge.

Ground level reduces across the site from south to north by approximately 1.5 m to 2.0 m, although the cobbled ramp slopes down towards the southeast, with the base of the ramp at a level approximately 3.0 m below that of adjoining street level.

Information provided by the consulting engineer indicates that the Fleet Trunk Sewer is located beneath the south-eastern part of the site at a depth of about 7 m.

The site is generally devoid of vegetation, with the exception of the eastern part of the site, where a number of mature trees are present along the boundary with the Grand Union Canal.

2.2 Previous Desk Study Findings

The site history was researched by Environ and is presented in the previous desk study, which indicated that the site has historically had a predominantly industrial usage, having been occupied by a glue factory, garages, stores, workshops, paint shop, a council depot, a

builder's yard and a London Electricity / EDF depot. The northern part of the site is also understood to have formed part of a former wharf, which was infilled in the mid-20th Century. The area around the site is understood to have had a predominantly residential history, although a number of potentially contaminative sites, including a coal and goods depots were located in the vicinity.

No active of historical landfill sites were identified within 250 m, nor were there any permits, controls or pollution incidents likely to have had any adverse impact on the site.

Reference to records compiled by the Health Protection Agency (formerly the National Radiological Protection Board) indicates that the site falls within an area where less than 1% of homes are affected by radon emissions; therefore, radon protective measures will not be necessary.

On the basis of the findings of the desk study research and an earlier site investigation, Environ concluded that it was unlikely for any significant contamination to be present within the near surface soils beneath the site, such that the risk to potential end users or other receptors was considered to be low. This assessment was based on a continuing commercial end use for the site.

2.3 Geology

The British Geological Survey (BGS) map of the area (Sheet 256) shows the site to be underlain by London Clay.

A review of publicly available information from the BGS database has revealed a number of deep boreholes located approximately 150 m to the south-southeast, which show that the London Clay extends to a depth of approximately 30.0 m, below which the Lambeth Group, Thanet Sand and underlying White Chalk are present.

2.4 Hydrology and Hydrogeology

The London Clay Formation is classified by the EA as an Unproductive Stratum, referring to rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.

The nearest surface water feature is the Grand Union Canal which forms the north-eastern boundary of the site. Historically the River Fleet[4], which rises on Hampstead Heath, flowed approximately 50 m to the south of the site, in a south-easterly direction between Camden Road and St Pancras Way.

Any groundwater flow within the London Clay will be at a very slow rate, due to its negligible permeability. The permeability will be predominantly secondary, through fissures in the clay and published data indicates the horizontal permeability of the London Clay to generally range between 1×10^{-11} m/s and 1×10^{-9} m/s.

The site is occupied by the existing building and areas of hardstanding and therefore infiltration of rainwater into the ground beneath the site is extremely limited, with the majority of surface runoff likely to drain into combined sewers in the road.

The site is not within an area shown by the Environment Agency to be at risk from flooding from rivers or the sea, but is located within an area that may be at risk from surface water

flooding, such that consideration should be given to the completion of a site specific flood risk assessment.

There are no Environment Agency designated Source Protection Zones (SPZs) within the vicinity.

2.5 Previous Investigation

The previous investigation by Environ in July 2004 comprised seven shallow boreholes, extended to a maximum depth of 2.8 m.

In summary, the ground conditions were found to comprise a moderate thickness of made ground, which extended to depths of between 0.2 m and 0.9 m, over firm brown grey clay of the London Clay which was proved to the maximum depth of 2.7 m. However, in Window Sampler Nos 6 and 7, located in the north-western part of the site, a significant thickness of made ground, extending to the maximum depths sampled at each location of between 1.5 m and 2.8 m, was encountered, which is likely to represent infilling of the former wharf which was present in this part of the site.

Groundwater was not generally encountered during drilling of the boreholes, although slight seepages were observed within the made ground on the northern part of the site.

The investigation did not encounter any evidence of widespread or significant contamination, which was generally confirmed through on-site headspace testing and subsequent laboratory analysis. The analysis carried out as part of the investigation did identify a number of elevated concentrations of arsenic, lead, copper, zinc and PAH when compared against the Dutch Intervention guideline values adopted at the time. However, when compared against current guideline values for a commercial site, only the concentration of lead recorded in the sample of made ground from Window Sample No 7 would be considered as being elevated.

Environ therefore concluded that there was a low risk of there being a significant contamination risk to potential end users or other receptors, which was based on the assumption that the site would remain in commercial usage.

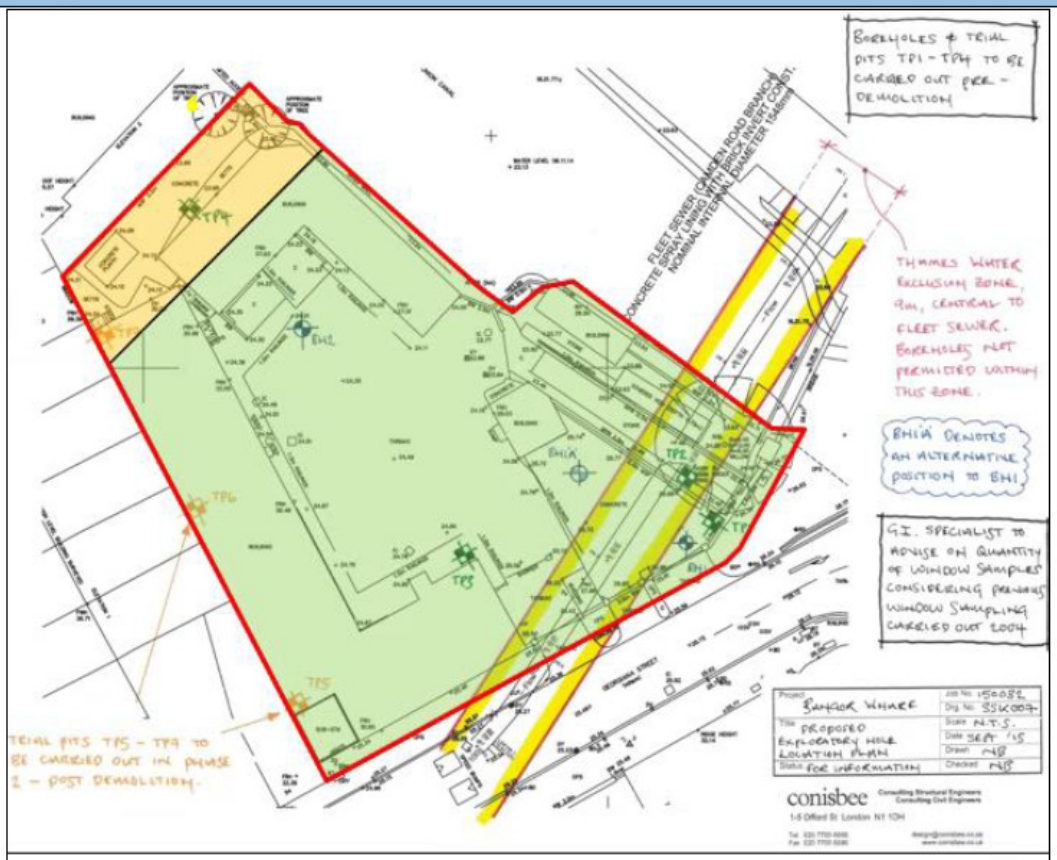
2.6 Preliminary / Detailed UXO Assessment

A preliminary UXO Risk Assessment was undertaken by First Line Defence (report ref; OPN2819, dated October 2010), which indicated a potential risk for the presence of unexploded ordnance (UXO). Further research in the form of a Detailed UXO Threat assessment was recommended. However, as the findings of this study would not be available until after the proposed site investigation was due to be undertaken, on-site mitigation measures were required, the scope of which are discussed in Section 3.1 below.

The findings of the Detailed UXO Threat Assessment (report ref; 2819AT00, dated October 2015) can be summarised as follows.

The majority of the site has been assessed as low risk, with only a relatively limited area on the north-western part of the site that has been assessed as medium risk. It is therefore recommended that all personnel working on the site attend a site specific UXO awareness briefing, which can be included as part of a site indication.

Risk Map



Medium Risk

Low Risk

Low and Medium Risk Areas:

- Site Specific Unexploded Ordnance Awareness Briefings to all personnel conducting intrusive works

Medium Risk Area:

- Unexploded Ordnance (UXO) Specialist Presence on Site to support shallow intrusive works
- Intrusive Magnetometer Survey of all Borehole and pile locations down to a maximum bomb penetration depth

For indicative purposes – not to scale

Additional mitigation measures will only be required in the medium risk area, which should include the presence of a UXO engineer to provide a watching brief and, where applicable, carry out a non-intrusive magnetometer survey of all shallow intrusive positions, such as trial pits, service trenches and shallow foundations. For all deep intrusive works within the medium risk area, such as piling, an intrusive magnetometer survey to the maximum predicted bomb penetration depth is recommended.

2.7 Trunk Sewer Structural Impact Assessment

The assessment of the potential impact of the proposed development on the Fleet Sewer by Conisbee included specialist input from Geotechnical Consulting Group in the form of a ground movement assessment (report ref 0011/10055, dated July 2015).

Assuming that the existing sewer is in relatively good condition and that no piling work is undertaken within the 3 m exclusion zone defined by Thames Water, the ground movement assessment concluded that the proposed development should not have any adverse impact, although the demolition strategy and construction methods should be designed to ensure that any potential ground movements are minimised. A requirement was identified to ensure that the existing confinement pressure ratio (CPR) was not reduced where the existing sewer extends beneath the Grand Union Canal, as the existing CPR is already below the Thames Water Criteria, and measures will therefore need to be implemented in order to mitigate any potential impact as a result of dewatering of the canal during the proposed reconstruction of the canal wall.

3.0 EXPLORATORY WORK

Access to the site was restricted by the presence of the existing building; therefore in order to meet the objectives described in Section 1.2 as far as possible within these restrictions, two cable percussion boreholes were advanced within the existing yard area, to a depth of 25.0 m (-0.7 m OD). Standard Penetration Tests (SPTs) were carried out at regular intervals and disturbed and undisturbed samples were recovered for subsequent laboratory examination and testing.

The cable percussion boreholes were supplemented by a series of five shallow trial pits, which were excavated by hand to expose the existing foundations and confirm the party wall conditions. An additional trial pit, Trial Pit A, was excavated during a previous site visit to provide the consulting engineers with information on the foundations of the bridge abutment on the eastern part of the site, the findings of which have been included within this report.

All of the above work was carried out under the supervision of a geotechnical engineer from GEA.

The borehole and trial pit records are appended, together with the results of the laboratory testing and a site plan indicating the exploratory locations. The Ordnance Datum (OD) levels shown on the borehole and trial pit records have been interpolated from spot heights shown on a site survey drawing (ref: SSK007, dated September 2015), which was provided by the consulting engineers.

Additional site investigation work is proposed following demolition works to confirm the boundary wall conditions and check for contamination beneath the footprint of the existing buildings. This work will be undertaken in due course and the findings issued as an addendum to this report.

3.1 Sampling Strategy

The scope of the works was specified by the consulting engineers, with input from GEA. The general borehole and trial pit positions were specified by the consulting engineers and positioned on site by GEA with due regard to the proposed development, whilst avoiding areas of known services.

Following the recommendations in the Preliminary UXO Risk Assessment, all personnel working on the site attended a site specific UXO awareness briefing, with additional mitigation measures for the exploratory locations. This included the attendance of a UXO engineer to provide a watching brief and carry out an intrusive magnetometer survey at each of the borehole locations.

A number of samples recovered from the boreholes were submitted to a geotechnical laboratory for a programme of testing that included moisture content and Atterberg limit tests, undrained triaxial compression tests and soluble sulphate and pH level analysis.

Two samples of the made ground and a single sample of natural soil was subjected to analysis for a range of common industrial contaminants and contamination indicative parameters. For this investigation the analytical suite for the soil included a range of metals, speciation of total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAH), total cyanide and monohydric phenols. The soil samples were selected to provide a general view of the chemical conditions of the soils that are likely to be involved in a human exposure or groundwater pathway and to provide advice in respect of re-use or for waste disposal classification.

The contamination analyses were carried out at an MCERTs accredited laboratory with the majority of the testing suite accredited to MCERTS standards. Details of the MCERTs accreditation and test methods are included in the Appendix together with the analytical results.

4.0 GROUND CONDITIONS

The investigation has confirmed the expected ground conditions in that, beneath a moderate thickness of made ground, the London Clay was encountered and proved to the full depth of the investigation.

4.1 Made Ground

The made ground generally comprised brown silty sandy clay with gravel, brick, concrete and ash and was found to extend to depths of between 0.6 m (23.65 m OD) and 1.6 m (23.05 m OD). A greater thickness was encountered in Trial Pit Nos 1 and 1A, where made ground was found to extend to the full depth of the pits to a depth of 2.0 m (24.2 m OD).

Apart from the presence of fragments of extraneous material noted above, no visual or olfactory evidence of contamination was observed during the fieldwork.

4.2 London Clay

The London Clay comprised an upper layer of firm becoming stiff fissured medium strength becoming high strength brown silty clay, with occasional grey markings, which was proved in each of the boreholes to depths of between 8.70 m (15.60 m OD) and 9.10 m (15.55 m OD) and was underlain by stiff becoming very stiff fissured high strength becoming very high strength dark grey silty clay with occasional partings of silt and sand to the full depth of the investigation, of 25.00 m (-0.70 m OD).

The results of laboratory classification tests indicate that the London Clay is of high volume change potential, whilst the results from the laboratory undrained triaxial compression tests, which are plotted against depth on a graph in the appendix, indicate the clay to generally increase in strength with depth from moderate strength to very high strength.

No visual or olfactory evidence of contamination was observed in this stratum.

4.3 Groundwater

Groundwater was not encountered during the investigation, although the made ground in Trial Pit No 3, was noted to be wet immediately above the concrete footing at a depth of approximately 0.8 m.

4.4 Soil Contamination

The table below sets out the values measured within four samples of made ground analysed; all concentrations are in mg/kg unless otherwise stated.

Determinant	TP1: 0.50 m to 1.00 m	TP2: 0.75 m	TP3: 0.40 m to 0.80 m	TP4: 0.50 m
pH	8.0	8.9	8.5	9.0
Arsenic	17.0	21.0	13.0	46.0
Cadmium	0.1	0.2	0.1	0.3
Chromium	66.0	53.0	63.0	31.0
Copper	36.0	32.0	38.0	540.0
Mercury	<0.1	0.2	0.1	0.4
Nickel	63.0	49.0	51.0	64.0
Lead	35.0	29.0	34.0	730.0
Selenium	<0.2	<0.2	<0.2	<0.2
Zinc	89.0	69.0	87.0	250.0
Total Cyanide	<0.5	<0.5	<0.5	<0.5
Total Phenols	<0.3	<0.3	<0.3	<0.3
Total PAH	<2.0	<2.0	<2.0	8.9
Benzo(a)pyrene	<0.1	<0.1	<0.1	0.7
Naphthalene	<0.1	<0.1	<0.1	0.2
TPH	<10.0	<10.0	<10.0	35.0
Total organic carbon %	0.5	0.8	0.9	1.1
Notes: Figure in **bold** indicates concentration in excess of risk-based soil guideline values, as discussed in Part 2 of this report				

4.4.1 Generic Quantitative Risk Assessment

The use of a risk-based approach has been adopted to provide an initial screening of the test results to assess the need for subsequent site-specific risk assessments. To this end the table below indicates those contaminants of concern that have values in excess of a generic human health risk based guideline values which are either that of the CLEA[1] Soil Guideline Value where available, or is a Generic Screening Value calculated using the CLEA UK Version 1.06[2] software assuming a commercial end use, or is based on the DEFRA Category 4 Screening values[3].

1 *Updated Technical Background to the CLEA Model (Science Report SC050021/SR3) Jan 2009* and Soil Guideline Value reports for specific contaminants; all DEFRA and Environment Agency.
2 Contaminated Land Exposure Assessment (CL|EA) Software Version 1.06 Environment Agency 2009
3 CL:AIRE (2013) *Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination* Final Project

The key generic assumptions for this end use are as follows:

- that groundwater will not be a critical risk receptor;
- that the critical receptor for human health will be working female adults aged 16 to 65 years old;
- that young children will not have prolonged exposure to the site;
- that the exposure duration will be a working lifetime of 49 years;
- that the critical exposure pathways will be direct soil and indoor dust ingestion, skin contact with soils and dust, and inhalation of dust and vapours; and
- that the building type equates to a three storey office.

It is considered that these assumptions are acceptable for this generic assessment of this site as the proposed development will not introduce any new pathways and will be almost entirely covered by the extent of the proposed buildings and areas of external hardstanding. Whilst the development does include residential accommodation, this is understood to be limited to the upper storeys, with commercial / retail space at ground floor level.

The tables of generic screening values derived by GEA and an explanation of how each value has been derived are included in the Appendix.

Where contaminant concentrations are measured at concentrations below the generic screening value it is considered that they pose an acceptable level of risk and thus further consideration of these contaminant concentrations is not required. However, where concentrations are measured in excess of these generic screening values there is considered to be a potential that they could pose an unacceptable risk and thus further action will be required which could include;

- additional testing to zone the extent of the contaminated material and thus reduce the uncertainty with regard to its potential risk;
- site specific risk assessment to refine the assessment criteria and allow an assessment to be made as to whether the concentration present would pose an unacceptable risk at this site; or
- soil remediation or risk management to mitigate the risk posed by the contaminant to a degree that it poses an acceptable risk.

When comparing the results from the contamination testing to those in the Soil Guideline Values and Generic Guideline Values, the analysis has not revealed any concentrations in excess of the generic risk-based screening values for these contaminants.

This assessment is based upon the potential for risk to human health, which at this site is considered to be the critical risk receptor. The significance of the contamination results is considered further in Part 2 of the report.

Report SP1010 and DEFRA (2014) *Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination* Policy Companion Document SP1010

4.5 Existing Foundations

The findings of the trial pits are summarised in the table below. Sketches and photographs of each pit are included in the Appendix.

Trial Pit No	Structure	Foundation detail	Bearing Stratum
A	Bridge Abutment	Mass concrete strip / trench fill Top 1.05 m to 1.15 m Base not proved Lateral projection 200mm to 300 mm	Not proved
1	Boundary Wall	Mass concrete strip / trench fill Top 1.80 m Base not proved Lateral projection 350mm	Not proved
1A	Retaining Wall	Not proved	Not proved
2	Retaining Wall	Mass concrete strip / raft Top 0.10 m Base 0.70 m Lateral projection not proved	Firm brown silty CLAY
3	Two-storey office building	Mass concrete strip / trench fill Top 0.80 m Base 1.10 m Lateral projection 200mm	Firm brown to brownish grey silty CLAY with occasional gravel
4	Single storey building	Concrete raft / Granite setts Top 0.00 m Base 0.40 m Lateral projection not proved	Made Ground (dark brown silty clayey sand with brick and ash)

Groundwater was not encountered within any of the trial pits, although the made ground in Trial Pit No 3 was noted to be wet immediately above the concrete footing at a depth of approximately 0.8 m.

Part 2: DESIGN BASIS REPORT

This section of the report provides an interpretation of the findings detailed in Part 1, in the form of a ground model, and then provides advice and recommendations with respect to the basement excavation, foundations and the potential impact on hydrogeology.

5.0 INTRODUCTION

It is proposed to develop the site for a mixed commercial and residential end use through the construction of a number of new buildings of up to a maximum of six storeys, with a communal courtyard which will be generally hard-covered, with nominal soft landscaping.

The development will also include construction of a new canal wall, either in the form of bored piles with a concrete capping beam or a traditional concrete retaining wall.

Anticipated loads for the proposed development are not known at this stage, but are expected to be moderate and thus typical of this type of development.

6.0 GROUND MODEL

On the basis of the fieldwork, the ground conditions at this site can be characterised as follows:

- below a generally moderate thickness of made ground, London Clay has been encountered and proved to the maximum depth of the investigation, of 25.00 m (-0.70 m OD);
- the made ground comprises brown silty sandy clay with gravel, brick, concrete and ash and was generally found to extend to depths of between 0.6 m (23.65 m OD) and 1.6 m (23.05 m OD);
- a more significant thickness was encountered on the eastern part of the site, where the made ground was found to extend to the full depth of the excavations of 2.0 m, whilst the previous investigation carried out by Environ, also encountered a significant thickness of made ground up to 2.8 m on the north-western part of the site, within the extent of the former canal wharf;
- the underlying London Clay comprises an upper layer of firm becoming stiff fissured medium strength becoming high strength brown silty clay, with occasional grey markings, which extends to depths of between 8.70 m (15.60 m OD) and 9.10 m (15.55 m OD);
- below this, stiff becoming very stiff fissured high strength becoming very high strength dark grey silty clay with occasional partings of silt and sand was proved to the full depth of the investigation;
- groundwater was not encountered during the investigation, although shallow seepages were recorded within the made ground on the north-western part of the site during the previous investigation;

- elevated lead was recorded within the made ground during the previous investigation, although only one of these concentrations is above present guideline values for a commercial end use; and

- all other contamination identified during the previous investigation is below present guideline values for a commercial end use.

7.0 ADVICE AND RECOMMENDATIONS

Piled foundations, extending into the London Clay, are likely to provide the most suitable solution, particularly given the likely loads of the proposed new six-storey buildings and the presence of the Fleet Trunk Sewer beneath part of the site.

Alternatively, for any lightly loaded or ancillary structures, it should be feasible to adopt light to moderately loaded spread or pad foundations bearing within the London Clay outside of the Thames Water exclusion zone. All foundations would need to bypass the made ground and may need to be deepened in accordance with NHBC guidelines if they are to be located in the vicinity of existing trees.

7.1 Spread Foundations

Moderate width strip or pad foundations bearing on the firm clay of the London Clay should be placed at a minimum depth of 1.5 m, assuming that no restrictions are applied on planting of shrubs in the vicinity of foundations, and that a no planting zone is applied in accordance with Table 4 of NBHC Standards Chapter 4.2 (2014). If trees are excluded within the zone of influence shown in Table 2 of the NHBC guidance, the minimum depth can be reduced to 0.75 m subject also to the further advice on new tree and shrub planting as detailed in the NHBC guidelines. The foundations may be designed to apply a net allowable bearing pressure of 100 kN/m^2. All foundations should bypass any made ground. This value incorporates an adequate factor of safety against bearing capacity failure and should ensure that settlement remains within normal tolerable limits.

Foundations will need to be deepened in the vicinity of existing and proposed trees and National House Building Council (NHBC) guidelines should be followed in this respect. High shrinkability clays should be assumed. Where trees are to be removed the required founding depth should be determined on the basis of the existing tree height if it is less than 50% of the mature height and on the basis of full mature height if the current height is more than 50% of the mature height. Where a tree is to be retained the final mature height should be adopted. Notwithstanding NHBC guidelines, all foundations should extend beyond the zone of desiccation. In this respect it would be prudent to have all foundation excavations inspected by a suitably experienced engineer. Due allowance should be made for future growth of the trees.

Where foundations are deepened to take account of trees an increased net allowable bearing pressure of 150 kN/m^2 may be adopted below a depth of 2.5 m.

The requirement for compressible material alongside foundations should be determined by reference to the NHBC guidelines.

7.2 Piled Foundations

For the ground conditions at this site some form of bored pile is likely to be the most appropriate type. A conventional rotary augered pile may be appropriate, with temporary casing installed to maintain stability and prevent groundwater inflows, or alternatively the use of bored piles installed using continuous flight auger (cfa) techniques, which would not require the provision of casing, would also be appropriate.

The following table of ultimate coefficients may be used for the preliminary design of bored piles from ground floor level, based on the measured SPT and cohesion vs depth and level graph in the appendix.

Stratum	Level (m OD)	kN / m²
Ultimate Skin Friction		
Made Ground	Ground Level to 23.0	Ignore
London Clay (α = 0.5)	23.0 to -0.5	Increasing linearly from 25 to 95
Ultimate End Bearing		
London Clay	14.5 to -0.5	Increasing linearly from 855 to 1710

In the absence of pile tests, guidance from the London District Surveyors Association[4] (LDSA) suggests that a factor of safety of 2.6 should be applied to the above coefficients in the computation of safe theoretical working loads. On the basis of the above coefficients and a factor of safety of 2.6, the following safe working loads have been estimated for 300 mm and 450 mm diameter CFA piles.

Level (m OD)	Diameter (mm)	Safe Working Load (kN)
12.5 [12.0]	300	225
	450	360
8.5 [16.0]	300	270
	450	425

The above examples are not intended to constitute any form of recommendation with regard to pile size or type, but merely serve to illustrate the use of the above coefficients.

Specialist piling contractors should be consulted with regard to the design of an appropriate piling scheme and their attention should be drawn to potential groundwater inflows within the made ground, along with silt and sand partings and the potential presence of claystones within the London Clay.

Some restrictions on the use of piles are likely to apply due the proximity of the site to the Fleet Trunk Sewer, which should be confirmed through further consultation with the relevant asset protection team.

4 LDSA (2009) *Foundations No 1 – Guidance notes for the design of straight shafted bored piles in London Clay*. LDSA Publication

7.3 Shallow Excavations

On the basis of the borehole and trial pit findings it is considered that shallow excavations for foundations and services that extend through the made ground should remain generally stable in the short term, although some instability may occur. Where personnel are required to enter excavations, a risk assessment should be carried out and temporary lateral support or battering of the excavation sides considered in order to comply with normal safety requirements.

Inflows of groundwater into shallow excavations are not generally anticipated, although seepages may be encountered from perched water tables, particularly within the vicinity of existing foundations, although such inflows should be suitably controlled by sump pumping.

7.4 Ground Floor Slab

In view of the moderate and locally significant thickness of made ground it is likely that suspended floor slabs will be required in order to prevent or restrict excessive and / or differential settlement of the weak made ground, which is likely to occur if ground bearing slabs are adopted.

The floor slabs of the existing buildings are likely to be ground bearing and it may therefore be possible to adopt ground bearing floor slabs if it can be determined that the existing slabs have performed satisfactorily and that the new loads do not exceed the existing loads.

If ground bearing slabs are to be adopted, the formation level should be proof rolled, with any soft spots revealed being removed and replaced with suitably compacted granular fill.

7.5 Effect of Sulphates

Chemical analyses of selected samples of the made ground have revealed generally low concentrations of soluble sulphate, corresponding to Class DS-1 and ACEC AC-1 of Table C1 of BRE Special Digest 1 Part C (2005).

Chemical analyses of selected samples of the London Clay have revealed generally low concentrations of soluble sulphate, corresponding to Class DS-5 and ACEC AC-4s of Table C1 of BRE Special Digest 1 Part C (2005). However, the samples were noted to contain traces of gypsum which are likely to have contributed to the results and it is likely therefore that the classification can be downgraded, although further testing may be advisable in this respect.

The guidelines contained in the above digest should be followed in the design of foundation concrete.

7.6 Site Specific Risk Assessment

The results of the contamination testing carried out as part of this investigation have not identified any elevated contaminants. However, when compared against current guideline values for a commercial end use, the testing carried out as part of the previous investigation identified an elevated concentration of lead within a sample of made ground tested from Window Sample No 7, located on the north-western part of the site in the area of the former canal wharf. No elevated concentrations of the other contaminants were identified.

The exact source of the contamination is unknown: However, the made ground was noted as containing variable amounts of extraneous material, including ash, and it is therefore likely that a fragment of such material was present within the samples tested, accounting for the

elevated concentration. Lead compounds are relatively immobile and unlikely to be in a soluble form and are considered to be non-volatile or of a low volatility. The contamination does not therefore present a significant vapour risk or a significant risk of leaching and migration within any perched groundwater within the made ground. As the site is underlain by the London Clay, classified as Unproductive Strata, a risk to groundwater has not been identified.

Whilst end users will be effectively isolated from direct contact from any contaminants within the made ground by the extent of the existing and proposed buildings and areas of external hardstanding, protection measures will be required where any soft landscaping is included in the design proposals. At this stage it is recommended that a cover thickness of imported subsoil and topsoil of 600 mm in thickness should be specified for any areas of landscaping in accordance with recommendations from BRE[5]. It is likely to be possible to reduce the final thickness of cover required, but this will need to be determined once final levels have been established and the concentrations of potential contaminants within the imported material and in the soils at formation level are known.

It is also recommended that a watching brief be maintained during ground works and any suspected contamination should be brought to the attention of a geo-environmental engineer. The elevated contaminants could also pose a potential risk to ground workers in the short term and a safe programme of working will be required, as outlined below.

This assessment will be reviewed and updated upon completion of the additional works to confirm the ground conditions and presence / absence of contamination beneath the footprint of the existing buildings that currently occupy the site. This work will be undertaken in due course following demolition works and will be issued as an addendum to this report.

7.6.1 Site Workers

Site workers should be made aware of the potential for the presence of contaminated material within the made ground and in accordance with standard construction practice, a safe programme of working should be identified to protect workers handling any soil. The method of site working should be in accordance with guidelines set out by HSE[6] and CIRIA[7] and the requirements of the Local Authority Environmental Health Officer. In addition, it is also recommended that a watching brief be maintained during ground works and any suspected contamination, especially in areas not covered by the investigation, should be brought to the attention of a geo-environmental engineer.

7.7 Waste Disposal

Under the European Waste Directive, waste is classified as being either Hazardous or Non-Hazardous and landfills receiving waste are classified as accepting hazardous or non-hazardous wastes or the non-hazardous sub-category of inert waste in accordance with the Waste Directive. Waste classification is a staged process and this investigation represents the preliminary sampling exercise of that process. Once the extent and location of the waste that is to be removed has been defined, further sampling and testing may be necessary. The results from this ground investigation should be used to help define the sampling plan for such further testing, which could include WAC leaching tests where the totals analysis indicates the soil to be a hazardous waste or inert waste from a contaminated site. It should however be

5 BRE (2004) *Cover systems for land regeneration. Thickness of cover systems for contaminated land.* BRE pub 465
6 HSE (1992) HS(G)66 *Protection of workers and the general public during the development of contaminated land* HMSO
7 CIRIA (1996) *A guide for safe working on contaminated sites* Report 132, Construction Industry Research and Information Association

noted that the Environment Agency guidance WM3[8] states that landfill WAC analysis, specifically leaching test results, must not be used for waste classification purposes.

Any spoil arising from excavations or landscaping works, which is not to be re-used in accordance with the CL:AIRE[9] guidance, will need to be disposed of to a licensed tip. Waste going to landfill is subject to landfill tax at either the standard rate of £82.60 per tonne (about £150 per m^3) or at the lower rate of £2.60 per tonne (roughly £5 per m^3). However, the classifications for tax purposes and disposal purposes differ and currently all made ground and topsoil is taxable at the 'standard' rate and only naturally occurring soil and stones, which are accurately described as such in terms of the 2011 Order, would qualify for the 'lower rate' of landfill tax.

Based upon on the technical guidance provided by the Environment Agency it is considered likely that the soils encountered during this ground investigation, as represented by the three chemical analyses carried out, would be generally classified as follows;

Soil Type	Waste Classification (Waste Code)	WAC Testing Required Prior to Landfill Disposal?	Comments
Made ground	Non-hazardous (17 05 04)	No	-
London Clay	Inert (17 05 04)	Should not be required but confirm with receiving landfill	-

The above classification is generally confirmed by the results of the eight chemical analyses carried out by Environ. However, where high concentrations of lead are encountered, such as in the sample of made ground from a depth of 0.7 m in Window Sample No 7, where a concentration of 3800 mg/kg was recorded, a more onerous classification of Hazardous waste (17 05 03) may apply.

Under the requirements of the European Waste Directive all waste needs to be pre-treated prior to disposal. The pre-treatment process must be physical, thermal, chemical or biological, including sorting. It must change the characteristics of the waste in order to reduce its volume, hazardous nature, facilitate handling or enhance recovery. The waste producer can carry out the treatment but they will need to provide documentation to prove that this has been carried out. Alternatively, the treatment can be carried out by an approved contractor. The Environment Agency has issued a position paper[10] which states that in certain circumstances, segregation at source may be considered as pre-treatment and thus excavated material may not have to be treated prior to landfilling if the soils can be segregated onsite prior to excavation by sufficiently characterising the soils insitu prior to excavation.

The above opinion with regard to the classification of the excavated soils is provided for guidance only and should be confirmed by the receiving landfill once the soils to be discarded have been identified.

The local waste regulation department of the Environment Agency (EA) should be contacted to obtain details of tips that are licensed to accept the soil represented by the test results. The tips will be able to provide costs for disposing of this material but may require further testing.

8 Environment Agency 2015. *Guidance on the classification and assessment of waste.* Technical Guidance WM3 First Edition
9 CL:AIRE March 2011. *The Definition of Waste: Development Industry Code of Practice* Version 2
10 Environment Agency 23 Oct 2007 *Regulatory Position Statement Treating non-hazardous waste for landfill - Enforcing the new requirement*

8.0 OUTSTANDING RISKS AND ISSUES

This section of the report aims to highlight areas where further work is required as a result of limitations on the scope of this investigation, or where issues have been identified by this investigation that warrant further consideration. The scope of risks and issues discussed in this section is by no means exhaustive, but covers the main areas where additional work may be required.

The ground is a heterogeneous natural material and variations will inevitably arise between the locations at which it is investigated. This report provides an assessment of the ground conditions based on the discrete points at which the ground was sampled, but the ground conditions should be subject to review as the work proceeds to ensure that any variations from the Ground Model are properly assessed by a suitably qualified person.

The investigation has not identified the presence of any significant contamination and as such, remedial measures should not be required. However, as with any site there is a potential for areas of contamination to be present within the made ground beneath parts of the site not covered by the investigation it is recommended that a watching brief is maintained during any groundworks for the proposed new foundations and that if any suspicious soils are encountered that they are inspected by a geo-environmental engineer and further assessment may be required.

Additional site investigation work is proposed following demolition works to confirm the boundary wall conditions and check for contamination beneath the footprint of the existing buildings. This work will be undertaken in due course and the findings issued as an addendum to this report.

These areas of doubt should be drawn to the attention of prospective contractors and further investigation will be required or sufficient contingency should be provided to cover the outstanding risk.

APPENDIX

Site Plan

Borehole Records

Trial Pit Records

Laboratory Geotechnical Test Results

SPT & Cohesion / Depth & Level Graph

Chemical Analyses (Soil)

Generic Risk-Based Soil Screening Values

Detailed UXO Threat Assessment

Environ Reports

Geotechnical & Environmental Associates

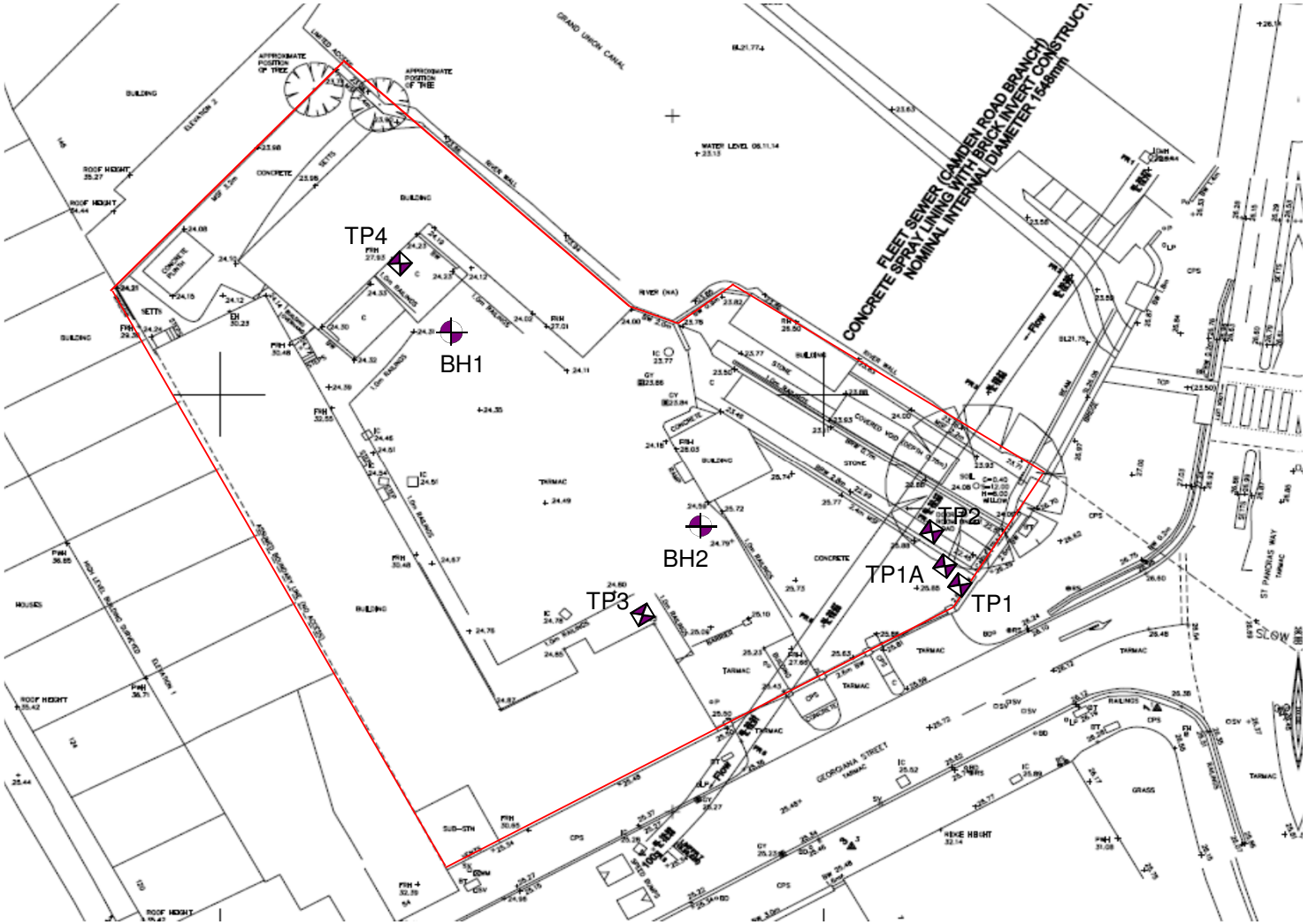
Widbury Barn
Widbury HilL
Ware
Herts SG12 7QE

Site Plan

Site	Bangor Wharf, Geoagiana Street, Camden, NW1 0QS
Client	One Housing Group
Engineer	Conisbee

Job Number J15227A

Sheet 1 / 1



Geotechnical & Environmental Associates	Widbury Barn Widbury Hill Ware,Herts SG12 7QE	**Site** Bangor Wharf, Georgiana Street, Camden, NW1 0QS	**Borehole Number** **BH1**

Boring Method	**Casing Diameter**	**Ground Level (mOD)**	**Client**	**Job Number**
Cable Percussion	150mm cased to 1.50m	24.30	One Housing Group	J15227A
	Location	**Dates** 26/10/2016	**Engineer** Conisbee	**Sheet** 1/3

Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
						(0.30)	Tarmac (100 mm) over Granite setts (200 mm)		
					24.00	0.30	Made Ground (brown silty sandy clay with gravel, brick, concrete and ash)		
0.40	D1								
						(0.90)			
0.90	D2								
					23.10	1.20	Firm becoming stiff fissured high strength brown silty CLAY with occasional grey markings		
1.20-1.65 1.20-1.65	CPT N=6 B1	1.20	DRY	1,1/1,1,2,2					
1.80	D3								
2.00-2.45	U1								
2.40	D4								
2.80	D5								
3.00-3.45 3.00-3.45	SPT N=9 S1	1.50	DRY	1,1/2,2,2,3					
3.70	D6								
4.00-4.45	U2								
4.50	D7								
4.80	D8								
						(7.50)			
5.00-5.45 5.00-5.45	SPT N=14 S2	1.50	DRY	2,2/3,3,4,4					
6.00-6.45	U3								
6.50	D9								
7.50-7.95 7.50-7.95	SPT N=21 S3	1.50	DRY	4,5/5,5,5,6					
					15.60	8.70	Stiff becoming very stiff fissured high strength becoming very high strength dark grey silty CLAY; claystone at 17.2 m		
8.80	D10								
9.00-9.45	U4								
9.50	D11								

Remarks
UXO awareness briefing - 30 minutes
Service Inspection pit excvated to 1.2 m - 1 hour 30 minutes
Chiseling on claystone from 17.2 m to 17.7 m - 30 minutes
Groundwater not encountered
UXO Clearance - 30 minutes

Scale (approx)	**Logged By**
1:50	MP

Figure No.
J15227A.BH1

Geotechnical & Environmental Associates	Widbury Barn Widbury Hill Ware,Herts SG12 7QE	**Site** Bangor Wharf, Georgiana Street, Camden, NW1 0QS	**Borehole Number** **BH1**

Boring Method	**Casing Diameter**	**Ground Level (mOD)**	**Client**	**Job Number**
Cable Percussion	150mm cased to 1.50m	24.30	One Housing Group	J15227A
	Location	**Dates** 26/10/2016	**Engineer** Conisbee	**Sheet** 2/3

Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
10.50-10.95 10.50-10.95	SPT N=23 S4	1.50	DRY	3,4/5,5,6,7					
12.00-12.45	U5								
13.50-13.95 13.50-13.95	SPT N=25 S5	1.50	DRY	4,5/5,6,7,7					
15.00-15.45	U6								
15.50	D13								
16.50-16.95 16.50-16.95	SPT N=27 S6	1.50	DRY	5,5/6,6,7,8					
						(16.30)			
17.70	D14								
18.00-18.45	U7								
18.50	D15								
19.50-19.95 19.50-19.95	SPT N=37 S7	1.50	DRY	6,8/8,9,9,11					

Remarks	**Scale (approx)**	**Logged By**
	1:50	MP
	Figure No. J15227A.BH1	

Geotechnical & Environmental Associates	Widbury Barn Widbury Hill Ware,Herts SG12 7QE	**Site** Bangor Wharf, Georgiana Street, Camden, NW1 0QS	**Borehole Number** **BH1**

Boring Method	**Casing Diameter**	**Ground Level (mOD)**	**Client**	**Job Number**
Cable Percussion	150mm cased to 1.50m	24.30	One Housing Group	J15227A
	Location	**Dates** 26/10/2016	**Engineer** Conisbee	**Sheet** 3/3

Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
21.00-21.45	U8								
21.50	D16								
22.50-22.95 22.50-22.95	SPT N=37 S8	1.50	DRY	6,7/8,9,9,11		(16.30)			
24.50-24.45	U9								
25.00	D17				-0.70	25.00	Complete at 25.00m		

Remarks	**Scale (approx)**	**Logged By**
	1:50	MP
	Figure No.	
	J15227A.BH1	

Geotechnical & Environmental Associates	Widbury Barn Widbury Hill Ware,Herts SG12 7QE	**Site** Bangor Wharf, Georgiana Street, Camden, NW1 0QS	**Borehole Number** **BH2**

Boring Method	**Casing Diameter**	**Ground Level (mOD)**	**Client**	**Job Number**
Cable Percussion	150mm cased to 1.50m	24.65	One Housing Group	J15227A
	Location	**Dates** 27/10/2016	**Engineer** Conisbee	**Sheet** 1/3

Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
						(0.35)	Tarmac (100 mm) over Granite setts (250 mm)		
					24.30	0.35	Made Ground (brown silty sandy clay with gravel, brick, and ash)		
0.50	D1								
0.80	D2					(1.25)			
1.20-1.65 1.20-1.65	CPT N=5 B1	1.20	DRY	1,0/1,1,1,2					
					23.05	1.60	Firm becoming stiff fissured medium strength becoming high strength brown silty CLAY with occasional grey markings		
1.80	D3								
2.00-2.45	U1								
2.50	D4								
2.80	D5								
3.00-3.45	U2								
3.50	D6								
3.80	D7								
4.00-4.45 4.00-4.45	SPT N=10 S1	1.50	DRY	2,2/2,2,3,3					
4.70	D8								
5.00-5.45	U3								
						(7.50)			
5.50	D9								
6.00-6.45 6.00-6.45	SPT N=14 S2	1.50	DRY	2,3/3,3,4,4					
7.50-7.95	U4								
8.00	D10								
9.00-9.45 9.00-9.45	SPT N=15 S3	1.50	DRY	3,3/3,4,4,4	15.55	9.10	Stiff becoming very stiff fissured high strength becoming very high strength dark grey silty CLAY		

Remarks
Service inspection pit excavated to 1.2 m - 1 hour 30 minutes
Groundwater not encountered
UXO Clearance - 30 minutes

Scale (approx)	**Logged By**
1:50	MP

Figure No. J15227A.BH2

Geotechnical & Environmental Associates	Widbury Barn Widbury Hill Ware,Herts SG12 7QE	**Site** Bangor Wharf, Georgiana Street, Camden, NW1 0QS	**Borehole Number** **BH2**

Boring Method	**Casing Diameter**	**Ground Level (mOD)**	**Client**	**Job Number**
Cable Percussion	150mm cased to 1.50m	24.65	One Housing Group	J15227A
	Location	**Dates** 27/10/2016	**Engineer** Conisbee	**Sheet** 2/3

Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
10.50-10.95	U5								
11.00	D11								
12.00-12.45 12.00-12.45	SPT N=18 S4	1.50	DRY	4,4/4,4,5,5					
13.50-13.95	U6								
14.00	D12								
15.00-15.45 15.00-15.45	SPT N=25 S5	1.50	DRY	5,5/5,6,7,7					
16.50-16.95	U7								
17.00	D13								
						(15.90)			
18.00-18.45 18.00-18.45	SPT N=29 S6	1.50	DRY	6,6/7,7,7,8					
19.50-19.95	U8								

Remarks	**Scale (approx)**	**Logged By**
	1:50	MP
	Figure No. J15227A.BH2	

Geotechnical & Environmental Associates	Widbury Barn Widbury Hill Ware,Herts SG12 7QE	**Site** Bangor Wharf, Georgiana Street, Camden, NW1 0QS	**Borehole Number** **BH2**

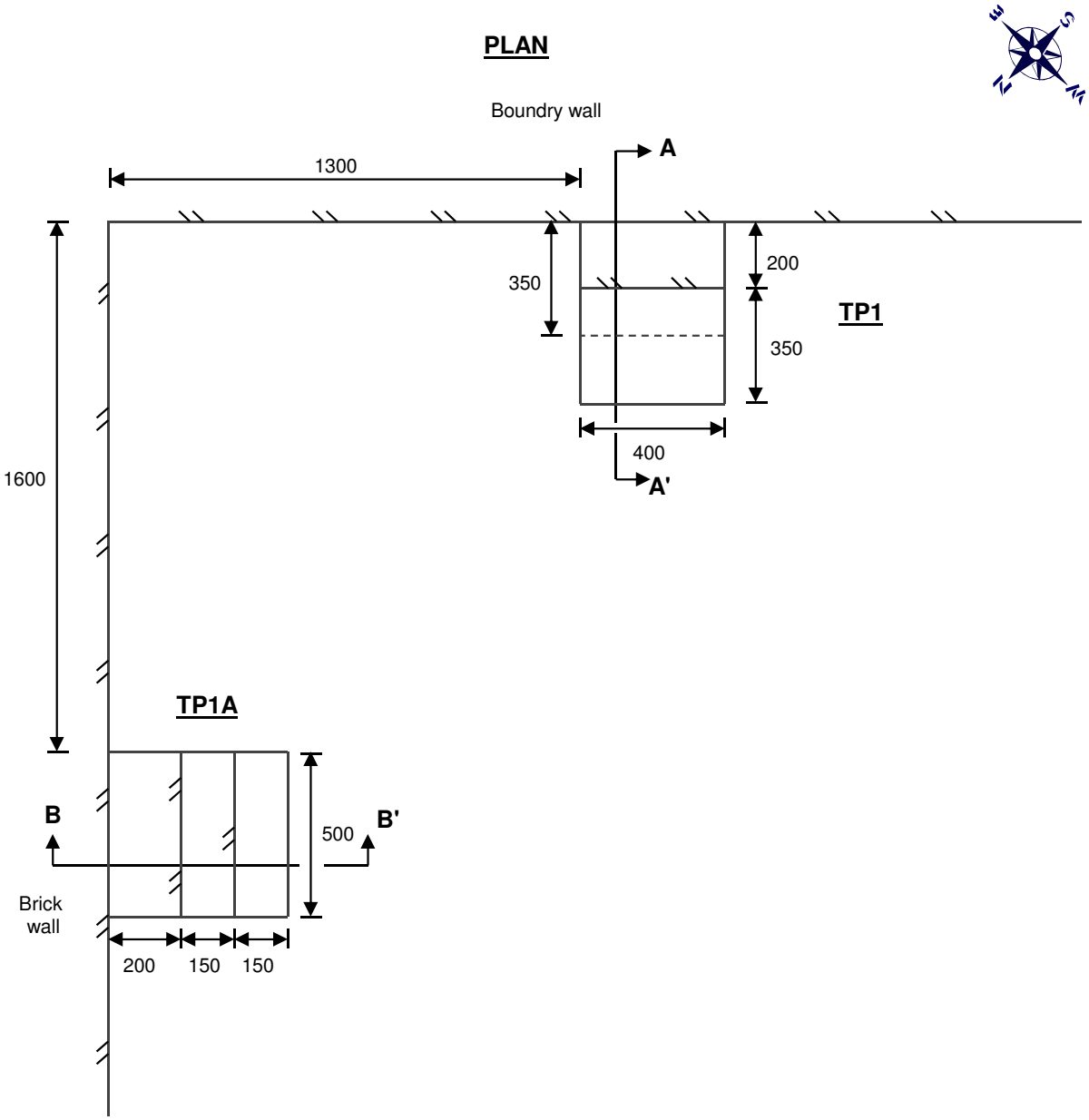
Boring Method	**Casing Diameter**	**Ground Level (mOD)**	**Client**	**Job Number**
Cable Percussion	150mm cased to 1.50m	24.65	One Housing Group	J15227A
	Location	**Dates** 27/10/2016	**Engineer** Conisbee	**Sheet** 3/3

Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
20.00	D14								
21.00-21.45 21.00-21.45	SPT N=35 S7	1.50	DRY	7,7/8,8,9,10					
22.50-22.95	U9					(15.90)			
23.00	D15								
24.50-24.95 24.50-24.95	SPT N=38 S8	1.50	DRY	7,8/8,9,9,12					
					-0.35	25.00	Complete at 25.00m		

Remarks	**Scale (approx)**	**Logged By**
	1:50	MP
	Figure No. J15227A.BH2	

Geotechnical & Environmental Associates	Widbury Barns Widbury Hill Ware Herts SG12 7QE	**Site** Bangor Wharf, Georgiana Street, Camden, NW1 0QS	**Trial Pit Number** **1 & 1A**

Excavation Method	**Dimensions**	**Ground Level (mOD)**	**Client**	**Job Number**
Manual	TP1 - 400 x 550 x 2000 TP1 A 500 x 500 x 2000	26.20	One Housing Group	J15227A
	Location	**Dates**	**Engineer**	**Sheet**
	Ground Level	26/10/2015	Conisbee	1/2

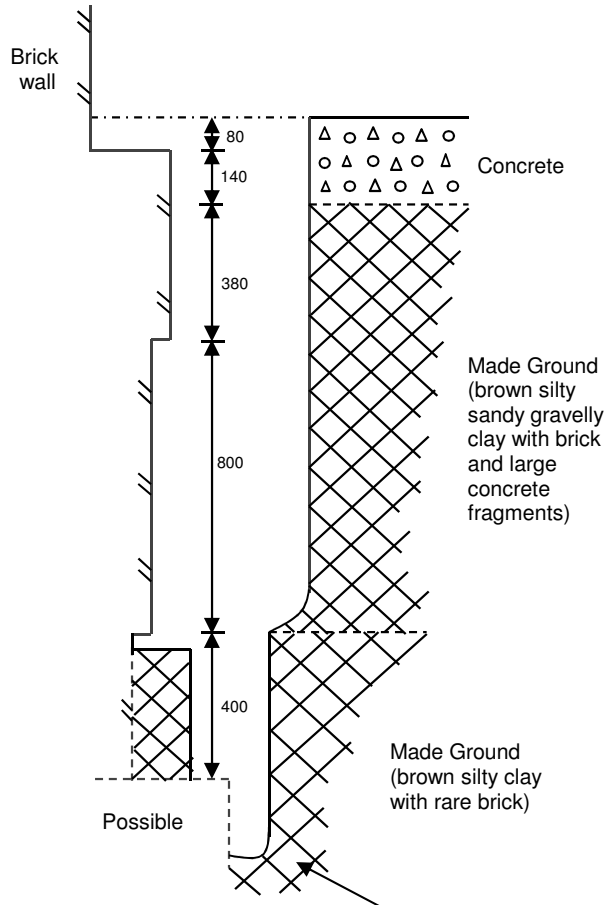


Remarks:	Scale:
All dimensions in millimetres	1:20
Trial pit sides remained stable during excavation	Logged by:
Groundwater not encountered	MP

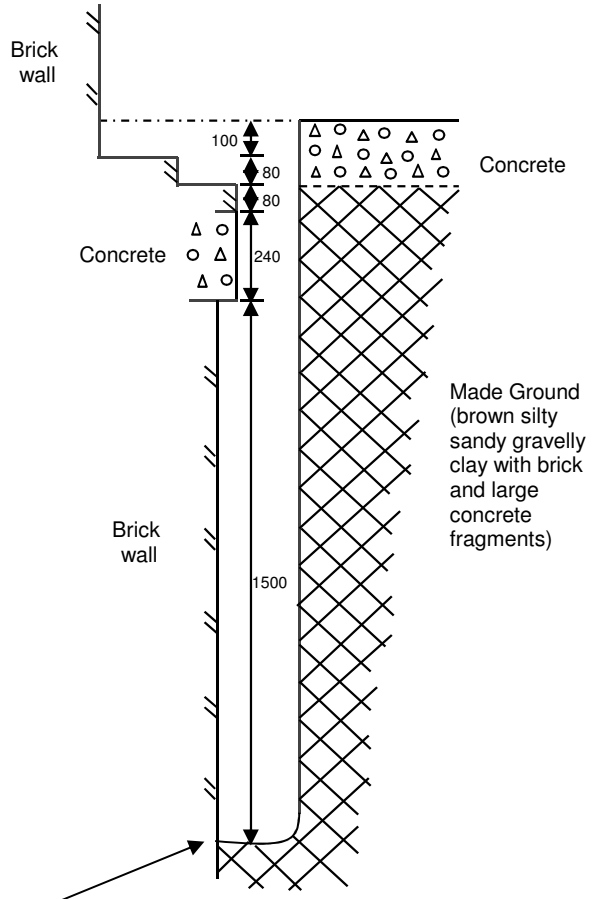
Geotechnical & Environmental Associates	Widbury Barns Widbury Hill Ware Herts SG12 7QE	**Site** Bangor Wharf, Georgiana Street, Camden, NW1 0QS	**Trial Pit Number** **1 & 1A**

Excavation Method	**Dimensions**	**Ground Level (mOD)**	**Client**	**Job Number**
Manual	TP1 - 400 x 550 x 2000 TP1 A 500 x 500 x 2000	26.20	One Housing Group	J15227A
	Location	**Dates**	**Engineer**	**Sheet**
	Ground Level	26/10/2015	Conisbee	2/2

TP1 - SECTION A - A'



TP1A - SECTION B - B'



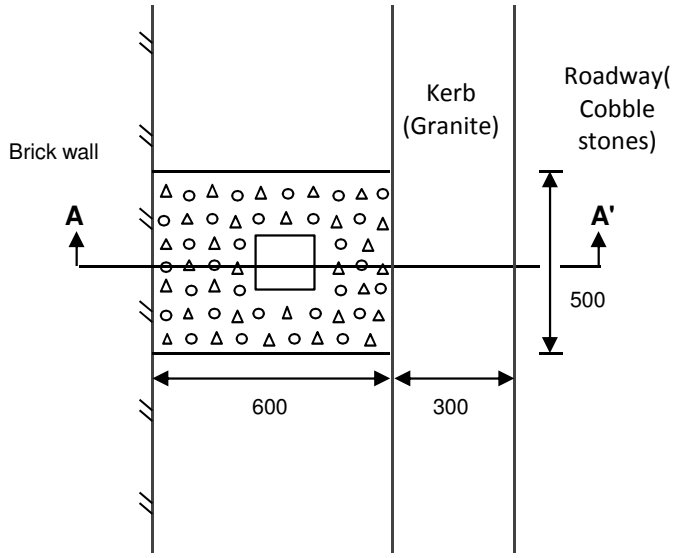
Trial pits deepened to 2.0 m with hand auger

Remarks:	Scale:
All dimensions in millimetres	1:20
Trial pit sides remained stable during excavation	Logged by:
Groundwater not encountered	MP

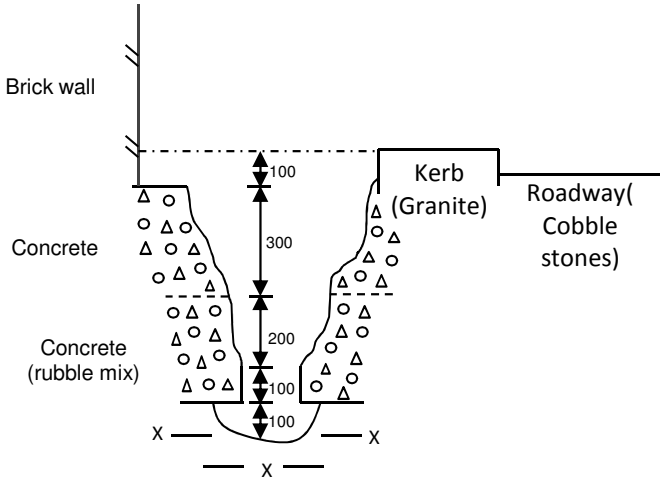
Geotechnical & Environmental Associates	Widbury Barns Widbury Hill Ware Herts SG12 7QE	**Site** Bangor Wharf, Georgiana Street, Camden, NW1 0QS	**Trial Pit Number** **2**

Excavation Method	**Dimensions**	**Ground Level (mOD)**	**Client**	**Job Number**
Manual	500 x 600 x 800	22.50	One Housing Group	J15227A
	Location	**Dates**	**Engineer**	**Sheet**
	Ground Level	26/10/2015	Conisbee	1/1

PLAN



SECTION A - A'



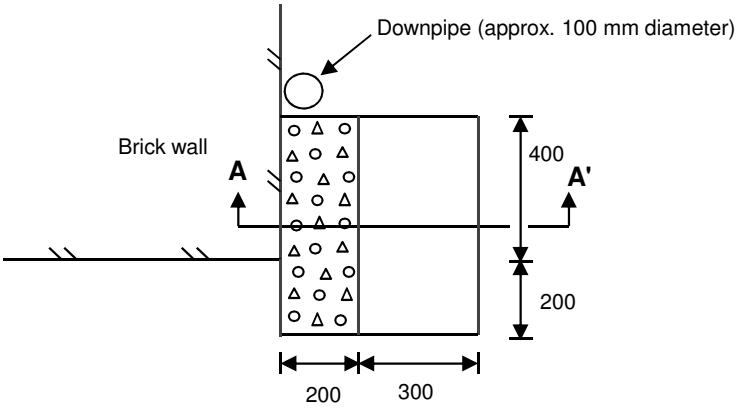
Firm brown silty CLAY

Remarks:	Scale:
All dimensions in millimetres	1:20
Trial pit sides remained stable during excavation	Logged by:
Groundwater not encountered	MP

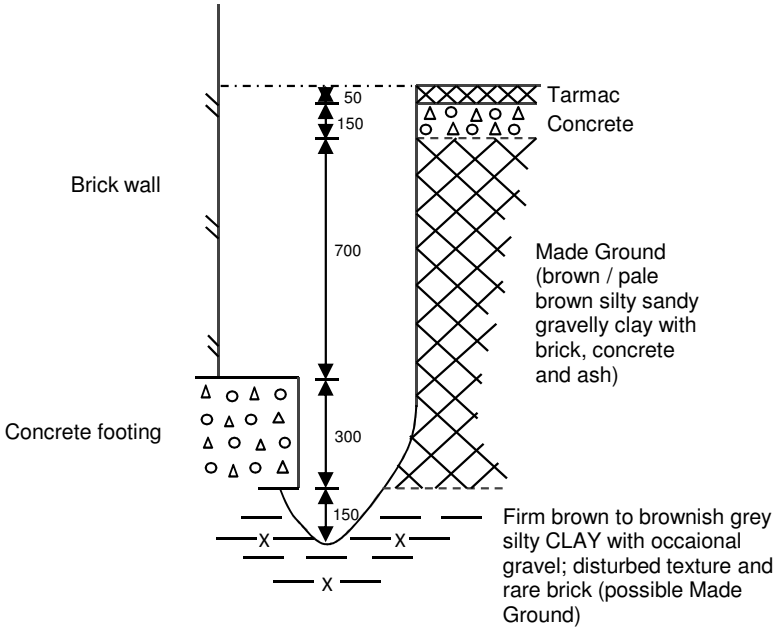
Geotechnical & Environmental Associates	Widbury Barns Widbury Hill Ware Herts SG12 7QE	**Site** Bangor Wharf, Georgiana Street, Camden, NW1 0QS	**Trial Pit Number** 3

Excavation Method	**Dimensions**	**Ground Level (mOD)**	**Client**	**Job Number**
Manual	500 x 600 x 1350	24.80	One Housing Group	J15227A
	Location	**Dates**	**Engineer**	**Sheet**
	Ground Level	26/10/2015	Conisbee	1/1

PLAN



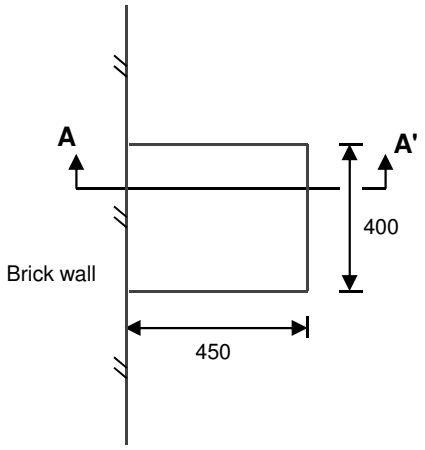
SECTION A - A'



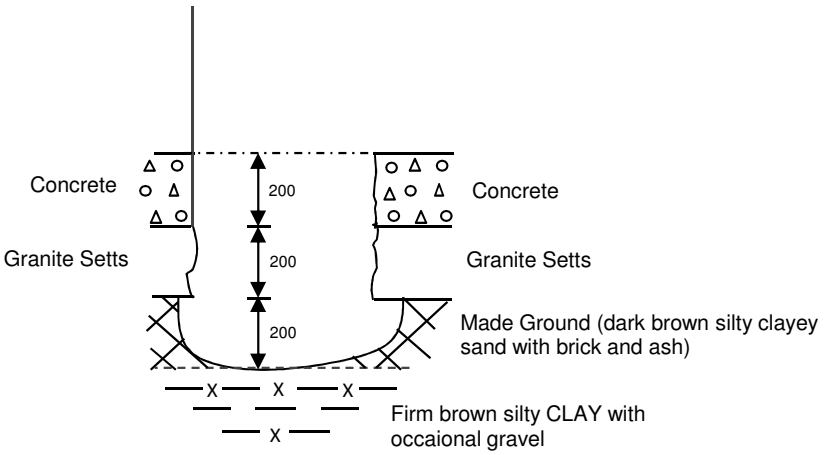
Remarks:	Scale:
All dimensions in millimetres	1:20
Trial pit sides remained stable during excavation	Logged by:
Groundwater not encountered; however, soils were noticably wet immediately above footing	MP

Geotechnical & Environmental Associates Widbury Barns Widbury Hill Ware Herts SG12 7QE			**Site** Bangor Wharf, Georgiana Street, Camden, NW1 0QS	**Trial Pit Number** **4**
Excavation Method Manual	**Dimensions** 400 x 450 x 600	**Ground Level (mOD)** 24.25	**Client** One Housing Group	**Job Number** J15227A
	Location Ground Level	**Dates** 26/10/2015	**Engineer** Conisbee	**Sheet** 1/1

PLAN



SECTION A - A'



Remarks:	Scale:
All dimensions in millimetres	1:20
Trial pit sides remained stable during excavation	Logged by:
Groundwater not encountered	MP

SUMMARY OF GEOTECHNICAL TESTING

Sample details					Classification Tests					Density Tests		Undrained Triaxial Compression			Chemical Tests			Other tests and comments
Borehole / Trial Pit	Sample Ref	Depth (m)	Type	Description	MC (%)	LL (%)	PL (%)	PI (%)	<425 µm (%)	Bulk Mg/m³	Dry Mg/m³	Cell Pressure kPa	Deviator Stress kPa	Shear Stress kPa	pH	2:1 W/S SO4 (g/L)	W/S Mg (mg/L)	
BH1	1	2.00	U	Stiff fissured yellowish brown CLAY	29					1.96	1.52	40	151	76	8.3	1.30		
BH1	1	3.00	D	Yellowish brown silty CLAY	32	73	27	46	100									
BH1	2	4.00	U	Stiff fissured yellowish brown CLAY with rare gypsum	32					1.94	1.47	80	170	85				
BH1	2	5.00	D	Brown silty CLAY	32	77	27	50	100									
BH1	3	6.00	U	Stiff fissured brown CLAY with rare gypsum	32					1.95	1.48	120	214	107	8.0	7.50	890	
BH1	4	9.00	U	Stiff fissured greyish brown CLAY with rare fine sand	27					2.03	1.60	180	281	140				
BH1	5	12.00	U	Stiff fissured greyish brown CLAY	27					2.02	1.59	240	285	142				
BH1	5	13.50	D	Dark brown silty CLAY	25	66	22	44	100									
BH1	6	15.00	U	Stiff fissured greyish brown CLAY with rare patches of fine sand	26					1.73	1.37	300	320	160				
BH1	7	18.00	U	Stiff fissured greyish brown CLAY with occasional fine to medium gravel and pocket of mudstone/siltstone	29					1.99	1.54	360	253	127				

Sample type: B (Bulk disturb.) BLK (Block) C (Core) D (Disturbed) LB (Large Bulk dist.) U (Undisturbed)

Checked and Approved by

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS®

SUMMARY OF GEOTECHNICAL TESTING

Sample details					Classification Tests					Density Tests		Undrained Triaxial Compression			Chemical Tests			Other tests and comments
Borehole / Trial Pit	Sample Ref	Depth (m)	Type	Description	MC (%)	LL (%)	PL (%)	PI (%)	<425 µm (%)	Bulk Mg/m³	Dry Mg/m³	Cell Pressure kPa	Deviator Stress kPa	Shear Stress kPa	pH	2:1 W/S SO4 (g/L)	W/S Mg (mg/L)	
BH1	8	21.00	U	Stiff fissured greyish brown CLAY with rare fine sand	25					1.97	1.58	420	762	381				
BH1	9	24.50	U	Stiff fissured greyish brown CLAY with rare fine sand (visible surface fractures)	26					1.92	1.52	490	359	179				
BH2	1	2.00	U	Firm to stiff yellowish brown slightly sandy CLAY with rare fine gravel	29					2.00	1.55	40	93	46				
BH2	2	3.00	U	Stiff fissured yellowish brown CLAY	31					2.00	1.53	60	177	89				
BH2	1	4.00	D	Brown silty CLAY	31	74	26	48	100						7.9	8.90	790	
BH2	3	5.00	U	Stiff fissured brown with light grey mottling CLAY with rare gypsum	34					1.94	1.45	100	163	81				
BH2	4	7.50	U	Stiff fissured brown CLAY with rare fine sand and gypsum	27					1.98	1.56	150	252	126				
BH2	3	9.00	D	Brown silty CLAY	27	64	23	41	100									
BH2	5	10.50	U	Stiff fissured greyish brown CLAY	27					2.02	1.59	210	224	112				
BH2	6	13.50	U	Stiff fissured greyish brown CLAY	27					2.03	1.60	270	308	154				

Sample type: B (Bulk disturb.) BLK (Block) C (Core) D (Disturbed) LB (Large Bulk dist.) U (Undisturbed)

Checked and Approved by

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS®

SUMMARY OF GEOTECHNICAL TESTING

Sample details					Classification Tests					Density Tests		Undrained Triaxial Compression			Chemical Tests			Other tests and comments
Borehole / Trial Pit	Sample Ref	Depth (m)	Type	Description	MC (%)	LL (%)	PL (%)	PI (%)	<425 µm (%)	Bulk Mg/m³	Dry Mg/m³	Cell Pressure kPa	Deviator Stress kPa	Shear Stress kPa	pH	2:1 W/S SO4 (g/L)	W/S Mg (mg/L)	
BH2	7	16.50	U	Stiff fissured greyish brown CLAY	27					2.00	1.57	330	378	189				
BH2	6	18.00	D	Dark brown silty CLAY	28	74	25	49	100									
BH2	8	19.50	U	Stiff to very stiff fissured greyish brown CLAY with rare medium gravel.	27					1.95	1.54	390	315	157				
BH2	9	22.50	U	Stiff fissured greyish brown CLAY	24					1.97	1.59	450	658	329				

Sample type: B (Bulk disturb.) BLK (Block) C (Core) D (Disturbed) LB (Large Bulk dist.) U (Undisturbed)

Checked and Approved by

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS®

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH1
Sample Ref	1
Depth (m)	2.00
Sample Type	U

Description:

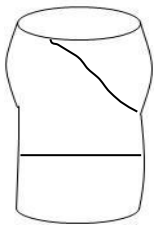
Stiff fissured yellowish brown CLAY

Remarks : Surface fractures and wax

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.7
Diameter	(mm)	102.5
Moisture Content	(%)	29
Bulk Density	(Mg/m³)	1.96
Dry Density	(Mg/m³)	1.53
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.8
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	40
Strain at failure	(%)	11.9
Maximum Deviator Stress	(kPa)	151
Shear Stress Cu	(kPa)	76

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	110

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS®

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH1
Sample Ref	2
Depth (m)	4.00
Sample Type	U

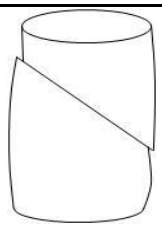
Description:

Stiff fissured yellowish brown CLAY with rare gypsum

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.2
Diameter	(mm)	102.0
Moisture Content	(%)	32
Bulk Density	(Mg/m³)	1.94
Dry Density	(Mg/m³)	1.47
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.5
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	80
Strain at failure	(%)	7.5
Maximum Deviator Stress	(kPa)	170
Shear Stress Cu	(kPa)	85

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	30

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH1
Sample Ref	3
Depth (m)	6.00
Sample Type	U

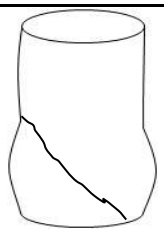
Description:

Stiff fissured brown CLAY with rare gypsum

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.5
Diameter	(mm)	102.5
Moisture Content	(%)	32
Bulk Density	(Mg/m³)	1.95
Dry Density	(Mg/m³)	1.48
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.7
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	120
Strain at failure	(%)	9.9
Maximum Deviator Stress	(kPa)	214
Shear Stress Cu	(kPa)	107

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	60

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS®

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH1
Sample Ref	4
Depth (m)	9.00
Sample Type	U

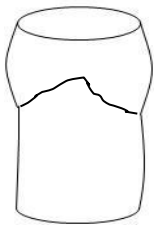
Description:

Stiff fissured greyish brown CLAY with rare fine sand

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.4
Diameter	(mm)	102.5
Moisture Content	(%)	27
Bulk Density	(Mg/m³)	2.03
Dry Density	(Mg/m³)	1.60
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.9
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	180
Strain at failure	(%)	14.4
Maximum Deviator Stress	(kPa)	281
Shear Stress Cu	(kPa)	140

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	40

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH1
Sample Ref	5
Depth (m)	12.00
Sample Type	U

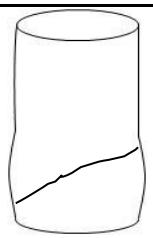
Description:

Stiff fissured greyish brown CLAY

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.4
Diameter	(mm)	102.5
Moisture Content	(%)	27
Bulk Density	(Mg/m³)	2.02
Dry Density	(Mg/m³)	1.60
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.3
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	240
Strain at failure	(%)	3.5
Maximum Deviator Stress	(kPa)	285
Shear Stress Cu	(kPa)	142

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	40

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS®

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH1
Sample Ref	6
Depth (m)	15.00
Sample Type	U

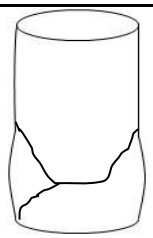
Description:

Stiff fissured greyish brown CLAY with rare patches of fine sand

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	234.8
Diameter	(mm)	102.4
Moisture Content	(%)	26
Bulk Density	(Mg/m³)	1.73
Dry Density	(Mg/m³)	1.37
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.5
Axial displacement rate	(%/min)	1.7
Cell pressure	(kPa)	300
Strain at failure	(%)	7.2
Maximum Deviator Stress	(kPa)	320
Shear Stress Cu	(kPa)	160

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	60

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH1
Sample Ref	7
Depth (m)	18.00
Sample Type	U

Description:

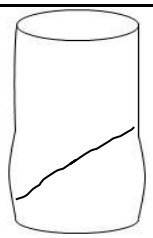
Stiff fissured greyish brown CLAY with occasional fine to medium gravel and pocket of mudstone/siltstone

Remarks : Some patching required

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.4
Diameter	(mm)	102.4
Moisture Content	(%)	29
Bulk Density	(Mg/m³)	1.99
Dry Density	(Mg/m³)	1.54
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.3
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	360
Strain at failure	(%)	4.0
Maximum Deviator Stress	(kPa)	253
Shear Stress Cu	(kPa)	127

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	50

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH1
Sample Ref	8
Depth (m)	21.00
Sample Type	U

Description:

Stiff fissured greyish brown CLAY with rare fine sand

Remarks : Fractures at top of sample

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	175.3
Diameter	(mm)	102.5
Moisture Content	(%)	25
Bulk Density	(Mg/m³)	1.97
Dry Density	(Mg/m³)	1.58
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.6
Axial displacement rate	(%/min)	2.3
Cell pressure	(kPa)	420
Strain at failure	(%)	9.1
Maximum Deviator Stress	(kPa)	762
Shear Stress Cu	(kPa)	381

Mode of failure

Orientation of the sample	Vertical
Distance from top of tube mm	240

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH1
Sample Ref	9
Depth (m)	24.50
Sample Type	U

Description:

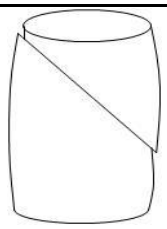
Stiff fissured greyish brown CLAY with rare fine sand

Remarks : Visible surface fractures

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.5
Diameter	(mm)	102.9
Moisture Content	(%)	26
Bulk Density	(Mg/m³)	1.92
Dry Density	(Mg/m³)	1.53
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.5
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	490
Strain at failure	(%)	6.5
Maximum Deviator Stress	(kPa)	359
Shear Stress Cu	(kPa)	179

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	30

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS®

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH2
Sample Ref	1
Depth (m)	2.00
Sample Type	U

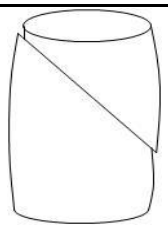
Description:

Firm to stiff yellowish brown slightly sandy CLAY with rare fine gravel

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.4
Diameter	(mm)	101.8
Moisture Content	(%)	29
Bulk Density	(Mg/m³)	2.00
Dry Density	(Mg/m³)	1.55
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.9
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	40
Strain at failure	(%)	13.9
Maximum Deviator Stress	(kPa)	93
Shear Stress Cu	(kPa)	46

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	30

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS®

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH2
Sample Ref	2
Depth (m)	3.00
Sample Type	U

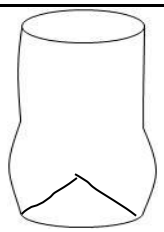
Description:

Stiff fissured yellowish brown CLAY

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.4
Diameter	(mm)	101.6
Moisture Content	(%)	31
Bulk Density	(Mg/m³)	2.00
Dry Density	(Mg/m³)	1.53
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	1.1
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	60
Strain at failure	(%)	19.9
Maximum Deviator Stress	(kPa)	177
Shear Stress Cu	(kPa)	89

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	40

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS®

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH2
Sample Ref	3
Depth (m)	5.00
Sample Type	U

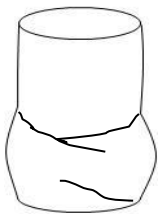
Description:

Stiff fissured brown with light grey mottling CLAY with rare gypsum

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.4
Diameter	(mm)	102.2
Moisture Content	(%)	34
Bulk Density	(Mg/m³)	1.94
Dry Density	(Mg/m³)	1.45
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	1.1
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	100
Strain at failure	(%)	19.9
Maximum Deviator Stress	(kPa)	163
Shear Stress Cu	(kPa)	81

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	30

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH2
Sample Ref	4
Depth (m)	7.50
Sample Type	U

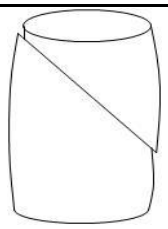
Description:

Stiff fissured brown CLAY with rare fine sand and gypsum

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.5
Diameter	(mm)	103.0
Moisture Content	(%)	27
Bulk Density	(Mg/m³)	1.98
Dry Density	(Mg/m³)	1.56
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.6
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	150
Strain at failure	(%)	8.9
Maximum Deviator Stress	(kPa)	252
Shear Stress Cu	(kPa)	126

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	30

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS®

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH2
Sample Ref	5
Depth (m)	10.50
Sample Type	U

Description:

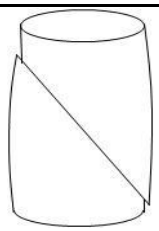
Stiff fissured greyish brown CLAY

Remarks : Horizontal fracture base of sample

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.4
Diameter	(mm)	102.1
Moisture Content	(%)	27
Bulk Density	(Mg/m³)	2.02
Dry Density	(Mg/m³)	1.59
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.6
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	210
Strain at failure	(%)	7.9
Maximum Deviator Stress	(kPa)	224
Shear Stress Cu	(kPa)	112

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	30

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS®

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH2
Sample Ref	6
Depth (m)	13.50
Sample Type	U

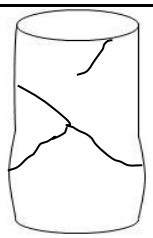
Description:

Stiff fissured greyish brown CLAY

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.4
Diameter	(mm)	102.3
Moisture Content	(%)	27
Bulk Density	(Mg/m³)	2.03
Dry Density	(Mg/m³)	1.59
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.4
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	270
Strain at failure	(%)	6.0
Maximum Deviator Stress	(kPa)	308
Shear Stress Cu	(kPa)	154

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	100

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS®

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH2
Sample Ref	7
Depth (m)	16.50
Sample Type	U

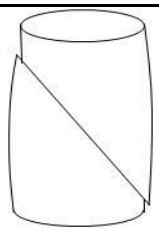
Description:

Stiff fissured greyish brown CLAY

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.3
Diameter	(mm)	102.6
Moisture Content	(%)	27
Bulk Density	(Mg/m³)	2.00
Dry Density	(Mg/m³)	1.57
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.5
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	330
Strain at failure	(%)	6.5
Maximum Deviator Stress	(kPa)	378
Shear Stress Cu	(kPa)	189

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	40

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS

UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH2
Sample Ref	8
Depth (m)	19.50
Sample Type	U

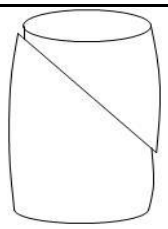
Description:

Stiff to very stiff fissured greyish brown CLAY with rare medium gravel.

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.2
Diameter	(mm)	103.0
Moisture Content	(%)	27
Bulk Density	(Mg/m³)	1.95
Dry Density	(Mg/m³)	1.53
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.4
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	390
Strain at failure	(%)	5.0
Maximum Deviator Stress	(kPa)	315
Shear Stress Cu	(kPa)	157

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	90

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

BANGOR WHARF
J15227A

GEOLABS®
UKAS TESTING 1982

BS 1377 : Part 7 : 1990 Clause 8

Quick Undrained Triaxial Compression Test

BH/TP No	BH2
Sample Ref	9
Depth (m)	22.50
Sample Type	U

Description:

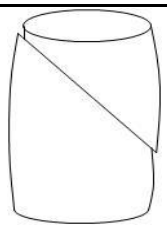
Stiff fissured greyish brown CLAY

Remarks : Visible surface fractures

Specimen Details

Specimen conditions		Undisturbed
Length	(mm)	201.5
Diameter	(mm)	102.0
Moisture Content	(%)	24
Bulk Density	(Mg/m³)	1.97
Dry Density	(Mg/m³)	1.59
Test Details		
Latex membrane thickness	(mm)	0.3
Membrane correction	(kPa)	0.6
Axial displacement rate	(%/min)	2.0
Cell pressure	(kPa)	450
Strain at failure	(%)	7.9
Maximum Deviator Stress	(kPa)	658
Shear Stress Cu	(kPa)	329

Mode of failure



Orientation of the sample	Vertical
Distance from top of tube mm	40

Checked and Approved by:

Operations Manager
20/11/2015

Project Number:

GEO / 23314

Project Name:

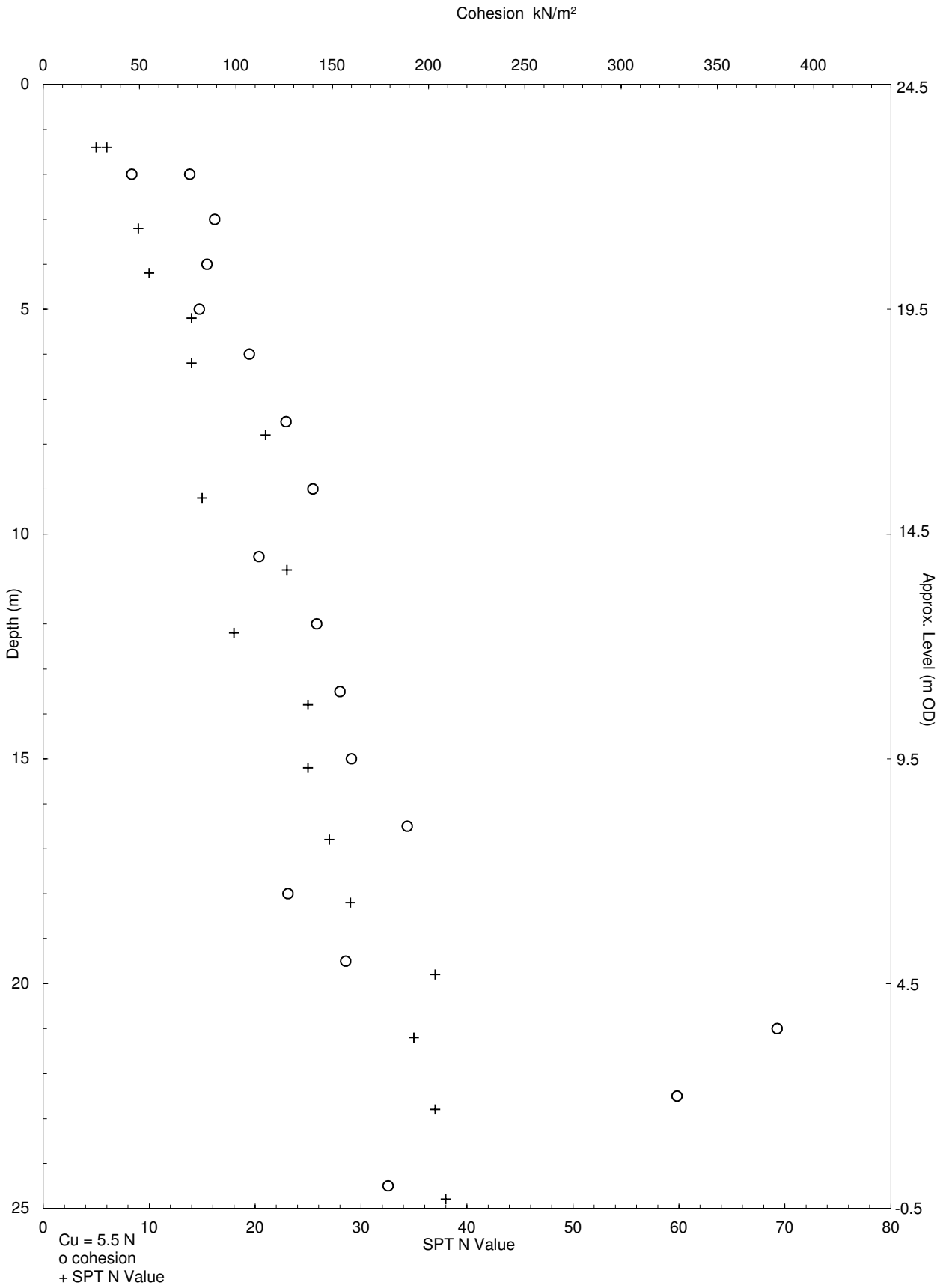
BANGOR WHARF
J15227A

GEOLABS®

UKAS TESTING 1982

Geotechnical & Environmental Associates	Widbury Barn Widbury Hill Ware Herts SG12 7QE	**SPT & Cohesion / Depth & Level Graph**

Site	Bangor Wharf, Georgiana Street, Camden, NW1 0QS	**Job Number** J15227A
Client	One Housing Group	**Sheet** 1 / 1
Engineer	Conisbee	



Results - Soil

Project: J15227A - Bangor Wharf, Georgiana Street, NW1

Client: GEA				**Chemtest Job No.:**	15-25340	15-25340	15-25340	15-25340
Quotation No.:				**Chemtest Sample ID.:**	211484	211485	211486	211487
Order No.: J15227A				Client Sample Ref.:	TP1	TP2	TP3	TP4
				Client Sample ID.:	1	1	1	1
				Sample Type:	SOIL	SOIL	SOIL	SOIL
				Top Depth (m):	0.50	0.75	0.40	0.50
				Bottom Depth (m):	1.00		0.80	
				Date Sampled:	26-Oct-2015	26-Oct-2015	26-Oct-2015	26-Oct-2015
Determinand	**Accred.**	**SOP**	**Units**	**LOD**				
Moisture	N	2030	%	0.020	21	22	26	15
Stones	N	2030	%	0.020	< 0.020	< 0.020	< 0.020	< 0.020
Soil Colour	N	2040		N/A	Brown	Brown	Grey	Brown
Other Material	N	2040		N/A	NONE	NONE	NONE	Stones
Soil Texture	N	2040		N/A	Clay	Clay	Clay	Sand
pH	M	2010		N/A	8.0	8.9	8.5	9.0
Sulphate (2:1 Water Soluble) as SO4	M	2120	g/l	0.010	0.24	0.15	0.032	0.21
Chloride (Extractable)	M	2220	g/l	0.010	0.048	0.075	0.23	0.051
Cyanide (Total)	M	2300	mg/kg	0.50	< 0.50	< 0.50	< 0.50	< 0.50
Sulphide (Easily Liberatable)	M	2325	mg/kg	0.50	1.3	1.5	150	7.3
Sulphate (Total)	M	2430	mg/kg	100	890	1200	2700	6100
Arsenic	M	2450	mg/kg	1.0	17	21	13	46
Cadmium	M	2450	mg/kg	0.10	0.14	0.19	0.11	0.29
Chromium	M	2450	mg/kg	1.0	66	53	63	31
Copper	M	2450	mg/kg	0.50	36	32	38	540
Mercury	M	2450	mg/kg	0.10	< 0.10	0.22	0.10	0.43
Nickel	M	2450	mg/kg	0.50	63	49	51	64
Lead	M	2450	mg/kg	0.50	35	29	34	730
Selenium	M	2450	mg/kg	0.20	< 0.20	< 0.20	< 0.20	< 0.20
Zinc	M	2450	mg/kg	0.50	89	69	87	250
Total Organic Carbon	M	2625	%	0.20	0.53	0.75	0.88	1.1
TPH >C5-C6	N	2670	mg/kg	1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH >C6-C7	N	2670	mg/kg	1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH >C7-C8	N	2670	mg/kg	1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH >C8-C10	N	2670	mg/kg	1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH >C10-C12	N	2670	mg/kg	1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH >C12-C16	N	2670	mg/kg	1.0	< 1.0	< 1.0	< 1.0	5.2
TPH >C16-C21	N	2670	mg/kg	1.0	< 1.0	< 1.0	< 1.0	11
TPH >C21-C35	N	2670	mg/kg	1.0	< 1.0	< 1.0	< 1.0	19
Total TPH >C5-C35	N	2670	mg/kg	10	< 10	< 10	< 10	35
Naphthalene	M	2700	mg/kg	0.10	< 0.10	< 0.10	< 0.10	0.18
Acenaphthylene	M	2700	mg/kg	0.10	< 0.10	< 0.10	< 0.10	< 0.10
Acenaphthene	M	2700	mg/kg	0.10	< 0.10	< 0.10	< 0.10	0.12
Fluorene	M	2700	mg/kg	0.10	< 0.10	< 0.10	< 0.10	0.13
Phenanthrene	M	2700	mg/kg	0.10	< 0.10	< 0.10	< 0.10	0.88
Anthracene	M	2700	mg/kg	0.10	< 0.10	< 0.10	< 0.10	< 0.10
Fluoranthene	M	2700	mg/kg	0.10	< 0.10	0.44	< 0.10	1.4

Chemtest
The right chemistry to deliver results

Results - Soil

Project: J15227A - Bangor Wharf, Georgiana Street, NW1

Client: GEA				**Chemtest Job No.:**	15-25340	15-25340	15-25340	15-25340
Quotation No.:				**Chemtest Sample ID.:**	211484	211485	211486	211487
Order No.: J15227A				Client Sample Ref.:	TP1	TP2	TP3	TP4
				Client Sample ID.:	1	1	1	1
				Sample Type:	SOIL	SOIL	SOIL	SOIL
				Top Depth (m):	0.50	0.75	0.40	0.50
				Bottom Depth (m):	1.00		0.80	
				Date Sampled:	26-Oct-2015	26-Oct-2015	26-Oct-2015	26-Oct-2015
Determinand	**Accred.**	**SOP**	**Units**	**LOD**				
Pyrene	M	2700	mg/kg	0.10	< 0.10	0.24	< 0.10	1.3
Benzo[a]anthracene	M	2700	mg/kg	0.10	< 0.10	< 0.10	< 0.10	0.63
Chrysene	M	2700	mg/kg	0.10	< 0.10	< 0.10	< 0.10	0.89
Benzo[b]fluoranthene	M	2700	mg/kg	0.10	< 0.10	< 0.10	< 0.10	1.0
Benzo[k]fluoranthene	M	2700	mg/kg	0.10	< 0.10	< 0.10	< 0.10	0.50
Benzo[a]pyrene	M	2700	mg/kg	0.10	< 0.10	< 0.10	< 0.10	0.71
Indeno(1,2,3-c,d)Pyrene	M	2700	mg/kg	0.10	< 0.10	< 0.10	< 0.10	0.45
Dibenz(a,h)Anthracene	M	2700	mg/kg	0.10	< 0.10	< 0.10	< 0.10	0.17
Benzo[g,h,i]perylene	M	2700	mg/kg	0.10	< 0.10	< 0.10	< 0.10	0.50
Total Of 16 PAH's	M	2700	mg/kg	2.0	< 2.0	< 2.0	< 2.0	8.9
Total Phenols	M	2920	mg/kg	0.30	< 0.30	< 0.30	< 0.30	< 0.30

Chemtest
The right chemistry to deliver results

Report Information

Key

U	UKAS accredited
M	MCERTS and UKAS accredited
N	Unaccredited
S	This analysis has been subcontracted to a UKAS accredited laboratory that is accredited for this analysis
SN	This analysis has been subcontracted to a UKAS accredited laboratory that is not accredited for this analysis
T	This analysis has been subcontracted to an unaccredited laboratory
I/S	Insufficient Sample
U/S	Unsuitable Sample
N/E	not evaluated
<	"less than"
>	"greater than"

Comments or interpretations are beyond the scope of UKAS accreditation
The results relate only to the items tested
Uncertainty of measurement for the determinands tested are available upon request
None of the results in this report have been recovery corrected
All results are expressed on a dry weight basis
The following tests were analysed on samples as received and the results subsequently corrected to a dry weight basis TPH, BTEX, VOCs, SVCOs, PCBs, Phenols
For all other tests the samples were dried at < 37°C prior to analysis
All Asbestos testing is performed at our Coventry laboratory
Issue numbers are sequential starting with 1 all subsequent reports are incremented by 1

Sample Deviation Codes

A - Date of sampling not supplied
B - Sample age exceeds stability time (sampling to extraction)
C - Sample not received in appropriate containers
D - Broken Container

Sample Retention and Disposal

All soil samples will be retained for a period of 60 days from the date of receipt
All water samples will be retained for 14 days from the date of receipt
Charges may apply to extended sample storage

If you require extended retention of samples, please email your requirements to:
customerservices@chemtest.co.uk

GEA Geotechnical & Environmental Associates

Widbury Barn
Widbury Hill
Ware
Herts SG12 7QE

Generic Risk-Based Soil Screening Values

Site	Bangor Wharf, Georgiana Street, Camden, NW1 0QS	**Job Number** J15227A
Client	One Housing Group	**Sheet** 1 / 2
Engineer	Conisbee	

Proposed End Use Commercial

Soil pH 8

Soil Organic Matter content % 2.5

Contaminant	Screening Value mg/kg	Data Source
Metals		
Arsenic	640	C4SL
Cadmium	410	C4SL
Chromium (III)	30400	LQM/CIEH
Chromium (VI)	49	C4SL
Copper	71,700	LQM/CIEH
Lead	2330	C4SL
Elemental Mercury	170	SGV
Inorganic Mercury	3600	SGV
Nickel	1350	LQM/CIEH
Selenium	13000	SGV
Zinc	665,000	LQM/CIEH
Hydrocarbons		
Benzene	50	C4SL
Toluene	2200	SGV
Ethyl Benzene	48000	SGV
Xylene	1300	SGV
Aliphatic C5-C6	6200	LQM/CIEH
Aliphatic C6-C8	18000	LQM/CIEH
Aliphatic C8-C10	5100	LQM/CIEH
Aliphatic C10-C12	24000	LQM/CIEH
Aliphatic C12-C16	83000	LQM/CIEH
Aliphatic C16-C35	1,800,000	LQM/CIEH
Aromatic C6-C7	See Benzene	LQM/CIEH
Aromatic C7-C8	See Toluene	LQM/CIEH
Aromatic C8-C10	8600	LQM/CIEH
Aromatic C10-C12	29000	LQM/CIEH
Aromatic C12-C16	37000	LQM/CIEH
Aromatic C16-C21	28000	LQM/CIEH
Aromatic C21-C35	28000	LQM/CIEH
PRO (C_5 –C_{10})	40150	Calc
DRO (C_{12} –C_{28})	1,948,000	Calc
Lube Oil (C_{28} –C_{44})	1,828,000	Calc
TPH	**1000**	Trigger for speciated testing

Contaminant	Screening Value mg/kg	Data Source
Anions		
Soluble Sulphate	500 mg/l	Structures
Sulphide	50	Structures
Chloride	400	Structures
Others		
Organic Carbon (%)	10	Methanogenic potential
Total Cyanide	12000	WRAS
Total Mono Phenols	3200	SGV
PAH		
Naphthalene	480.00	C4SL exp & LQM/CIEH
Acenaphthylene	97,000	LQM/CIEH
Acenaphthene	98,000	LQM/CIEH
Fluorene	69,000	LQM/CIEH
Phenanthrene	22,000	LQM/CIEH
Anthracene	540,000	LQM/CIEH
Fluoranthene	23,000	LQM/CIEH
Pyrene	54,000	LQM/CIEH
Benzo(a) Anthracene	95.0	C4SL exp & LQM/CIEH
Chrysene	140	C4SL exp & LQM/CIEH
Benzo(b) Fluoranthene	100.0	C4SL exp & LQM/CIEH
Benzo(k) Fluoranthene	140.0	C4SL exp & LQM/CIEH
Benzo(a) pyrene	42.40	C4SL
Indeno(1 2 3 cd) Pyrene	61.0	C4SL exp & LQM/CIEH
Dibenzo(a h) Anthracene	13.00	C4SL exp & LQM/CIEH
Benzo (g h i) Perylene	660	C4SL exp & LQM/CIEH
Screening value for PAH	**605.7**	B(a)P / 0.15
Chlorinated Solvents		
1,1,1 trichloroethane (TCA)	1280	LQM/CIEH
tetrachloroethane (PCA)	332	LQM/CIEH
tetrachloroethene (PCE)	146	LQM/CIEH
trichloroethene (TCE)	14.8	LQM/CIEH
1,2-dichloroethane (DCA)	1	LQM/CIEH
vinyl chloride (Chloroethene)	0.113	LQM/CIEH
tetrachloromethane (Carbon tetra	6.6	LQM/CIEH
trichloromethane (Chloroform)	180	LQM/CIEH

Notes

Concentrations measured below the above values may be considered to represent 'uncontaminated conditions' which pose 'LOW' risk to human health. Concentrations measured in excess of these valuesindicate a potential risk which require further, site specific risk assessment.

SGV - Soil Guideline Value, derived from the CLEA model and published by Environment Agency 2009

LQM/CIEH - Generic Assessment Criteria for Human Health Risk Assessment 2nd edition (2009)derived using CLEA 1.04 model 2009

C4SL - Defra Category 4 Screening value based on Low Level of Toxicological Risk

C4SL exp & LQM/CIEH calculated using C4SL revisions to exposure assessment but LQM/CIEH health croiteria values

Calc - sum of nearest available carbon range specified including BTEX for PRO fraction

B(a)P / 0.15 - GEA experince indicates that Benzo(a) pyrene (one of the most common and most carcenogenic of the PAHs) rarely exceeds 15% of the total PAH concentration, hence this Total PAH threshold is regarded as being conservative

Geotechnical & Environmental Associates	Widbury Barn Widbury Hill Ware Herts SG12 7QE	**Generic Risk-Based Soil Screening Values**

Site	Bangor Wharf, Georgiana Street, Camden, NW1 0QS	**Job Number** J15227A
Client	One Housing Group	**Sheet** 2 / 2
Engineer	Conisbee	

Proposed End Use **Commercial**

The key generic assumptions for this end use are as follows;

- that groundwater will not be a critical risk receptor;
- that the critical receptor for human health will be a working female aged 16 to 65 years old;
- that the exposure duration will be be 49 years;
- that the building type equates to a to a three-storey office.
- that the critical exposure pathways will be direct soil and indoor dust ingestion, skin contact with soils and dust, and inhalation of dust and vapours;

Where contaminant concentrations are measured at concentrations below the generic screening value it is considered that they pose an acceptable level of risk and thus further consideration of these contaminant concentrations is not required. However, where concentrations are measured in excess of the generic screening value there is considered to be a potential that they could pose an unacceptable risk and thus further action will be required which could include:

- additional testing to zone the extent of the contaminated material and thus reduce the uncertainty with regard to its potential risk;
- site specific risk assessment to refine the assessment criteria and allow an assessment to be made as to whether the concentration present would pose an unacceptable risk at this site; or
- soil remediation or risk management to mitigate the risk posed by the contaminant to a degree that it poses an acceptable risk.

1ST LINE DEFENCE
UXO SOLUTIONS

Detailed Unexploded Ordnance (UXO) Threat Assessment

Project Name	Bangor Wharf		
Client	GEA Ltd		
Site Address	Bangor Wharf, Georgiana Street, Camden, NW1 0QS		
Report Reference	2819AT00	Revision	00
Date	30th October 2015		
Originator	AT		

1ST LINE DEFENCE
UXO SOLUTIONS

Find us on Twitter and Facebook

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

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

Executive Summary

Site Location

The site is situated in the London Borough of Camden, south of Regent's Canal.

The site currently contains the offices and storage buildings, along with a yard and car parking of a small building construction company.

The site is situated north-west of Georgiana Street. The site is situated 200m south-east of Camden Road Overground Station. The site is in an area of mixed use, with residential properties to the east and south-west, and commercial properties to the south-east and north-west.

The site is centred on the approximate OS grid reference: TQ 2934184021

Proposed Works

Site investigation works are planned on site before any development takes place. Two boreholes and four trial pits will take place before demolition. Three more trial pits will take place on site post-demolition.

Geology and Bomb Penetration Depth

Seven trial pits have already taken place within the site area. They do not extend far enough into the ground to allow for an assessment of bomb penetration depth. The top levels of geology appear to be made ground and then clay.

UXO Risk Assessment

1st Line Defence considers there to be a **Low Risk** from UXO for the majority of the site of proposed works, with a small area of **Medium Risk** in the north of the site. This assessment is based on the following factors:

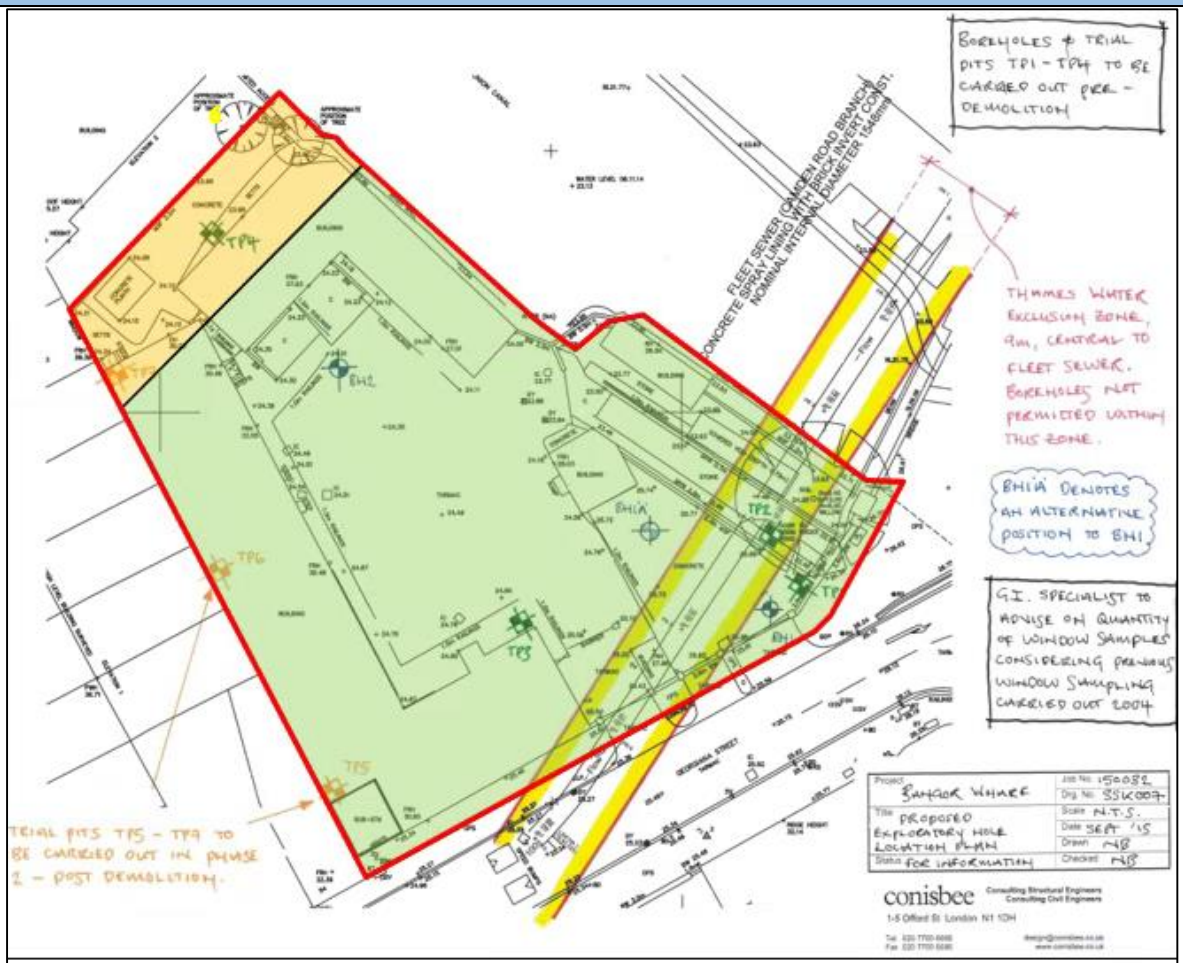
- During WWII the Metropolitan Borough of St Pancras was subjected to a Moderate-High Density bombing campaign, with 258.4 items falling per 1,000 acres. The borough was hit due to its proximity to Central London as well as the targets that lay within the borough, such as the railway infrastructure of both King's Cross and St. Pancras railway stations.
- London bomb census mapping records HE bomb incidents and Incendiary Bomb Showers in the surrounding area. There is no evidence to suggest that HE bombs fell within the boundary of the proposed site. Bomb Incident Records available for St Pancras also record no bombing within the site area.
- No significant damage on site is recorded on the LCC Bomb Damage Mapping, or can be seen on RAF aerial photography. Damage can be seen on the other side of Georgiana Street, but it is not considered close enough to affect the risk of UXO within the site area. A small building within the south-east of the site is recorded as 'ruin' on post-war historic OS mapping. However, this ruin does not appear to be due to bombing on site, and appears to be a solid structure in RAF aerial photography. It is likely that this building was derelict or abandoned. The area certainly does not appear to have been occupied by rubble/debris which may have obscured evidence of UXO.
- Given the groundcover, levels of access and lack of serious damage within the wharf area, it is not considered likely that evidence of UXBs would have gone unnoticed and the risk in the majority of the site area is therefore considered to be Low.
- Of concern is the open water area of Regent's Canal. If a UXB had fallen into the canal, it is very unlikely that it would have been noted and dealt with. UXO has been found in the canal post-war. This area is thus regarded as Medium risk in the areas below the level of post-war fill. A small buffer zone into the main part of the site area has been included.
- The site does not appear to have significantly changed post- WWII, although the area of the site that was part of the canal has been filled in. Any redevelopments on site post WWII can partly mitigate the UXO risk as any present items of UXO may have been uncovered during the works. The risk from deep-buried unexploded bombs is only considered mitigated at locations where post war piling or deep foundations have taken place. Any smaller redevelopments will have mitigated the risk of encountering shallow buried UXO, especially 1kg incendiaries and anti-aircraft projectiles.

UXO Risk Assessment
• There is not considered to be any risk of encountering UXO within the level of the fill material in the former canal area (as the canal section was filled in post-war). Any UXO which fell undetected into the water is likely to be encountered at or just below the base of the former waterbody.

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

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

Risk Map



Medium Risk

Low Risk

Low and Medium Risk Areas:

- Site Specific Unexploded Ordnance Awareness Briefings to all personnel conducting intrusive works

Medium Risk Area:

- Unexploded Ordnance (UXO) Specialist Presence on Site to support shallow intrusive works
- Intrusive Magnetometer Survey of all Borehole and pile locations down to a maximum bomb penetration depth

For indicative purposes – not to scale

Contents

Annexes

List of Report Annexes	
Annex A	Site Location Maps
Annex B	Recent Aerial Photography
Annex C	Site Plan
Annex D	Pre and Post-WWII Historical Maps
Annex E	Examples of German Air Delivered Ordnance
Annex F	Example of 50kg Bomb Entry Hole
Annex G	Examples of UXO Incidents
Annex H	London WWI Bomb Plot Map
Annex I	London WWII Bomb Density Map
Annex J	London ARP Consolidated & Weekly Bomb Census Maps
Annex K	London V1 Flying Bomb Map
Annex L	London County Council Bomb Damage Map
Annex M	1948 RAF Aerial Photography of the Site
Annex N	Examples of Anti-Aircraft Projectiles
Annex O	Risk Map

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

Site: Bangor Wharf
Client: GEA Ltd

1. Introduction

1.1. Background

1st Line Defence has been commissioned by GEA Ltd to produce a Detailed Unexploded Ordnance (UXO) Threat Assessment for the proposed works at Bangor Wharf.

UXO in the UK can originate from three principal sources:

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

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

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

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

2. UK Regulatory Environment

2.1. General

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

2.2. CDM Regulations 2015

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

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

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

2.3. The 1974 Health and Safety at Work Act

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

2.4. Additional Legislation

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

3. Role of Commercial UXO Contractors and The Authorities

3.1. Commercial UXO Contractors

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

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

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

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

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

3.2. The Authorities

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

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

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

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

4. The Report

4.1. Report Objectives

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

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

4.2. Risk Assessment Process

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

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

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

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

4.3. Sources of Information

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

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

Research involved a visit to the National Archives, Kew.

5. Reporting Conditions

5.1. General Considerations

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

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

5.2. Background to Bombing Records

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

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

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

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

6. The Site

6.1. Site Location

The site is situated in the London Borough of Camden, south of Regent's Canal.

The site is situated north-west of Georgiana Street. The site is situated 200m south-east of Camden Road Overground Station. The site is in an area of mixed use, with residential properties to the east and south-west, and commercial properties to the south-east and north-west.

The site is centred on the approximate OS grid reference: **TQ 2934184021**

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

6.2. Site Description

The site currently contains the offices and storage buildings, along with a yard and car parking of a small building construction company.

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

7. Scope of the Proposed Works

7.1. General

Site investigation works are planned on site before any development takes place. Two boreholes and four trial pits will take place before demolition. Three more trial pits will take place on site post-demolition.

8. Ground Conditions

8.1. General Geology

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

8.2. Site Specific Geology

Seven trial pits have already taken place within the site area. They do not extend far enough into the ground to allow for an assessment of bomb penetration depth. The top levels of geology appear to be made ground and then clay.

9. Site History

9.1. Ordnance Survey Historical Maps

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

WWI Period		
Date	**Scale**	**Description**
1913 – 1914	1:2,500	The site area is labelled as 'Bangor Wharf'. A mix of structures can be seen inside the site area, with most of the southern part of the site area entirely covered by buildings and a yard area can be seen inside the north of the site. Part of the northern part of the site is occupied by part of the Regent's Canal. There was no mapping available between this map edition and the next that was of sufficient quality to show any change within the site area.

Post-WWII		
Date	**Scale**	**Description**
1953	1:1,250	Significant change can be seen since the previous map edition as the buildings within the site area appear to have completely changed. The site area is still labelled as 'Bangor Wharf', but the largest building within the site area, to the west, is labelled as a 'Council Depot'. The remainder of the site appears to be occupied by smaller buildings as well as a yard. A small area of 'ruin' can be seen in the south-east of the site. The buildings to the south of the site on the other side of Georgiana Street have been mostly replaced by a new large building, the St Pancras Generating Station.
1970 – 1971	1:2,500	The site appears to be roughly unchanged since the previous map edition. The site is now labelled as an 'Electricity Board Depot'. The small part of the canal that was within the site area has now been filled in. A new 'park' area can be seen north of the site on the other side of the canal.
1982 – 1987	1:1,250	The site has reverted to being called a 'depot' and does not appear to have significantly changed since the previous map edition. The areas north of the site on the other side of the Regent's Canal, and south of the site on the other side of Georgiana Street.

10. Aerial Bombing Introduction

10.1. General

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

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

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

10.2. Generic Types of WWII German Air-delivered Ordnance

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

Generic Types of WWII German Air Delivered Ordnance	
High Explosive (HE) Bombs	
Frequency	In terms of weight of ordnance dropped, HE bombs were the most frequent weapon deployed by the Luftwaffe during WWII.
Size/Weight	Most bombs were 50kg, 250kg or 500kg (overall weight, about half of which was high explosive) though larger bombs of up to 2000kg were also used.
Description	High explosive bombs are thick-skinned and typically have sufficient mass and velocity and a suitably streamlined shape to enable them to penetrate the ground if they failed to explode on the surface.
Likelihood of detecting Unexploded	Although efforts were made to identify the presence of unexploded ordnance following a raid, often the damage and destruction caused by bombs which did detonate often made observation of UXB entry holes impossible. The entry hole of an unexploded bomb can be as little as 20cm in diameter and easily overlooked in certain ground conditions (See **Annex F**). Furthermore, ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded 50kg bomb. UXB's therefore present the greatest risk to present–day intrusive works.
Aerial or Parachute Mines	
Frequency	These were much less frequently deployed than HE and Incendiary bombs due to their size, cost and their difficulty technically to deploy.
Size/Weight	Their weight was either 500kg or 1000kg (overall weight, of which about 2/3 was explosive) depending on the type of mine. Their length ranged from 1.73-2.64m.
Description	The Luftmines (LMA-500kg and LMB-1000kg) were magnetic sea mines which were thin walled, cylindrical in shape with a hemispherical nose and were deployed under a green artificial silk parachute about 8m in diameter. They were fitted with magnetic and later with acoustic or magnetic/acoustic firing. When the mine hit the water and sank to more than 8ft, hydrostatic pressure and the dissolution of a soluble plug actuated the magnetic device and the mine

	became operational against shipping. The mine was also armed with a clockwork bomb fuze which caused the bomb to explode when used against land targets, and this was started by the impact of hitting the ground. The Bombenmine (BM 1000, Monika, or G Mine) was also used. This was fitted with a tail made from Bakelite which broke up on impact. It had a photoelectric cell beneath a cover which detonated the bomb if exposed to light to counteract the work of bomb disposal units.
Likelihood of detecting Unexploded	The aerial mines were either 500kg or 1000kg (overall weight, of which about 2/3 was explosive) depending on the type of mine. Their length ranged from 1.73-2.64m. They were much less frequently deployed than H.E. and Incendiary bombs due to their size, cost and the fact that they could not be delivered to point targets. If functioning correctly, parachute mines would generally have had a slow rate of descent (falling at about 40 mph) and were very unlikely to have penetrated the ground. Where the parachute failed, mines would have simply shattered on impact if the main charge failed to explode. There have been extreme cases when these items have been found unexploded. However, in these scenarios, the ground was either extremely soft or the munition fell into water. When operating as designed they caused considerable damage due to the high weight of explosive and their detonation at or near the surface. However 1st Line Defence does not consider there to be a significant threat from unexploded aerial mines on land.
1kg Incendiary Bombs	
Frequency	In terms of number of weapons dropped these small Incendiaries were the most numerous. Millions of these weapons were dropped throughout WWII.
Size/Weight	1kg
Description	These thermite filled devices were jettisoned from air-dropped containers. Some variants had explosive heads and these present a risk of detonation during intrusive works.
Likelihood of detecting Unexploded	They had very limited penetration capability and in urban areas especially would usually have been located in post-raid surveys. If they failed to initiate and fell in water, on soft vegetated ground, or bomb rubble, they could easily have gone unnoticed.
Large Incendiary Bombs	
Frequency	These items of ordnance were not as common as the 1kg Incendiaries however they were still more frequently deployed than the Parachute Mines and Anti-Personnel Bomblets.
Size/Weight	These could weigh up to 350kg.
Description	They had various flammable fill materials (including oil and white phosphorus), and a small explosive charge. They were designed to explode and burn close to the surface. Although they were often the same shape as HE bombs, they were thin-skinned and generally did not penetrate the surface.
Likelihood of detecting Unexploded	If they did penetrate the ground, complete combustion did not always occur and in such cases they could remain a risk to intrusive works.
Anti-personnel (AP) Bomblets	
Frequency	They were not commonly used and generally considered to pose a low risk to most works in the UK.
Size/Weight	The size and weight ranged depending on the type used. The most common was the “Butterfly Bomb” (SD2) which weighed 2kg and contained 225 grams of TNT.
Description	The ‘Butterfly Bomb’ had an 8cm long, thin, cylindrical, cast iron outer shell which hinged open when the bomblet deployed gave it the superficial appearance of a large butterfly. A steel cable 15 cm long was attached via a spindle to an aluminium fuze. The wings at the end were canted at an angle to the airflow, which turned the spindle anti-clockwise as the bomblet fell. After the spindle had revolved approximately 10 times (partially unscrewing itself from the bomb) it released a spring-loaded pin inside the fuze, which fully armed the SD2 bomb. They were generally lethal to anyone within a radius of 10 metres (33 ft) and could inflict serious shrapnel injuries. There were a number of variants, the most common being the SD2 which weighed 2kg

	and contained 225 grams of TNT. They were not commonly used and generally considered to pose a low risk to most works in the UK.
Likelihood of detecting Unexploded	SD2 bomblets were not dropped individually, but were packed into containers holding between 6 and 108 submunitions however, AP bombs had little ground penetration ability and should have been located by the post-raid survey unless they fell into water, dense vegetation or bomb rubble.

10.3. Failure Rate of German Air-Delivered Ordnance

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

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

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

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

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

10.4. V-Weapons

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

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

11. UXB Ground Penetration

11.1. General

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

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

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

11.2. The J Curve Effect

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

11.3. WWII UXB Penetration Studies

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

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

11.4. Site Specific Bomb Penetration Considerations

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

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

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

12. Initiation of Unexploded Ordnance

12.1. General

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

12.2. UXB Initiation Mechanisms

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

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

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

12.3. Effects of Detonation

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

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

13. The Threat from German UXBs

13.1. World War I

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

Two significant attacks on the City of London were recorded to have hit St Pancras. The first came from a Goth bomber in daylight on 9th July 1917. Three bombs fell within the borough, including two on St Pancras Road. Another attack came on the 17th February 1918, from a single Zeppelin that dropped five bombs in the borough, which apparently fell on and near St. Pancras station.

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

13.2. World War II Bombing of St Pancras

The Luftwaffe's objective for the attacks on London was to paralyse the commercial life of the capital by bombing the docks, warehouses, wharves, railway lines, factories and power stations. As the war progressed this strategy gradually changed to the indiscriminate bombing of civilian areas in an attempt to disrupt everyday life and hurt morale. The Metropolitan Borough of St. Pancras (in which the site was located during WWII) was subject to a moderate-high density bombing campaign as illustrated by the London bomb density data figures and map, see **Annex I**.

The Metropolitan Borough of St. Pancras during WWII was predominantly a residential borough but it had a few targets of note such as St. Pancras and Kings Cross railway stations and Regents Canal. Additionally the borough was located in close proximity to the centre of London and boroughs that were heavily hit. Luftwaffe photography also shows several targets within the flight path of St Pancras, including Lords Cricket Ground in Paddington and a pumping station in Holborn.

The relative inaccuracy of bombing of targets in or near St. Pancras, and the Luftwaffe's indiscriminate bombing of London meant that St. Pancras received a moderate-high bomb density.

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

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

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

13.3. Second World War Bombing Statistics

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

Record of German Ordnance Dropped on the Metropolitan Borough of St Pancras		
Area Acreage		**2694**
Weapons	High Explosive Bombs (all types)	641
	Parachute Mines	8
	Oil Bombs	14
	Phosphorus Bombs	11
	Fire Pot	0
	Pilotless Aircraft (V1)	20
	Long Range Rockets (V2)	2
Total		**696**
Number of Items per 1000 acres		**258.4**

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

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

13.4. London Air Raid Precautions Bomb Census Maps

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

London Consolidated Bomb Maps – Annex J	
Date Range	**Comments**
Night Bombing up to 7th October 1940	One HE bomb can be seen south of the site area, on the other side of Georgiana Street.
7th October 1940 to 6th June 1941	Six HE bombs fell in areas all around the site. The closest was on the other side of Georgiana Street.

London Weekly Bomb Maps – Annex J	
Date Range	**Comments**
21st to 28th October 1940	Two HE bombs can be seen, to the far west and east of the site.
11th to 18th November 1940	An Incendiary bomb shower can be seen to the south of the site area.
6th to 13th January 1941	One HE bomb can be seen south-east of the site.
5th to 12th May 1941	One UXB can be seen to the south-east of the site.

13.5. London V-Weapon Maps

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

V-Weapon Map – Annex K	
Date Range	**Comments**
Post-war consolidated Bomb Plot Map	**2 V1 Flying Bombs** fell in the general area. However, they are of no direct impact to the proposed site. Damage from V weapons cannot be attributed to the site in question.

13.6. St. Pancras Air Raid Precautions Bomb Incident Records

It should be noted that the archives of the London Borough of Camden were contacted for information they hold about the WWII bombing of the borough of St. Pancras. They do not hold a complete incident record set. It is possible that one never existed, or that it was destroyed or lost post-war.

Written incident records were obtained from the National Archives. A transcript of the associated written records for bombs which fell in the area is presented in the table below. It should be noted that the incident records from the National Archives do not comprise a complete record set and only cover the time period from 23rd December 1940 – 3rd June 1942. Only those recorded incidents on or in close proximity to the site have been highlighted.

Date Range	**Comments**
11th – 12th January 1941	One 250kg HE bomb strike on St Pancras Way. A direct hit demolished two houses, destroying three more. Two 50kg HE bombs on the power station on King's Road.

13.7. London County Council Bomb Damage Map

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

London County Council Bomb Damage Map – Annex L	
Date Range	**Comments**
Post-War Consolidated Bomb Damage Map	The buildings within the site area are registered as having sustained 'general blast damage'. This kind of damage would have likely meant some damage to the windows or roofing, possibly to the structure of the building. However, this damage would not have been severe, and would not have hampered access to the building in any way.

13.8. WWII-Era Aerial Photographs

High resolution scans of WWII-era aerial photography for the site area were obtained from the National Monuments Record (Historic England). Imagery dated 19th May 1948 is presented in **Annex M**.

There are no obvious signs of bomb damage within the proposed site boundary or surrounding area. LCC Bomb Damage Mapping had indicated some 'blast damage' within the site area, but this could have been repaired, or is not possible to see from the angle of this photography. The area of 'ruin' seen on historic mapping appears to refer to a building within the south-east of the site. This building occupies a small area and appears to still remain standing. It is possible that the building was abandoned and left derelict, possibly post-war. It does not seem likely based on the available records that this ruin was related to bomb damage.

South of the site, on the other side of Georgiana Street, bomb damage can be seen. Several areas of cleared ground and serious damage can be seen.

13.9. Abandoned Bombs

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

13.10. Bomb Disposal Tasks

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

13.11. Evaluation of Bombing Records

Item	Conclusion
Density of Bombing *It is important to consider the bombing density when assessing the possibility that UXBs remain in an area. High levels of bombing density could allow for error in record keeping due to extreme damage caused to the area.*	The Metropolitan Borough of St Pancras was subject to a moderate-high density of bombing with 258.4 items of ordnance recorded per 1000 acres. The site itself does not appear to have been hit by any items of ordnance, although several strikes were recorded in close proximity to the site, including strikes on the other side of Georgiana Street. It should be noted that the consolidated and weekly London Bomb Census Maps do not match up with each other.
Ground Cover *The type & amount of ground cover existing during WWII would have a substantial influence on any visual indication that may indicate UXO being present.*	The site was occupied by buildings and a yard that were part of a wharf during the war. A small part of the canal also was within the site area. The buildings and yard appear to have remained intact throughout the war and would likely be conductive to the observation of UXO. This would not have been true for the area of water within the site.
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 are also likely to have been subject to post-raid checks for evidence of UXO.*	The site was occupied by working wharf buildings and a yard during the war. It is considered likely that the site would have sustained a good access level during the war. The area of the site that was occupied by water would not have been frequently accessed.
Damage *If buildings or structures on a site suffered 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*	The site does not appear to have sustained serious damage during the war. Buildings within the site area are recorded as having sustained 'blast damage', which would not have been structural or serious. One small building within the south-east of the site was recorded as a 'ruin' on post-war historical OS mapping. However, this building still appears to be standing in RAF aerial photography, and was likely registered as a ruin for reasons other than bomb damage.
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 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.

14. The Threat from Allied Military Ordnance

14.1. General

In addition to the threat from aerial delivered UXO, this report also assesses the potential risk from Allied military ordnance. Contamination from items of Land Service (LSA) and Small Arms Ammunition (SAA) may result, for example, from historic occupation of an area or its use for military training. Inner city sites can be at risk from buried unexploded Anti-Aircraft projectiles fired during WWII.

14.2. Defending London from Aerial Attack

Both passive and active defences were deployed against enemy bombers attacking targets in the Greater London region.

Passive Defences	Active Defences
These included defence tactics such as: • To hinder the identification of targets, by using lighting blackouts at night and camouflaging strategic installations. • To mislead bomber pilots into attacking decoy sites located away from the city with the use of dummy buildings or lighting to replicate that of the city under attack. • To force attacking aircraft to higher altitudes with the use of barrage balloons.	These relied on a coordinated combination of a number of installations in order to actively engage and oppose attacking aircraft. Some of these installations were: • Fighter aircraft to act as interceptors. • Anti-aircraft gun batteries. • The use of rockets and missiles (later during WWII).

14.3. Anti-Aircraft Artillery (AAA) and Projectiles

At the start of WWII two types of Anti-Aircraft Artillery (AAA) guns were deployed: Heavy Anti-Aircraft Artillery (HAA), using large calibre weapons such as the 3.7" QF (Quick Firing) gun and Light Anti-Aircraft Artillery (LAA) using smaller calibre weapons such as 40mm Bofors gun.

During the early war period there was a severe shortage of AAA available and older WWI 3" and modified naval 4.5" guns were deployed alongside those available 3.7" weapons. The maximum ceiling height of fire at that time was around 11,000m for the 3.7" gun and less for other weapons. As the war progressed improved variants of the 3.7" gun were introduced and, from 1942, large 5.25 inch weapons began to be brought into service. These had significantly improved ceiling heights of fire reaching over 18,000m.

The LAA batteries were intended to engage fast low flying aircraft and were typically deployed around airfields or strategic installations. These batteries were mobile and could be moved to new positions with relative ease when required. The most numerous of these were the 40mm Bofors gun which could fire up to 120 x 40mm HE shells per minute to over 1800m.

The HAA projectiles were high explosive shells, usually fitted with a time delay or barometric pressure fuze to make them explode at a pre-determined height. If they failed to explode or strike an aircraft, they would eventually fall back to earth. Details of the most commonly deployed WWII AAA projectiles are shown below:

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

Although the larger unexploded projectiles could enter the ground they did not have great penetration ability and are therefore likely to be found close to WWII ground level. These shells are frequently mistakenly identified as small German air-delivered bombs, but are differentiated by the copper driving band found in front of the base. With a high explosive fill and fragmentation hazard these items of UXO present a significant risk if encountered. The smaller 40mm projectiles are similar in appearance and effect to small arms ammunition and, although still dangerous, present a lower hazard because of a lower explosive content. They are still dangerous because they were fitted with an impact initiated fuze which was also a spin-decay self-destruct mechanism.

Numerous unexploded AAA shells were recovered during and following WWII and are still occasionally encountered on sites today. The closest recorded HAA battery to the site was situated approximately 2.75km north-west in the vicinity of Primrose Hill. Illustrations of Anti-Aircraft artillery, projectiles and rockets are presented in **Annex N**.

14.4. Evaluation of Allied Military Ordnance Risk

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

Item	Conclusion
Military Camps	1st Line Defence could find no evidence of a Military Camp within the site.
Anti-Aircraft Defences	1st Line Defence could find no evidence of Anti-Aircraft Defences in the site proximity.
Home Guard Activity	Evidence of Home Guard training areas and activities is difficult to obtain. 1st Line Defence has no evidence of any Home Guard activities on the site.
Defensive Positions	There is no evidence of any defensive structures in the vicinity of the site.
Training or firing ranges	No evidence of these could be found.
Defensive Minefields	No evidence of these could be found.
Ordnance Manufacture	No evidence of ordnance manufacture could be found.
Military Related Airfields	The site was not situated within the vicinity of a military airfield.
Explosive Ordnance Clearance Tasks	1st Line Defence holds no records of EOD operations on the site.

15. Ordnance Clearance and Post-WWII Ground Works

15.1. General

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

15.2. UXO Clearance

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

15.3. Post war Redevelopment

The site does not appear to have significantly changed post- WWII. Any redevelopments on site post WWII can partly mitigate the UXO risk as any present items of UXO may have been uncovered during the works. The risk from deep-buried unexploded bombs is only considered mitigated at locations where post war piling or deep foundations have taken place. Any smaller redevelopments will have mitigated the risk of encountering shallow buried UXO, especially 1kg incendiaries and anti-aircraft projectiles.

16. 1st Line Defence Risk Assessment

16.1. Risk Assessment Stages

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

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

UXO Risk Assessment	
Quality of the Historical Record	The research has located and evaluated pre- and post-WWII Ordnance Survey maps, London WWII ARP bomb plots from 1940 to 1945, St Pancras Bomb Incident Records, LCC Bomb Damage Mapping, in-house data and post WWII era aerial photographs for the site. The quality of the historical record for this site is not considered to be good. The only official record set available was from the National Archives, which does not cover the whole scope of the war. A comprehensive record set may not even exist for the Municipal Borough of St Pancras. It may have been lost or destroyed, or may have never existed.
The Risk that the Site was Contaminated with UXO	After considering the following facts, 1st Line Defence believes that there is a **Low Risk** that unexploded high explosive bombs fell unnoticed and unrecorded within much of the site boundary with an area of **Medium Risk** identified at the level of the base and just below of the former canal which ran across the northern section of the site. See **Annex O** for Risk Maps. • During WWII the Metropolitan Borough of St Pancras was subjected to a Moderate-High Density bombing campaign, with 258.4 items falling per 1,000 acres. The borough was hit due to its proximity to Central London as well as the targets that lay within the borough, such as the railway infrastructure of both King's Cross and St. Pancras railway stations. • London bomb census mapping records HE bomb incidents and Incendiary Bomb Showers in the surrounding area. There is no evidence to suggest that HE bombs fell within the boundary of the proposed site. Bomb Incident Records available for St Pancras also record no bombing within the site area. • No significant damage on site is recorded on the LCC Bomb Damage Mapping, or can be seen on RAF aerial photography. Damage can be seen on the other side of Georgiana Street, but it is not considered close enough to affect the risk of UXO within the site area. A small building within the south-east of the site is recorded as 'ruin' on post-war historic OS mapping. However, this ruin does not appear to be due to bombing on site, and appears to be a solid structure in RAF aerial photography. It is likely that this building was derelict or abandoned. The area certainly does not appear to have been occupied by rubble/debris which may have obscured evidence of UXO. • Given the groundcover, levels of access and lack of serious damage within the wharf area, it is not considered likely that evidence of UXBs would have gone unnoticed and the risk in the majority of the site area is therefore considered to be Low.

	• Of concern is the open water area of Regent's Canal. If a UXB had fallen into the canal, it is very unlikely that it would have been noted and dealt with. UXO has been found in the canal post-war. This area is thus regarded as Medium risk in the areas below the level of post-war fill. A small buffer zone into the main part of the site area has been included.
The Risk that UXO Remains on Site	The site does not appear to have significantly changed post- WWII, although the area of the site that was part of the canal has been filled in. Any redevelopments on site post WWII can partly mitigate the UXO risk as any present items of UXO may have been uncovered during the works. The risk from deep-buried unexploded bombs is only considered mitigated at locations where post war piling or deep foundations have taken place. Any smaller redevelopments will have mitigated the risk of encountering shallow buried UXO, especially 1kg incendiaries and anti-aircraft projectiles.
The Risk that UXO may be Encountered during the Works	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. Since an air-dropped bomb may come to rest at any depth between just below ground level and its maximum penetration depth, there is also a chance that such an item could be encountered during shallow excavations (for services or site investigations) into the original WWII ground level. There is not considered to be any risk of encountering UXO within the level of the fill material in the former canal area (as the canal section was filled in post-war). Any UXO which fell undetected into the water is likely to be encountered at or just below the base of the former waterbody.
The Risk that UXO may be Initiated	The risk that UXO could be initiated if encountered will depend on its condition, how it is found and the energy with which it is struck. Certain construction activities such as piling and percussive drilling pose a greater risk of initiating UXO than, say, machine excavation where the force of impact is generally lower and the item more likely to be observed. If a UXB is struck by piling or percussive drilling equipment, the force of the impact can be sufficient to detonate the main high explosive charge irrespective of the condition of the fuze or other components. Violent vibration might also impart enough energy to a chemical detonator for it to function, and there is a potential risk that clockwork fuzes could restart. If piling works are planned at Bangor Wharf, there is a potential risk that a UXB, if present, could be initiated. The risk of initiation is assessed to be lower for any shallow intrusive works planned.
The Consequences of Encountering or Initiating Ordnance	The repercussions of the inadvertent detonation of UXO during intrusive ground works 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. If appropriate risk mitigation measures are put in place, the chances of initiating an item of UXO during ground works is comparatively low. The primary consequence of encounter of UXO will therefore be economic. This would be particularly notable in the case of a high-profile site and sites 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 loss of production. Generally, the first action of the police in most cases will be to isolate the locale whilst awaiting military assistance, even if this turns out to have been unnecessary.

16.2. Assessed Risk Level

Taking into consideration the findings of this study, 1st Line Defence considers there to be a **Low Risk** from unexploded ordnance on the majority of the site of proposed works, with a small area of **Medium Risk** in the north of the site.

Low Risk

This area was occupied by structures that were not seriously damaged or areas with no obvious signs of ground disturbance. It is considered likely that these properties and their surrounds would have been accessed throughout WWII and that checks would have been made for evidence of UXO. While this area of the site did contain a small building that was labelled as a 'ruin' on post-war historic OS mapping, this building still appears to remain standing throughout the war and its ruined state does not appear to be due to bomb damage.

Ordnance Type	Risk Level			
	Negligible	Low	Medium	High
German UXB's		✓		
Allied AAA		✓		
German Incendiaries and AP bomblets		✓		
Other Allied Military Ordnance	✓			

Medium Risk

This part of the site was occupied by Regent's Canal during WWII. It is not considered likely that bombs which fell within this part of the site area will have been noted or dealt with. There is not considered a risk that UXO will be present within the 'fill' material within the former canal. However, there is considered to be a risk that a UXB may remain at or just below the base of the canal, unless the channel was regularly dredged or the depth of the canal increased post-war. A small buffer zone into the main part of the site area has been included.

Ordnance Type	Risk Level			
	Negligible	Low	Medium	High
German UXB's			✓	
Allied AAA			✓	
German Incendiaries and AP bomblets			✓	
Other Allied Military Ordnance	✓			

17. Proposed Risk Mitigation Methodology

17.1. General

The following risk mitigation measures are recommended to support the proposed works at Bangor Wharf:

Type of Work	Recommended Mitigation Measure
All Works in Low & Medium Risk Areas	• **Site Specific Unexploded Ordnance Awareness Briefings to all personnel conducting intrusive works.** A specialised briefing is always advisable when there is a possibility of explosive ordnance contamination. It is an essential component of the Health & Safety Plan for the site and conforms to requirements of CDM Regulations 2007. All personnel working on the site should be instructed on the identification of UXB, actions to be taken to alert site management and to keep people and equipment away from the hazard. Posters and information of a general nature on the UXB threat should be held in the site office for reference and as a reminder.
Shallow Intrusive Works/Open Excavations in Medium Risk areas below the level of post-war fill	• **Unexploded Ordnance (UXO) Specialist Presence on Site to support shallow intrusive works:** When on site the role of the UXO Specialist would include; monitoring works using visual recognition and instrumentation and immediate response to reports of suspicious objects or suspected items of ordnance that have been recovered by the ground workers on site; providing UXO Awareness briefings to any staff that have not received them earlier and advise staff of the need to modify working practices to take account of the ordnance threat, and finally to aid Incident Management which would involve liaison with the local authorities and Police should ordnance be identified and present an explosive hazard.
Borehole/Piles in Medium Risk areas below the level of post-war fill	• **Intrusive Magnetometer Survey of all Borehole and pile locations down to a maximum bomb penetration depth:** 1st Line Defence can deploy a range of intrusive magnetometer techniques to clear ahead of all the pile locations. The appropriate technique is governed by a number of factors, but most importantly the site's ground conditions. The appropriate survey methodology would be confirmed once the enabling works have been completed.

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

1st Line Defence Limited **30th October 2015**

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

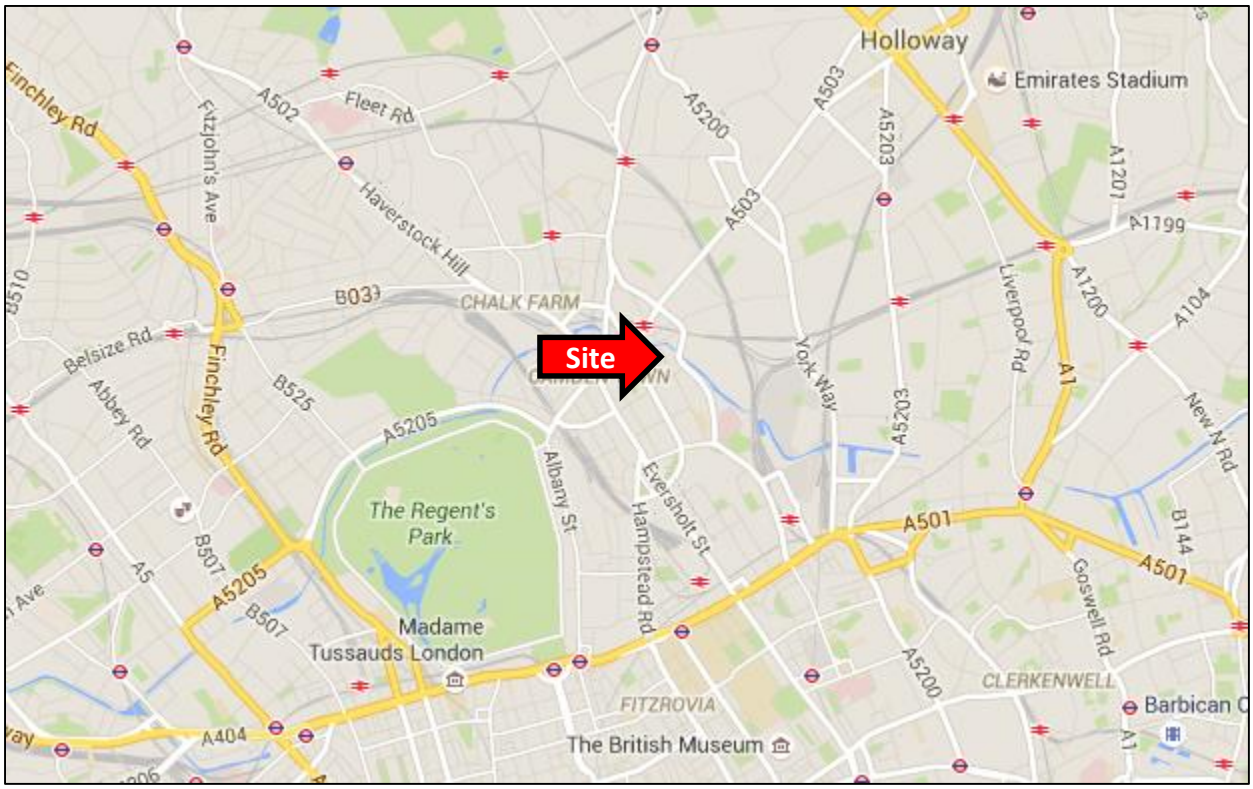
Bibliography

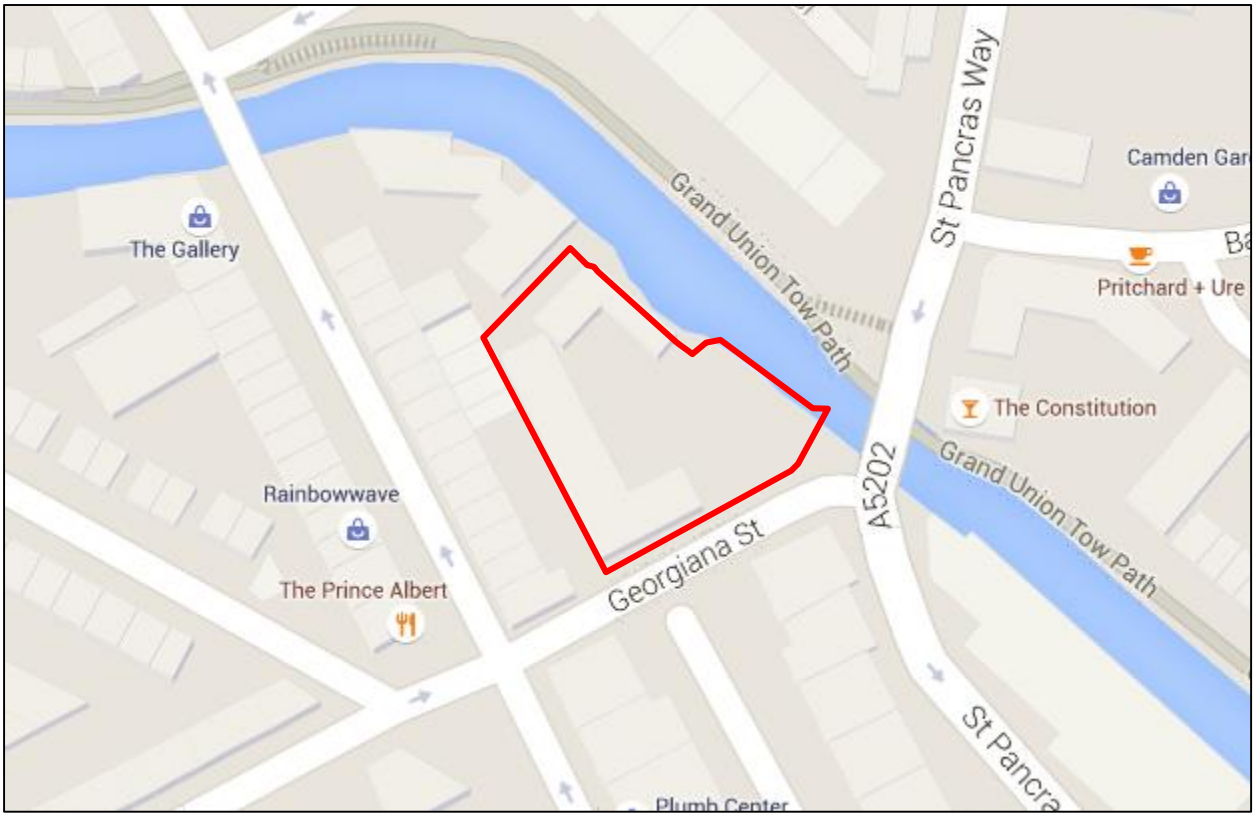
The key published documents consulted during this assessment are listed below:

- 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, Volume 1*, Battle of Britain Prints International Ltd., 1987
- Ramsey, W., *The Blitz Then and Now, Volume 2*, Battle of Britain Prints International Ltd., 1988
- Ramsey, W., *The Blitz Then and Now, Volume 3*, Battle of Britain Prints International Ltd., 1990
- 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: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

Source: Google Maps

Approximate site boundary

N

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: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

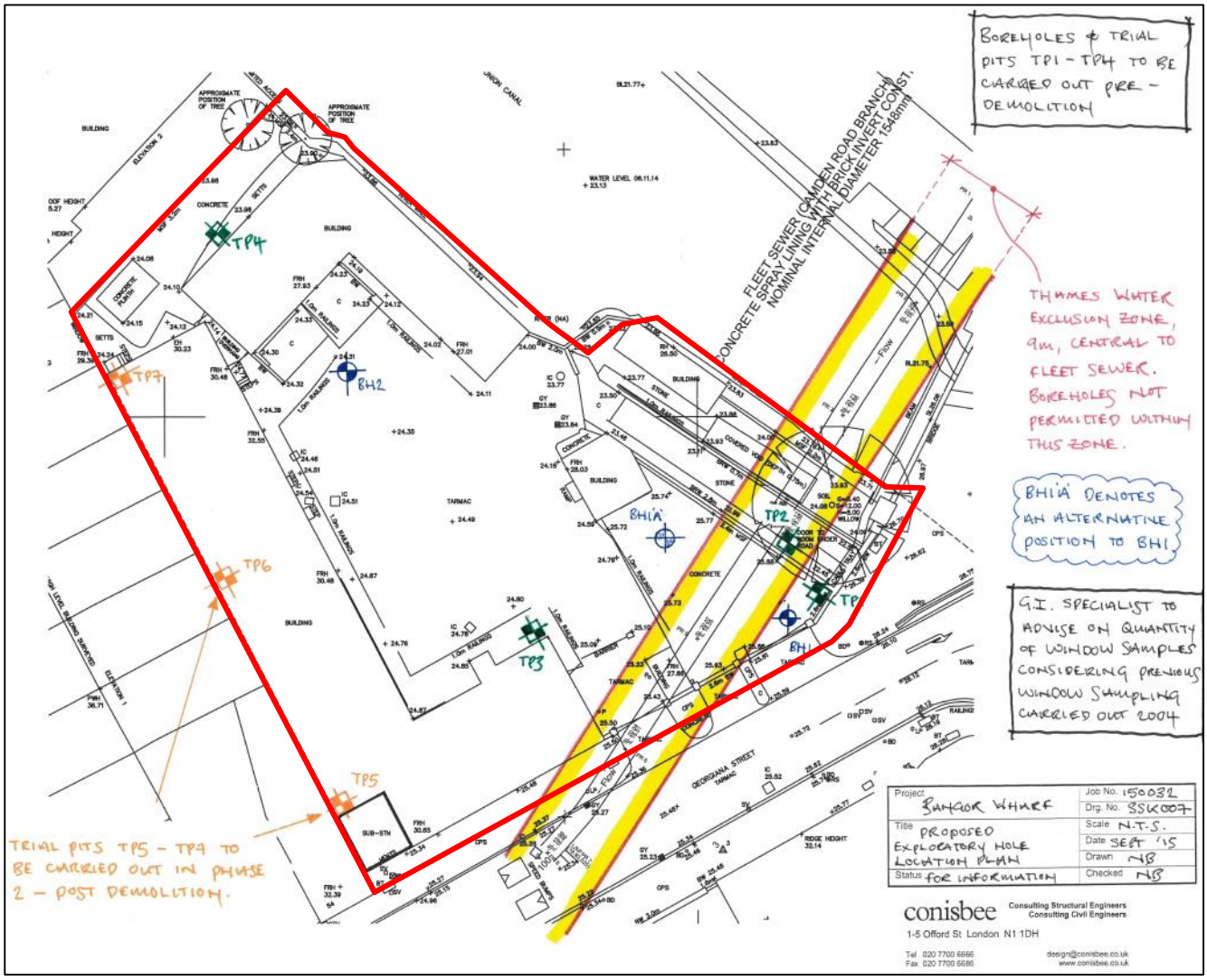
Source: Google Earth ™ Mapping Services

Approximate site boundary

N

Site Plan

Annex: **C1**



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: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

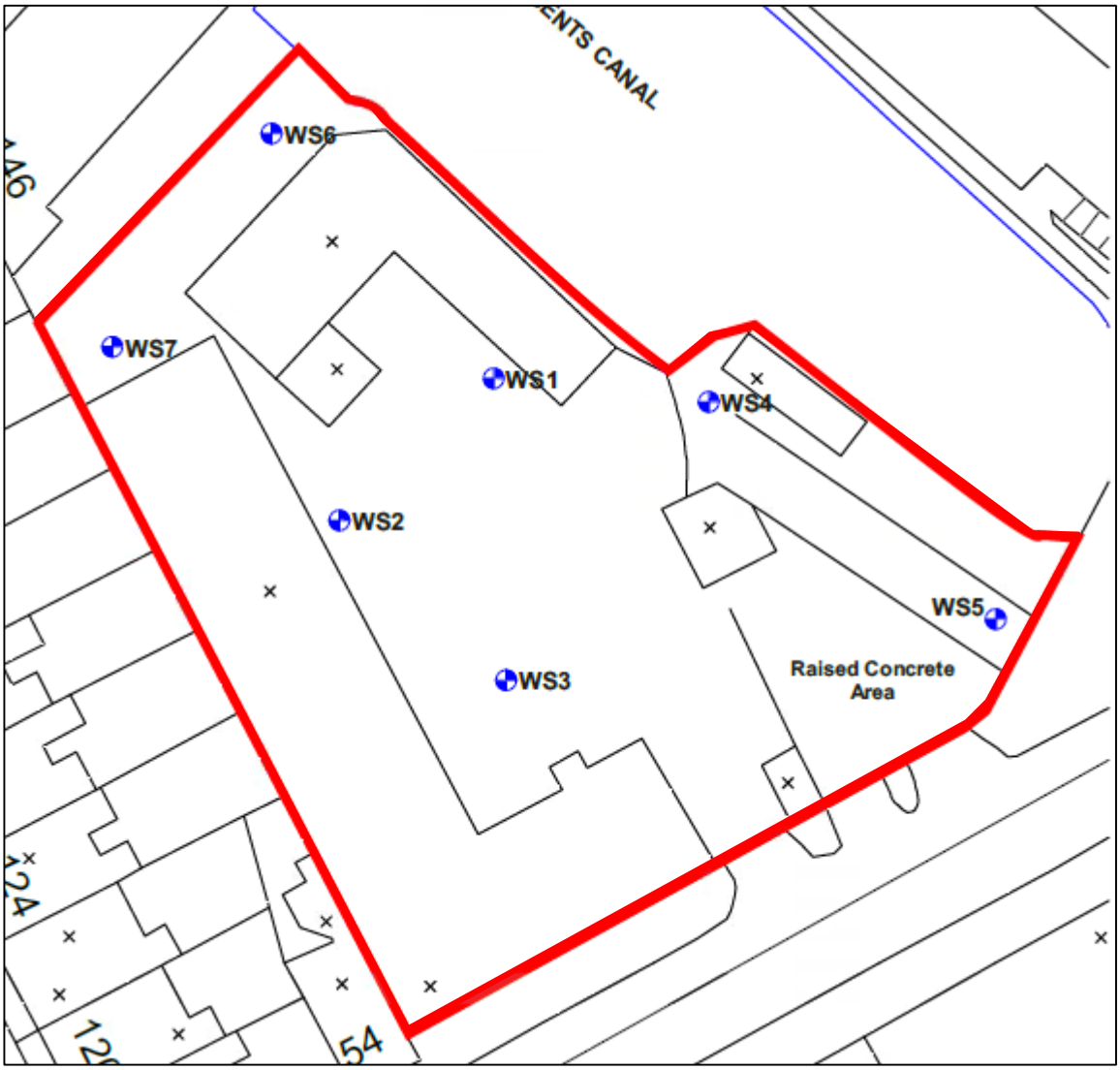
Source: GEA Ltd

Approximate site boundary

N

Site Plan

Annex: **C2**



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: **GEA Ltd**

Approximate site boundary

N

Project: **Bangor Wharf**

Ref: **OPN2819**

Source: GEA Ltd

1916 Historical Map

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: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

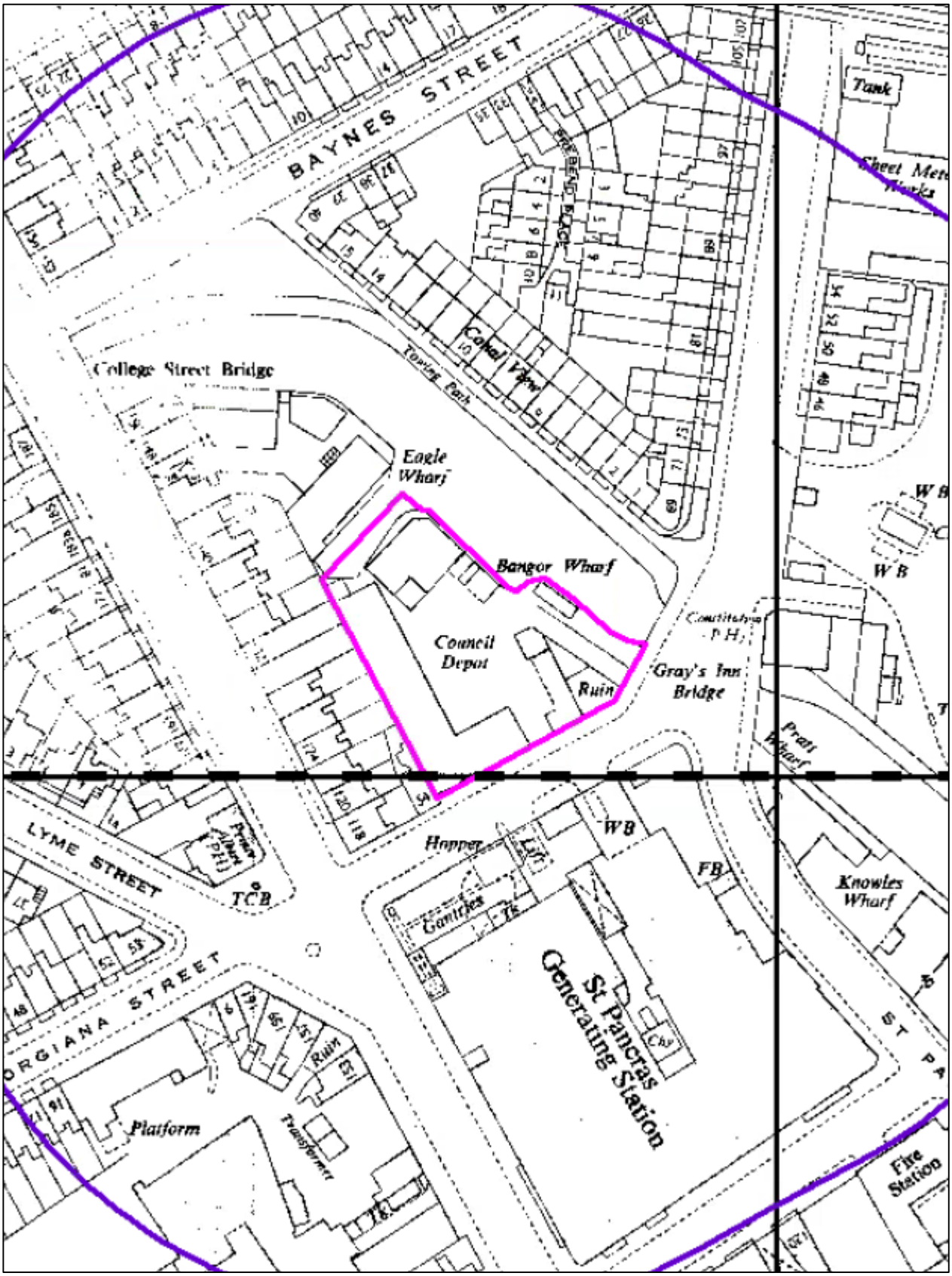
Source: Landmark Maps

Approximate site boundary

N

1953 Historical Map

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: **GEA Ltd**

Approximate site boundary

Project: **Bangor Wharf**

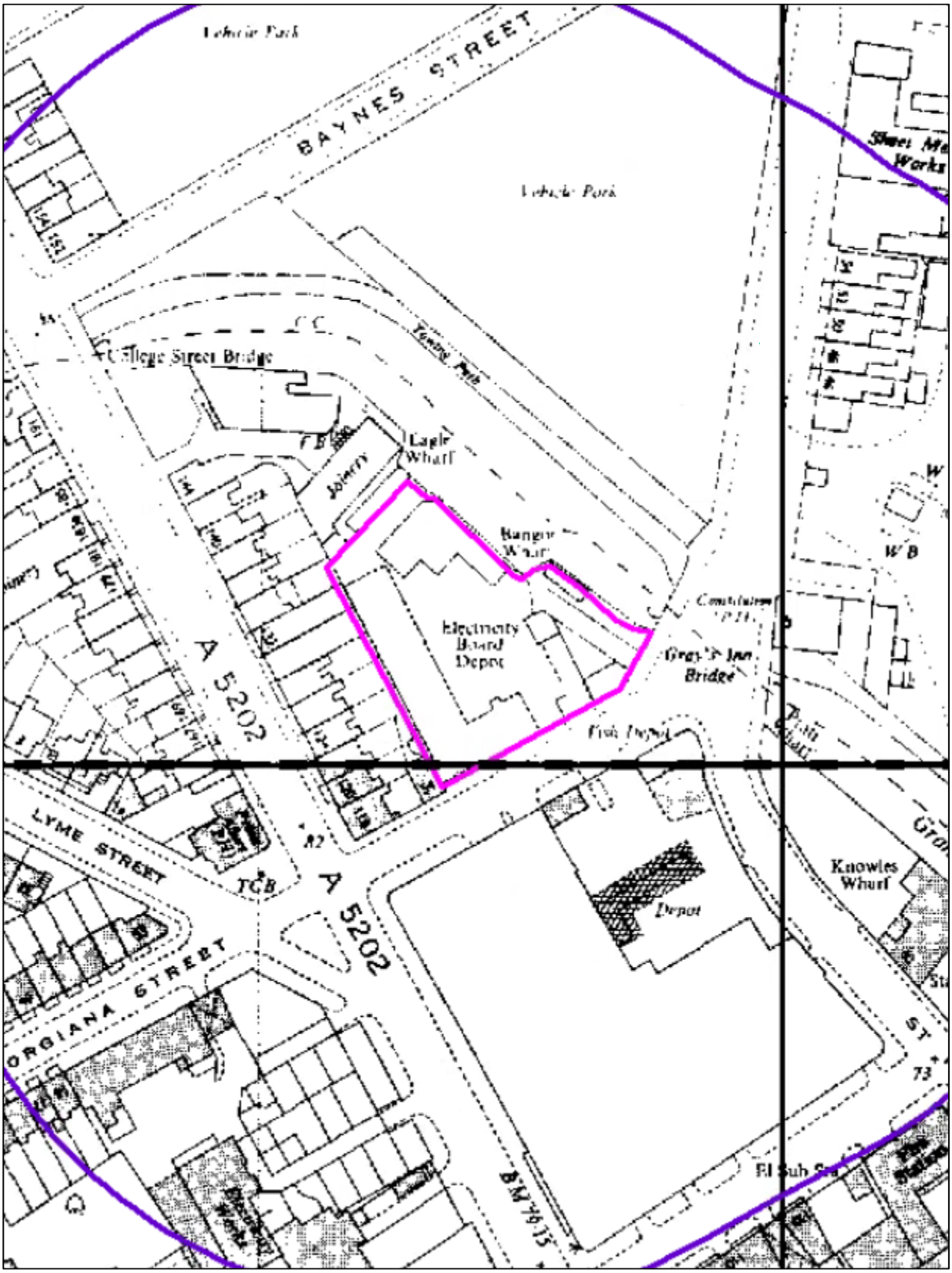
N

Ref: **OPN2819**

Source: Landmark Maps

1970 – 1971 Historical Map

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: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

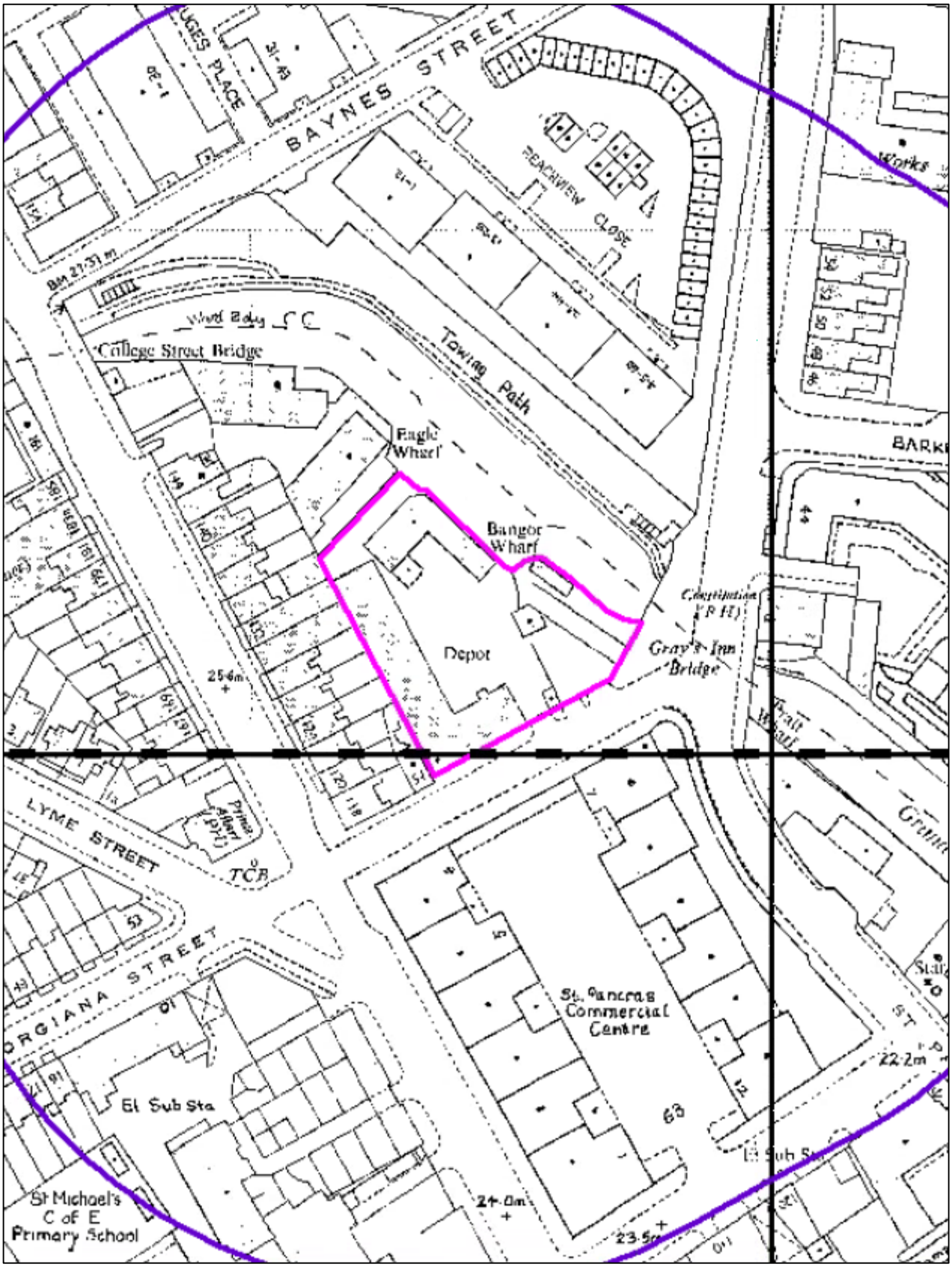
Source: Landmark Maps

Approximate site boundary

N

1982 – 1987 Historical Map

Annex: **D4**



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: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

Source: Landmark Maps

Approximate site boundary

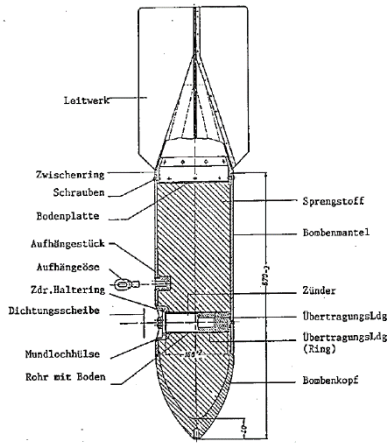
N

Common Types of German HE Air-Delivered Ordnance

Annex: **E1**

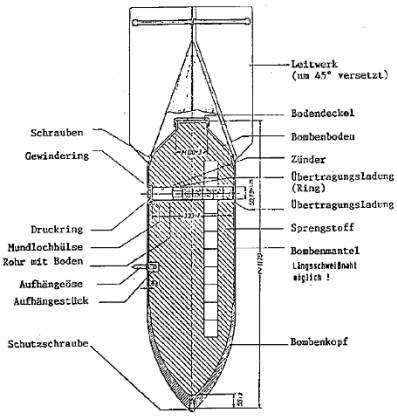
SC 50kg

Bomb Weight	40-54kg (110-119lb)
Explosive Weight	c25kg (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.



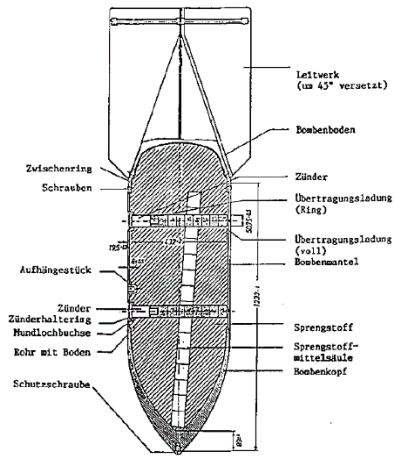
SC 250kg

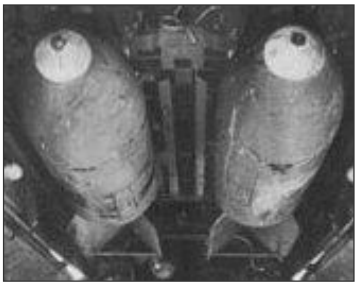
Bomb Weight	245-256kg (540-564lb)
Explosive Weight	125-130kg (276-287lb)
Fuze Type	Electrical impact/mechanical time delay fuze.
Bomb Dimensions	1640 x 512mm (64.57 x 20.16in)
Body Diameter	368mm (14.5in)
Use	Against railway installations, embankments, flyovers, underpasses, large buildings and below-ground 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).



SC 500kg

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 1-15/16 in. in length and diameter forming





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: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

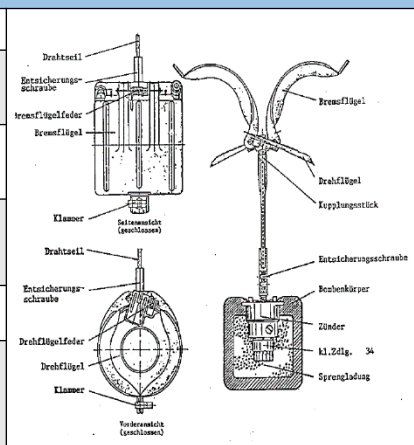
Source: Various sources

Common Types of German HE Air-Delivered Ordnance

Annex: **E2**

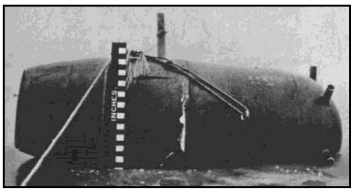
SD2 Butterfly Bomb

Bomb Weight	2kg (4.41lb)
Explosive Weight	7.5oz (212.6 grams) of TNT surrounded by a layer of bituminous composition.
Fuze Type	41 fuze (time) , 67 fuze (clockwork time delay) or 70 fuze (anti-handling device)
Bomb Dimensions	Length 240 mm Width 140 mm Height 310 mm
Body Diameter	3in (7.62 cm) diameter, 3.1in (7.874) long
Use	It was designed as an anti-personnel/fragmentation weapon. They were delivered by air, being dropped in containers that opened at a predetermined height, thus scattering the bombs.
Remarks	The smallest and most common conventional German bomb. Nearly 70% of bombs dropped on the UK were 50kg.



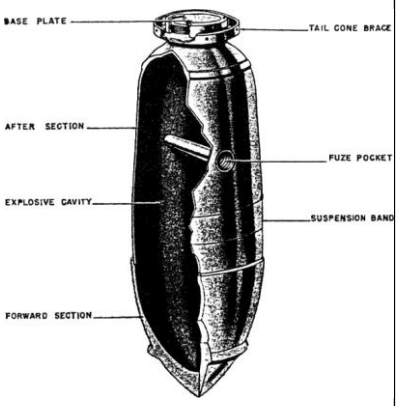
Parachute Mine (Luftmine B / LMB)

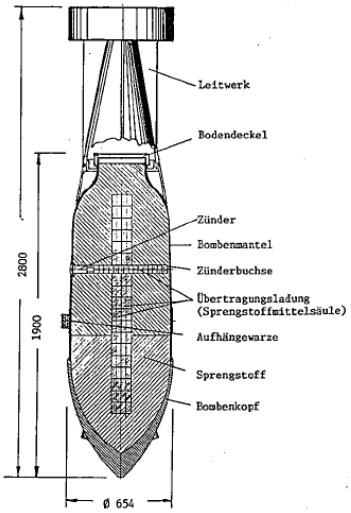
Bomb Weight	987.017kg (2176lb)
Explosive Weight	125-130kg (276-287lb)
Fuze Type	Impact/ Time delay / hydrostatic pressure fuze
Bomb Dimensions	1640 x 512mm (64.57 x 20.16in)
Body Diameter	368mm (14.5in)
Use	Against civilian, military and industrial targets. Designed to detonate above ground level to maximise damage to a wider area.
Remarks	Parachute Mines were normally carried by HE 115 (Naval operations), HE 111 and JU 88 aircraft types. Deployed a parachute when dropped in order to control its descent.



SC 1000kg

Bomb Weight	996-1061kg (1,058-1,146lb)
Explosive Weight	530-620kg (551-573lb)
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 (77 x 25.2in)
Body Diameter	654mm (18.5in)
Use	SC type bombs are 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: **GEA Ltd**

Project: **Bangor Wharf**

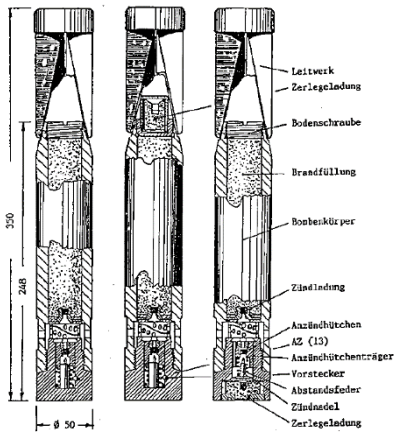
Ref: **OPN2819**

Source: Various sources

German Incendiary Bombs

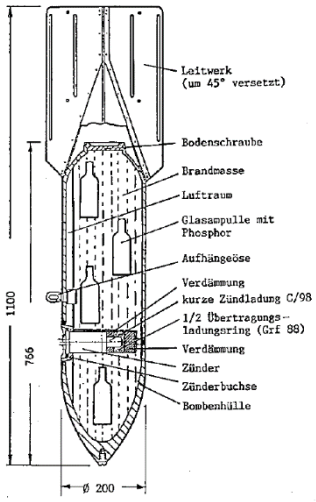
1kg Incendiary Bomb

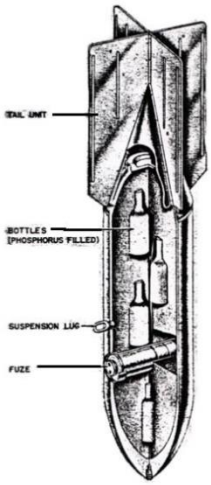
Bomb Weight	1.0 and 1.3kg (2.2 and 2.87lb)
Explosive Weight	680gm (1.3lb) Thermite
Fuze Type	Impact fuze
Bomb Dimensions	350 x 50mm (13.8 x 1.97in)
Body Diameter	50mm (1.97in)
Use	As incendiary – dropped in clusters against towns and industrial complexes
Remarks	Magnesium alloy case. Sometimes fitted 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

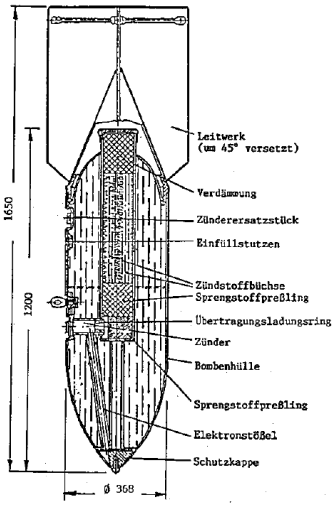
Bomb Weight	c41kg (90.4lb)
Explosive Weight	0.03kg (0.066lb)
Incendiary Filling	12kg (25.5lb) liquid filling with phosphor igniters in glass phials. Benzine 85%; Phosphorus 4%; Pure Rubber 10%
Fuze Type	Electrical impact fuze
Bomb Dimensions	1,100 x 280mm (43.2 x 8in)
Use	Against all targets where an incendiary effect is to be expected
Remarks	Early fill was a phosphorous/carbon disulphide incendiary mixture





Flam C-250 Oil Bomb

Bomb Weight	125kg (276lb)
Explosive Weight	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 living targets, against troop barracks and industrial installations. Thin casing – not designed for ground penetration



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

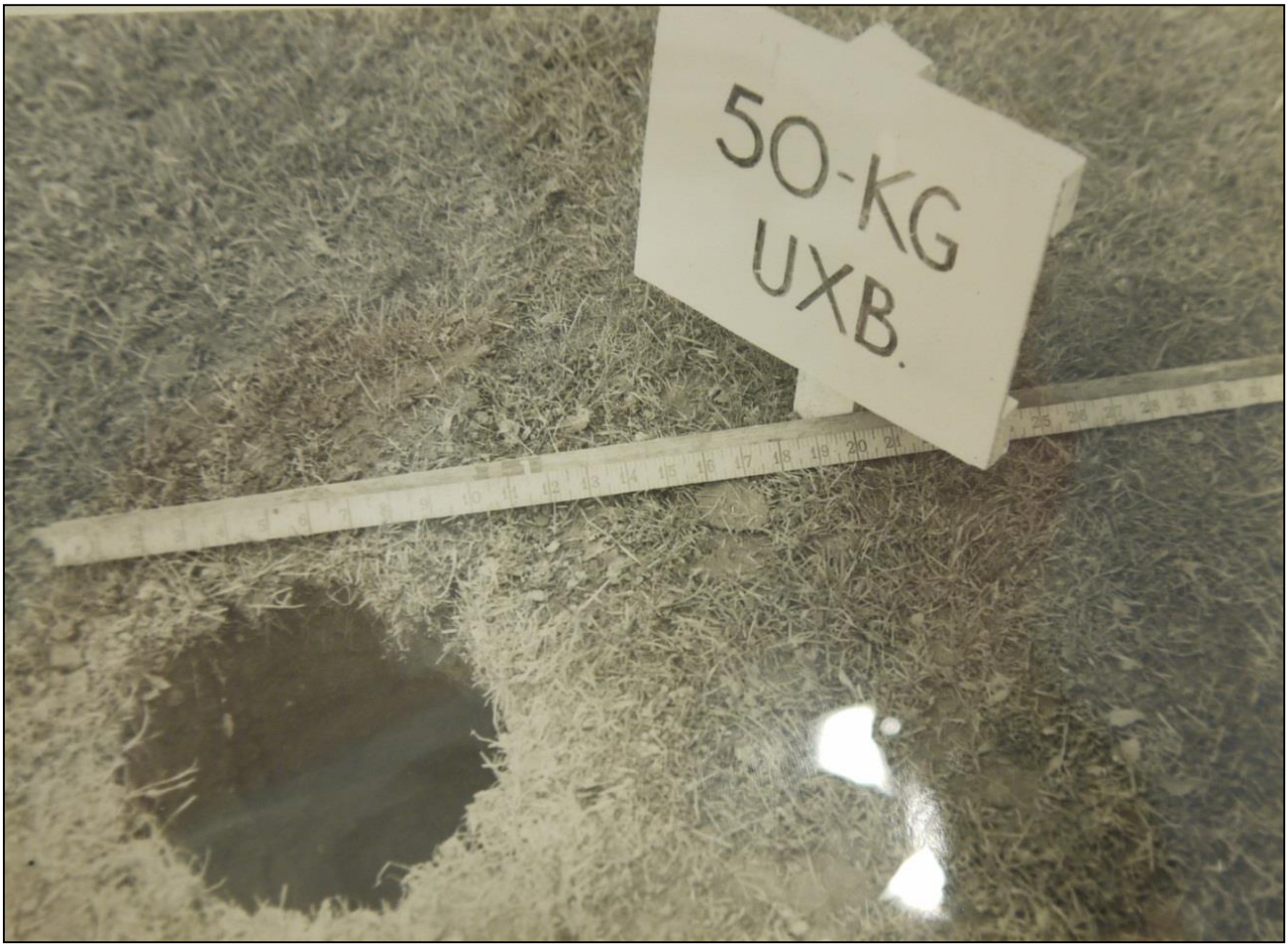
Client: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

Source: Various sources

50kg Bomb Entry Hole



German 50kg HE Bomb Entry Hole

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: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

Source: Archive sources

LIVE BBC NEWS CHANNEL

Page last updated at 14:45 GMT, Friday, 22 May 2009 15:45 UK

E-mail this to a friend Printable version

Building site WWII bomb exploded

A controlled explosion has been carried out on a World War II bomb found on a building site in East Sussex.

The 110lb (50kg) SC50 bomb, thought to have been dropped from a German aircraft in 1940 or 1941, was found at the Hollenden House site in Bexhill.

Children at St Peter and St Paul Primary School next door in Buckhurst Road were sent home early after the discovery on Thursday.

Police said a 160ft (50m) cordon was put round the site during the blast.

Breaking News: UXB in Beckton - controlled explosion ends the drama

Colin Grainger , Editor
Sunday, December 19, 2010
9:32 AM

The World War Two bomb that was found on the 2012 Olympic site in Stratford back in 2009. Picture: Steve Poston

Recommend 0 Tweet 3

+1 Recommend this on Google

Bomb disposal experts carried out a controlled explosion last night on a 250kg World War II shell discovered at Britain's largest sewage works.

Bomb disposal experts carried out a controlled explosion last night on a 250kg World War II shell discovered at Britain's largest sewage works.

The bomb was found at Beckton sewage works off Jenkins Lane after surveyors preparing the site for a £200m expansion detected an unusual magnetic force underground on Saturday morning.

The Thames Water workers immediately alerted police and army ordnance experts, who attended the site and confirmed it was an unexploded German warhead.

A 400-metre exclusion zone was set up before the bomb was destroyed at the works under controlled conditions at 9pm on Saturday.

Second World War bomb which caused commuter chaos has been diffused

By DAILY MAIL REPORTER
Last updated at 4:42 PM on 06th June 2008

Comments (0) | Share +1 0 Tweet 0 Like 3

An unexploded Second World War bomb which forced the closure of a number of transport routes in the capital was defused today.

Army experts worked to disarm the 2,000lb UXB faced delays after discovering metal used to make the Second World War device was thicker than expected.

This morning, however, military engineers managed to cut through the casing of the bomb, which measures 5ft by 2ft, enabling them to begin 'steaming' the explosive inside to make it safe.

Effort: Army experts' machines and the unexploded bomb in East London

Commuters faced the prospect of more Tube chaos, however, as lines near the danger area were closed.

The bomb, which is lying on a gas main just 50 yards from the main sewage pump for east London, was unearthed by a mechanical digger on Monday in the banks of the Lea in Bromley-by-Bow near the Olympic site.

Construction workers made the discovery while widening the bank to take barges for the 2012 Games village construction.

It had lain dormant there for more than 60 years.

Holiday beach cordoned off after landslip sends more than a THOUSAND Second World War bombs and rockets tumbling onto the sands

- **Bad weather led to ground movement which exposed the huge arsenal at Mappleton, East Riding**
- **A dog walker stumbled across the deadly find on Saturday and 15 controlled explosions were carried out**
- **Rockets, mortar bombs and 25-pounder bombs were recovered after they were fired into the cliffs by RAF aircraft during the war**
- **Most of the devices were dummy rounds used for bombing practice but contain enough explosives to cause terrible injuries**

By EMILY ALLEN and MARK BRANAGAN

PUBLISHED: 08:11, 23 July 2012 | **UPDATED:** 02:42, 24 July 2012

Share Tweet +1 Share 45 View comments

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:	**GEA Ltd**
Project:	**Bangor Wharf**
Ref:	**OPN2819**
Source:	Various news sources

Examples of Unexpected Detonation of WWII Bombs

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.

1st March 2013

BASF is expanding their its Ludwigshafen location by expanding several plants and building a TDI plant, which was the site of an explosion on Tuesday (Feb. 26). One person was injured in the blast, which BASF believes was caused when excavation work detonated a bomb.

Early reports had speculated that excavation work had detonated a bomb from World War II. While the age of the bomb has not been confirmed, BASF has said that an explosive device was detonated.

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."

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.

Tweet 0 Recommend 1

23rd October 2006

AP

A cutting machine lies wrecked by the side of the A3 motorway next to a small crater left by the explosion.

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.

The A3 Autobahn linking the cities of Frankfurt and Würzburg has been blocked in both directions.

More than 60 years since the end of World War II, construction workers still frequently unearth unexploded bombs and it is not uncommon for whole city districts to be cordoned off and even evacuated while bomb disposal experts defuse them.

Indeed, just last week, some 22,000 people were evacuated from their homes in Hanover when three World War II bombs were discovered.

Allied pilots rained nearly 2 million tons of explosives on Germany during the war. Landmines, hand grenades, mortar bombs and anti-tank devices from the fighting on German soil at the end of the war are also found, and authorities say it will take decades before the country is cleared of duds.

Between 400 and 600 bombs are discovered a year in the state of North Rhine-Westphalia alone, where the heavily industrialized Ruhr region was a major target for Allied bombers.

19th September 2013

WWII bomb injures 17 at Hattingen construction site

Published: 19 Sep 08 16:53 CET

Share +1 0 Tweet 0

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

- Liberals grit teeth ahead of May state election (17 Mar 12)
- Nazi death camp guard Demjanjuk dies (17 Mar 12)
- Stupid stunt causes bomb scare chaos (16 Mar 12)

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."

BBC Mobile | News | Sport | Weather | iPlayer | TV

NEWS EUROPE

Home | World | UK | England | N. Ireland | Scotland | Wales | Business | Politics | Health | Education | Sci/Envi

Africa | Asia | Europe | Latin America | Middle East | US & Canada

2 June 2010 Last updated at 15:37

Share

World War II bomb kills three in Germany

Three people have been killed and six injured trying to defuse a World War II bomb in central Germany.

2nd June 2010

AFP

All the victims were involved in an operation to defuse the bomb

Workers building a sports stadium had earlier unearthed the bomb in the town of Goettingen.

It was not immediately clear why the bomb, reportedly weighing 500kg (1,100lb), had detonated.

Unexploded WWII bombs dropped by Allied planes are frequently found in Germany, though it is unusual for them to explode unexpectedly.

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.

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: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

Source: Various news sources

BBC | Sign in | News | Sport | Weather | iPlayer | TV | Radio | More | Search

NEWS | Find local news

Bermondsey bomb: World War Two device safely removed

24 March 2015 | London

An unexploded World War Two bomb found in south London has been driven away safety 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.

London Fire Brigade said that between 2009 and 2014 it was called to seven unexploded Second World War bombs and five unexploded hand grenades.

Mile End volunteers find live grenade in Regent's Canal

6 November 2014 | London

The grenade was found while volunteers helped clear a stretch of Regent's Canal

Volunteers clearing up a stretch of canal in east London unearthed an unexploded grenade from World War Two.

The live grenade was found at about 15:00 GMT along a stretch of Regent's Canal near Salmon Lock in Mile End.

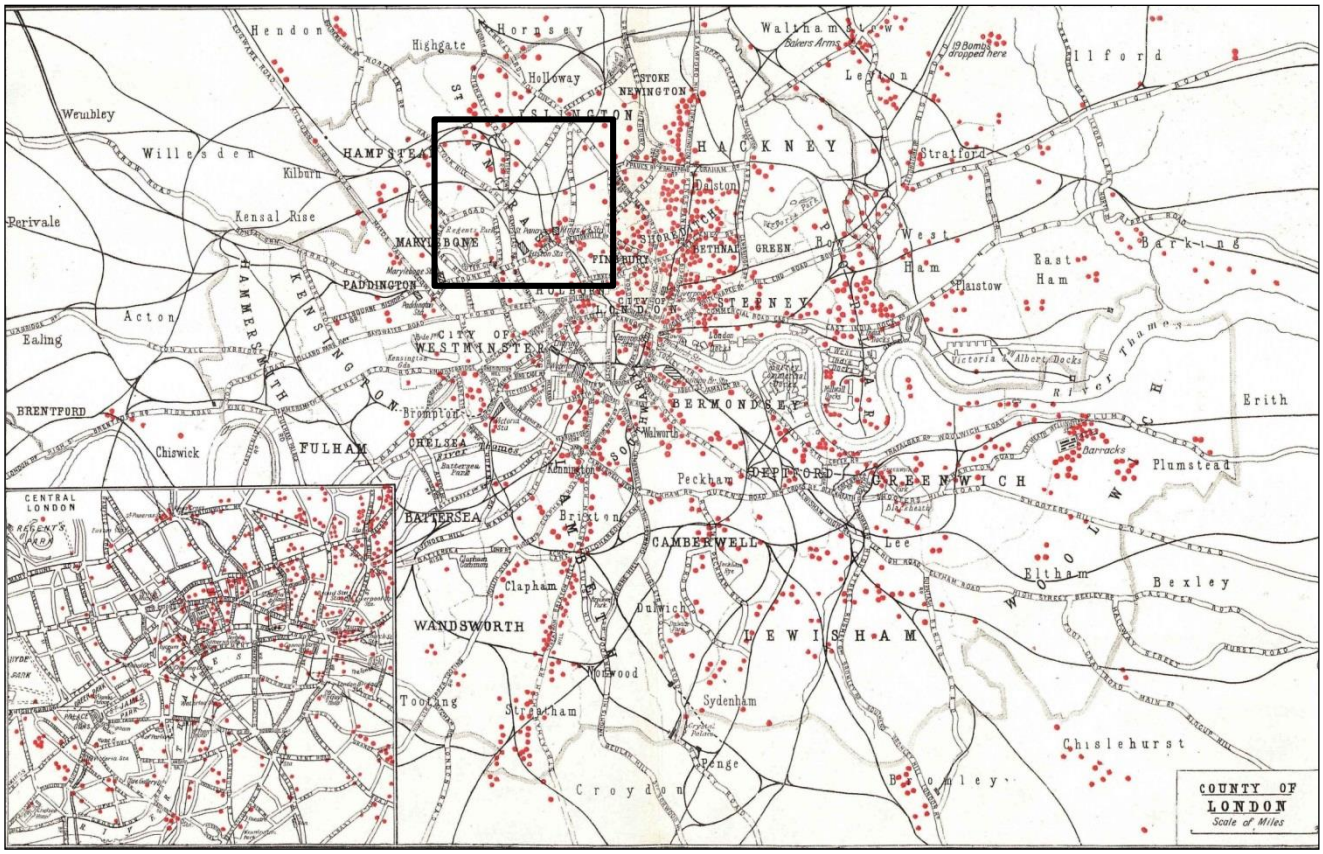
Scotland Yard said it was alerted by the Canal and River Trust, which organised the event, and it took the grenade away to dispose of it.

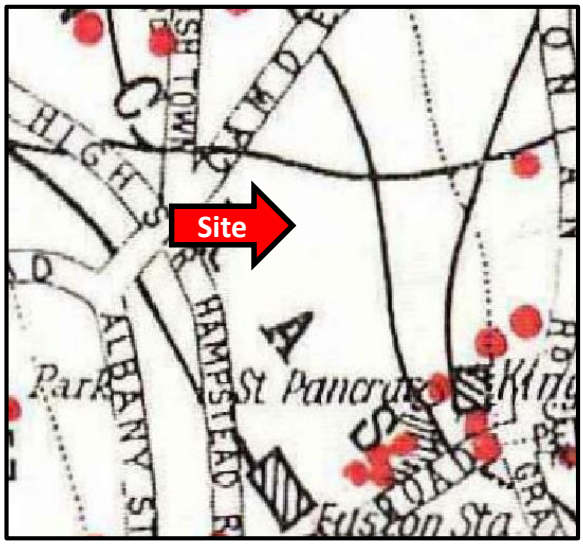
Debbie Vidler, from the trust, said: "We often find weird and wonderful things in the bottom of canals."

She added: "Today we discovered numerous shopping trolleys, bicycles, mobile phones... but we were not expecting to find a 70-year-old unexploded bomb."

WWI Bomb Plot Map, London

Annex: **H**





Examples of 50 and 100kg German WWI bombs

1ST LINE DEFENCE

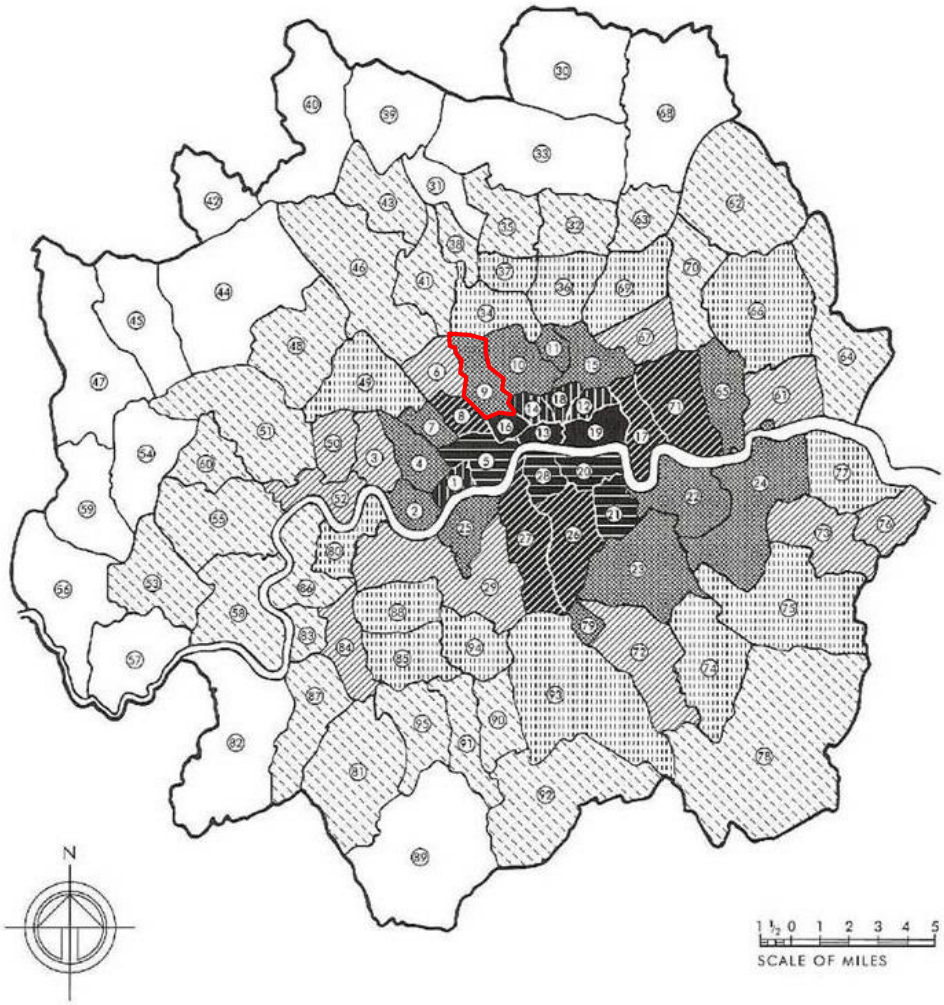
Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client:	**GEA Ltd**	
Project:	**Bangor Wharf**	
Ref:	**OPN2819**	Source: The National Archives, Kew

N

London WWII Bomb Density Map

Annex: I



No. OF BOMBS PER 1,000 ACRES

OVER 600	300 – 399	100 – 149
500 – 599	200 – 299	50 – 99
400 – 499	150 – 199	UNDER 50

1	Chelsea	25	Battersea	49	Willesden	72	Beckenham
2	Fulham	26	Camberwell	50	Acton	73	Bexley
3	Hammersmith	27	Lambeth	51	Ealing	74	Bromley
4	Kensington	28	Southwark	52	Brentford and Chiswick	75	Chislehurst and Sidcup
5	Westminster	29	Wandsworth	53	Feltham	76	Crayford
6	Hampstead	30	Cheshunt	54	Hayes and Harlington	77	Erith
7	Paddington	31	East Barnet	55	Heston and Isleworth	78	Orpington
8	St. Marylebone	32	Edmonton	56	Staines	79	Penge
9	St. Pancras	33	Enfield	57	Sunbury	80	Barnes
10	Islington	34	Hornsey	58	Twickenham	81	Epsom and Ewell
11	Stoke Newington	35	Southgate	59	Yiewsley and West Drayton	82	Esher
12	Bethnal Green	36	Tottenham			83	Kingston on Thames
13	City of London	37	Wood Green	60	Southall and Norwood	84	Malden and Coombe
14	Finsbury	38	Friern Barnet	61	Barking	85	Merton and Morden
15	Hackney	39	Potters Bar	62	Chigwell	86	Richmond
16	Holborn	40	Elstree	63	Chingford	87	Surbiton
17	Poplar	41	Finchley	64	Dagenham	88	Wimbledon
18	Shoreditch	42	Bushey	65	East Ham	89	Banstead
19	Stepney	43	Barnet U.D.	66	Ilford	90	Beddington and Wallington
20	Bermondsey	44	Harrow	67	Leyton	91	Carshalton
21	Deptford	45	Ruislip and Northwood	68	Waltham Holy Cross	92	Coulsdon and Purley
22	Greenwich	46	Hendon	69	Walthamstow	93	Croydon
23	Lewisham	47	Uxbridge	70	Wanstead and Woodford	94	Mitcham
24	Woolwich	48	Wembley	71	West Ham	95	Sutton and Cheam

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: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

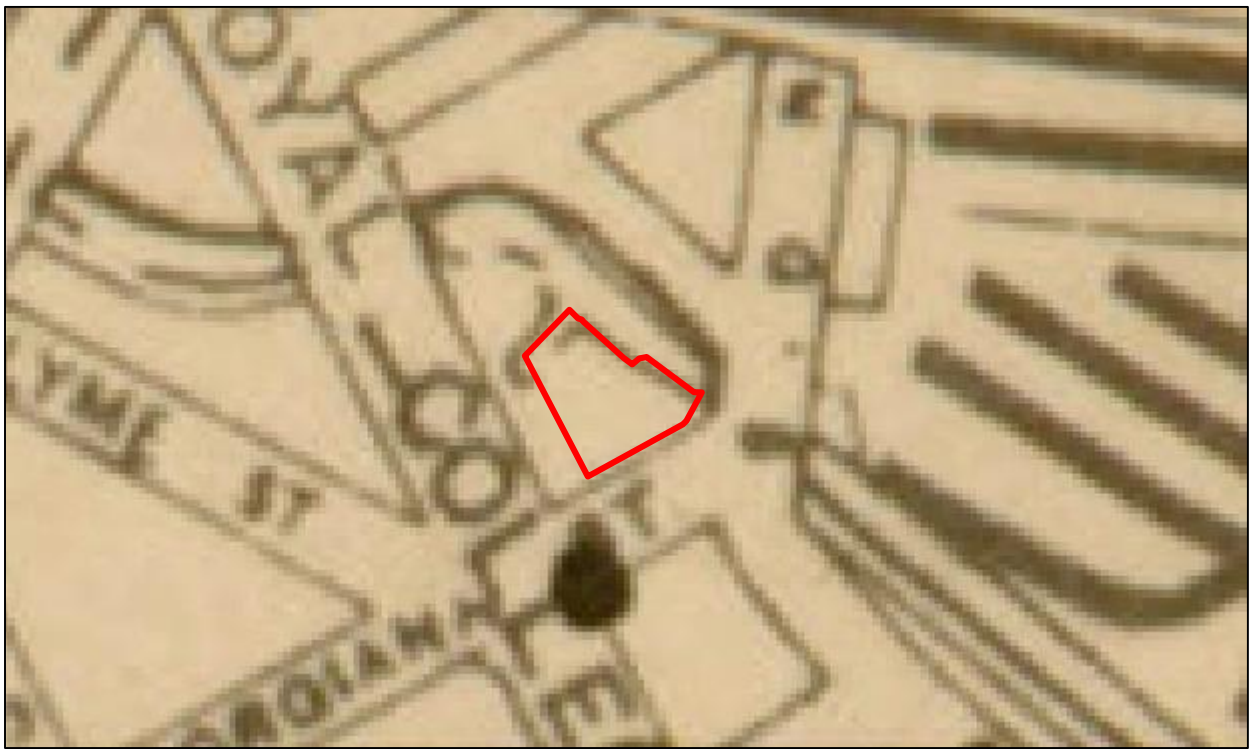
Source: The London Metropolitan Archives

N

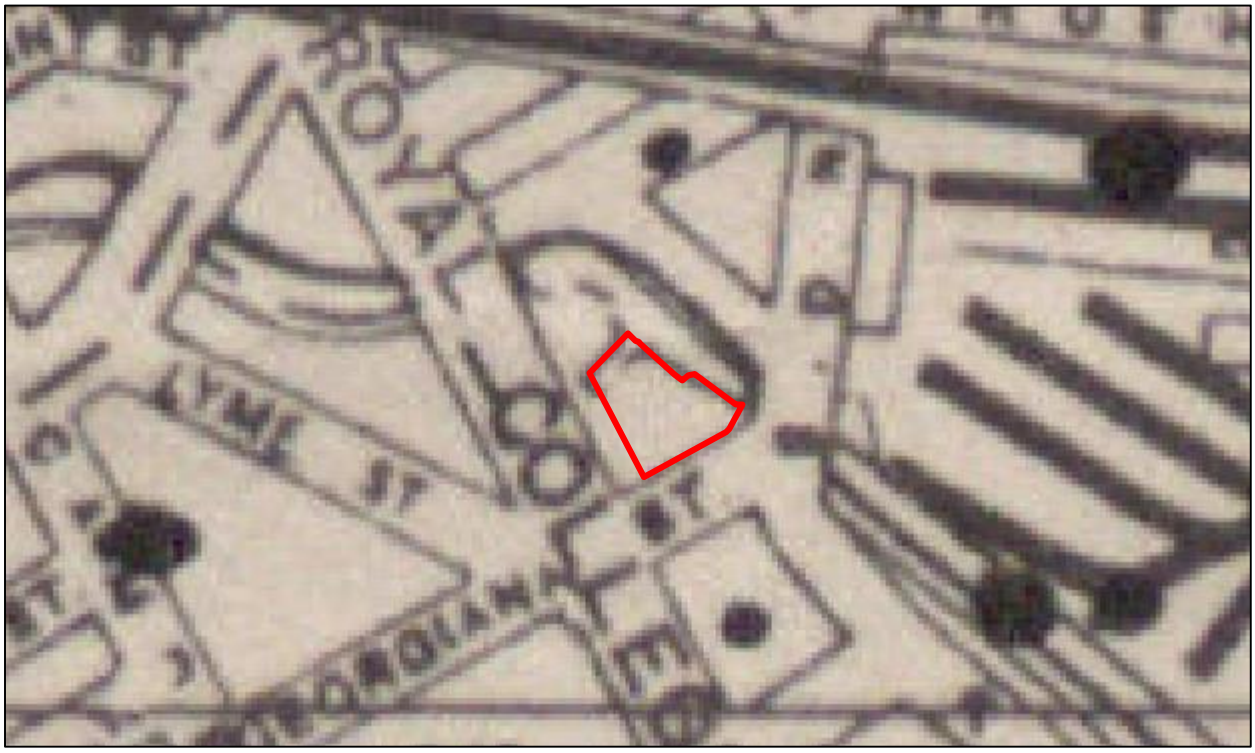
Consolidated London Bomb Census Mapping

Annex: **J1**

Night Bombing up to 7th October 1940



Night Bombing - 7th October 1940 to 28th July 1941



Recorded bomb strike

1ST LINE DEFENCE

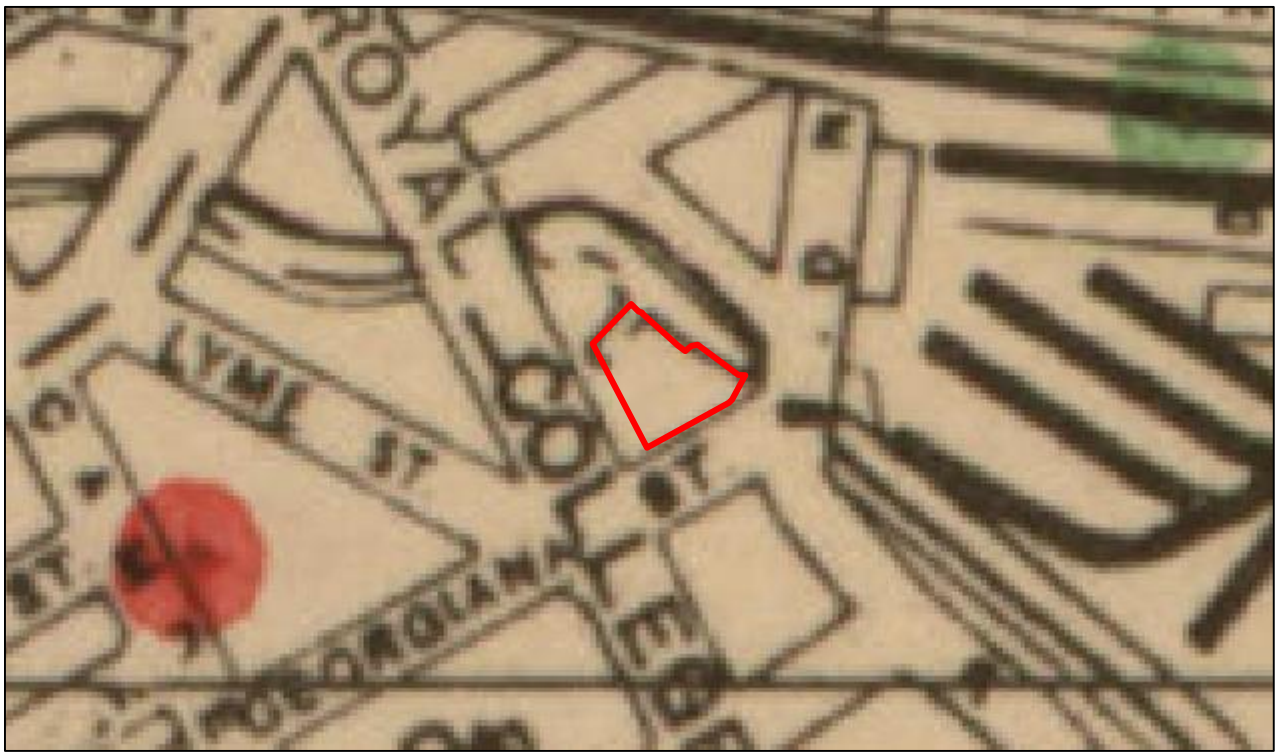
Unit 3, Maple Park
Essex Road, Hoddesdon,
Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client:	**GEA Ltd**	**Approximate site boundary**	N
Project:	**Bangor Wharf**		
Ref:	**OPN2819**	Source: The National Archives, Kew	

Weekly London Bomb Census Mapping

Annex: **J2**

Night Bombing 21st – 28th October 1940



Night Bombing 11th – 18th November 1940

Recorded HE bomb strike

Incendiary bomb shower

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: **GEA Ltd**

Approximate site boundary

Project: **Bangor Wharf**

N

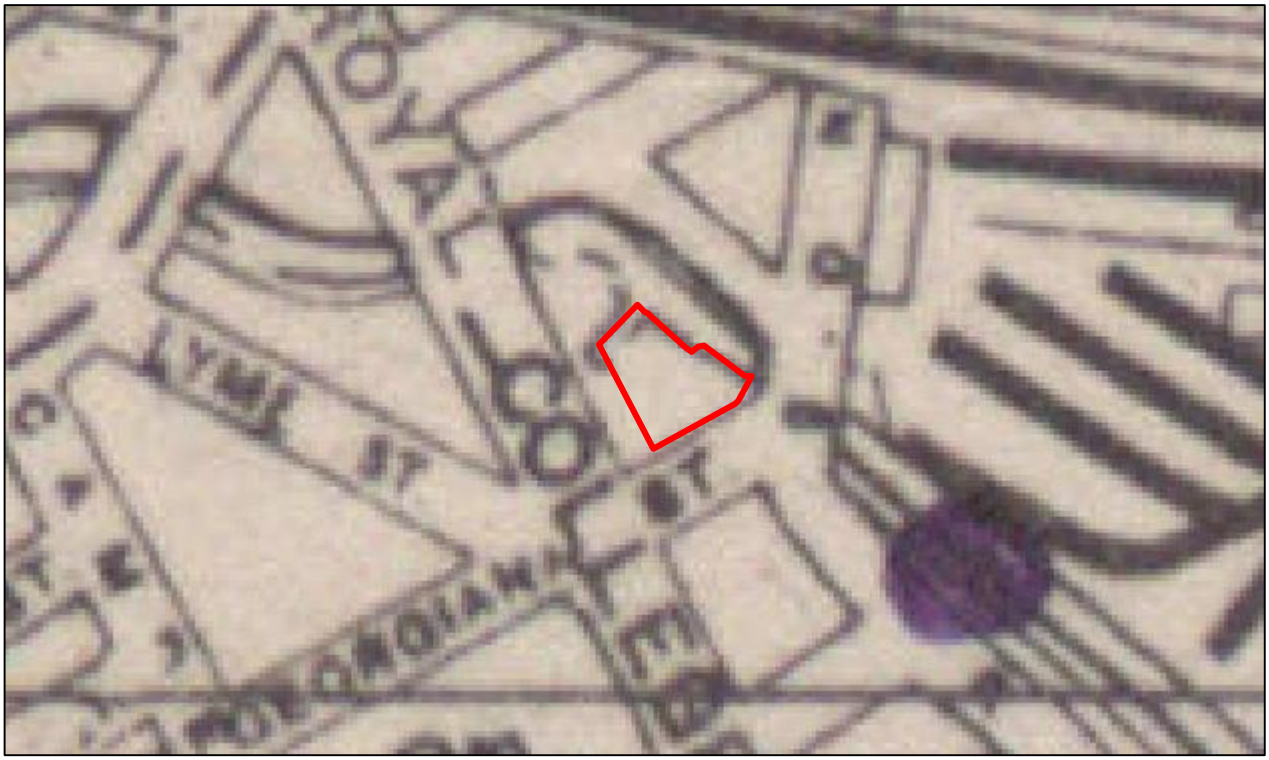
Ref: **OPN2819**

Source: The National Archives, Kew

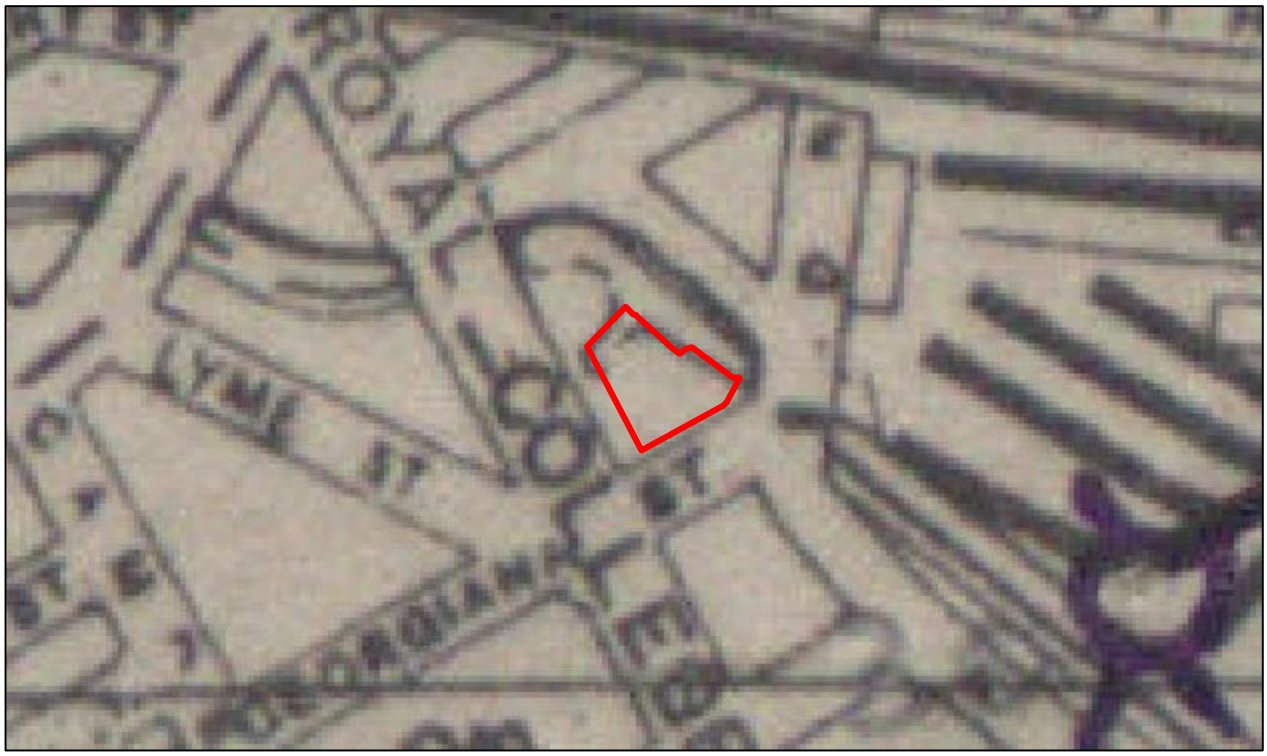
Weekly London Bomb Census Mapping

Annex: **J3**

Night Bombing 6th – 13th January 1941



Night Bombing 5th – 12th May 1941



Recorded HE bomb strike

Unexploded Bomb

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: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

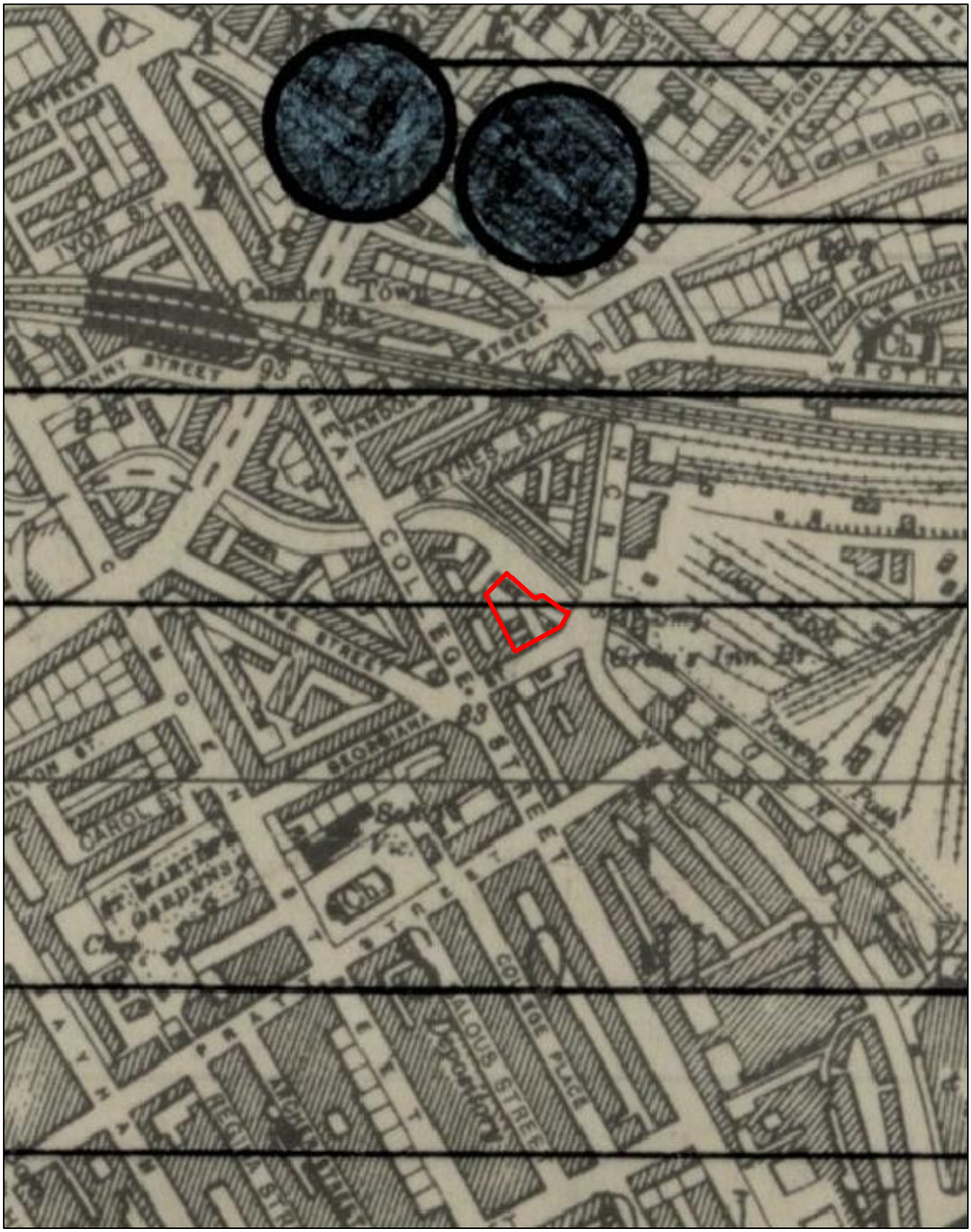
Source: The National Archives, Kew

Approximate site boundary

N

London V-1 Flying Bomb Map

Annex: **K**



V1 Flying Bomb

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: **GEA Ltd**

Approximate site boundary

N

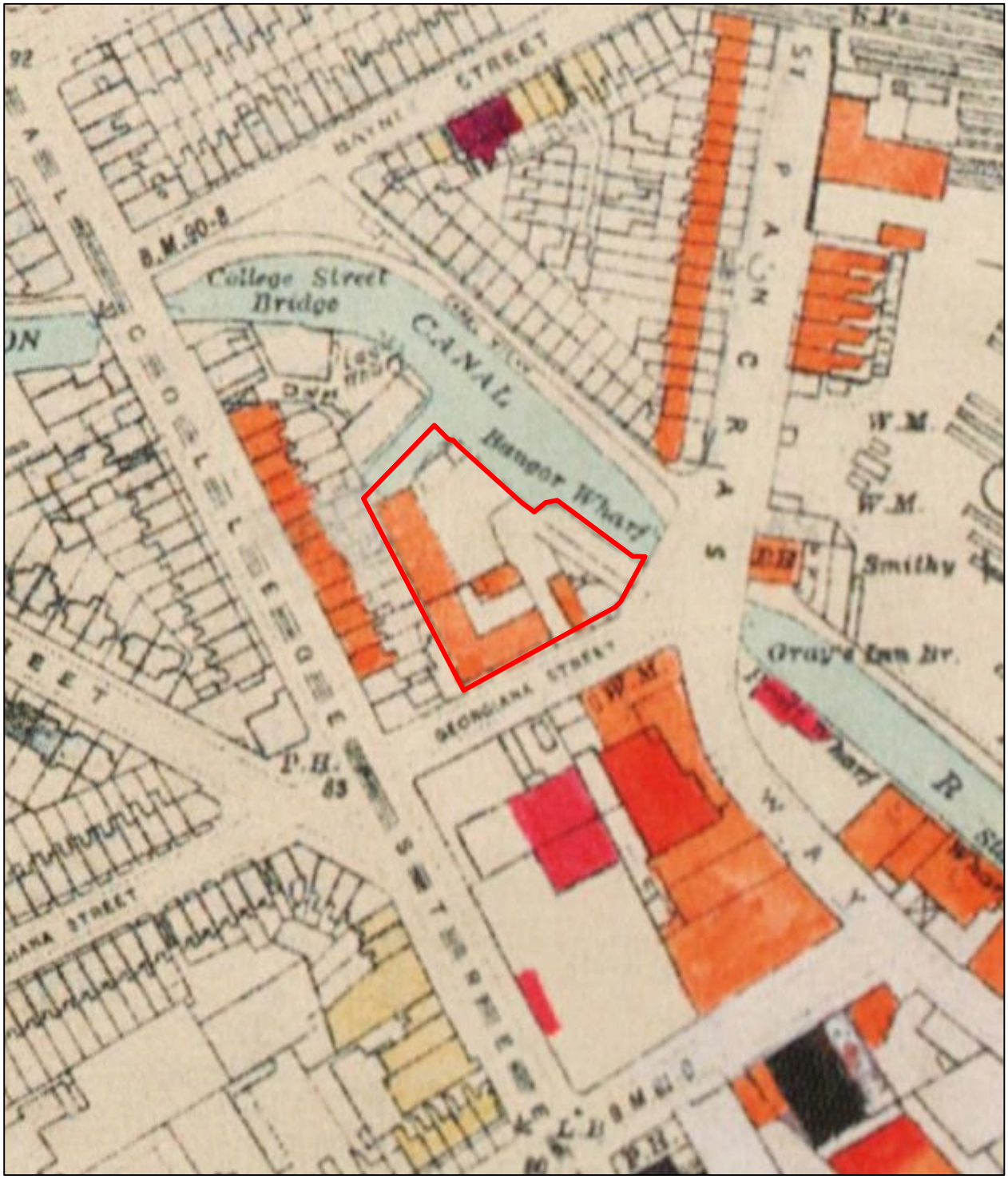
Project: **Bangor Wharf**

Ref: **OPN2819**

Source: The National Archives, Kew

London County Council Bomb Damage Map

Annex: **L**



Black	Total destruction	Orange	General blast damage; not structural
Purple	Damage beyond repair	Yellow	Blast damage, minor in nature
Dark Red	Seriously damaged; doubtful if repairable	Light Green	Clearance areas
Light Red	Seriously damaged, but repairable at cost		

V1 Flying Bomb

V2 Long Range Rocket

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: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

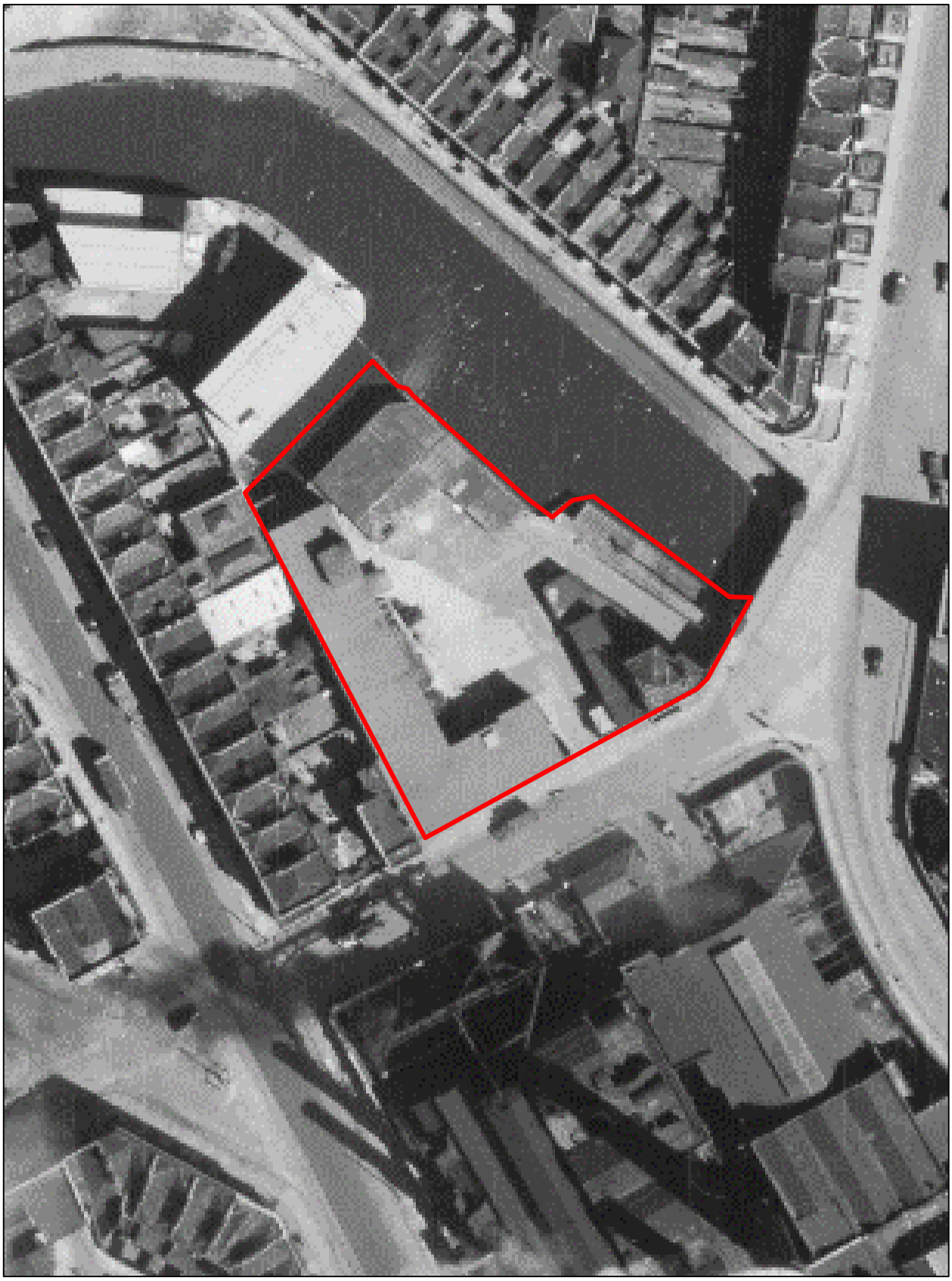
Source: London Metropolitan Archives

Approximate site boundary

N

RAF Aerial Photography 19th May 1948

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: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

Source: National Monuments Record Office (Historic England)

Approximate site boundary

N

RAF Aerial Photography 19th May 1948

Annex: **M2**

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: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

Source: National Monuments Record Office (Historic England)

Approximate site boundary

N

RAF Aerial Photography 19th May 1948

Annex: **M3**

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: **GEA Ltd**

Project: **Bangor Wharf**

Ref: **OPN2819**

Source: National Monuments Record Office (Historic England)

Approximate site boundary

N