6 Alpha Associates Limited
Quatro House, Frimley Road
Camberley, Surrey
GU16 7ER

T: +44(0) 203 371 3904
W: www.6alpha.com

Detailed Unexploded Ordnance (UXO) Risk Assessment

Study Site: Tybalds Estate, Camden, London
Client Name: Tibbalds Planning and Urban Design Limited
6 Alpha Project Number: P2771_V1.0
Date: 23rd February 2012

Originator: Gary Hubbard (23rd February 2012)
Quality Review: Lee Gooderham (5th March 2012)
Released by: Simon Cooke (6th March 2012)

This document is of UK origin and is copyright © 6 Alpha Associates Ltd. It contains proprietary information, which is disclosed for the purposes of assessment and evaluation only. The contents of this document shall not in whole or in part: (i) be used for any other purpose, (ii) be disclosed to any member of the recipient's organisation not having a need to know such information, nor to any third party individual, organisation or government, (iii) be stored in any retrieval system nor be reproduced or transmitted in any form by photocopying or any optical, electronic, mechanical or other means, without the prior written permission of the Managing Director, 6 Alpha Associates Limited, Quatro House, Frimley Road, Camberley, GU16 7ER, UK.

Contents

Figures

Annexes

EXECUTIVE SUMMARY

Study Site	The Client has specified the Study Site as "*Tybalds Estate, Camden, London*". The Site is located at National Grid Reference 530523, 181903.
Key Findings	Prior to the outbreak of World War Two (WWII) the authorities had identified *London* as an obvious primary bombing target for the *German Air Force* (*Luftwaffe*), given the amount of industrial, logistical and military facilities located within the capital. Numerous countermeasures were introduced including Barrage Balloons and Anti-Aircraft Artillery (AAA) in an attempt to deter low level bombing of the city. Despite this the *Luftwaffe* conducted numerous bombing raids against *London*, with virtually all boroughs of the city sustaining substantial damage and loss of life, which can be attributed to the quantity of bombs dropped and the inaccuracies of high altitude bombing at this time. This is evidenced by the very high bomb density statistics recorded by the *Holborn Metropolitan Borough* (in which the Site is located) of 863 High Explosive (HE) bombs per 1,000 acres. During WWII the Air Raid Precaution (ARP) wardens retained detailed records concerning many aspects of *Luftwaffe* bombing. These records have identified two High Explosive (HE) bomb strikes within the Site and an additional five within 25m of the Site boundary. Prior to WWII the Study Site has been identified by 1916 and 1938 County Series mapping as a densely developed area predominantly containing residential buildings. The *London County Council* (LCC) recorded damage sustained by property throughout WWII, these maps have identified significantly high levels of damage sustained within the southern portion (identified as "total destruction"), whilst the northern portion of the Site remains relatively undamaged apart from four residential houses located to the east and one to the west all identified as "seriously damaged – doubtful if repairable". Whilst these maps are considered definitive, the specific cause (e.g. HE bombs or Incendiary bombs) of damage is not indicated. In areas sustaining high levels of damage, debris could mask a unexploded bomb (UXB) entry hole. Based on the varying level of damage sustained on Site throughout the war, 6 Alpha has subdivided the Site for risk assessment purposes. • **AREA A** – northern section, which sustained limited localised levels of bomb damage. • **AREA B** – southern section, which sustained widespread high levels of bomb damage. Should a UXB have indeed landed on Site, the potential for penetration is significantly reduced due to the development on Site, the thickness of the made ground and also the "competent" natural strata beneath the Site. 6 Alpha has assessed that the maximum bomb penetration for the likely HE bombs on Site would not exceed 4m below ground level (bgl). Post WWII development has been limited in both scale and depth. Ground works may have reduced the potential for a UXO discovery within the footprint of structures built after WWII. However, given the scale of destruction and the bomb density for this Site, the potential for UXO encounter within these areas is considered to still pose a significant threat to future works.
Potential Threat Source	The threat is predominately posed by WWII *German* HE bombs, Incendiary Bombs and *British* Anti-Aircraft Artillery (AAA) projectiles (the latter were used to defend against *German* raids). This threat is principally confined from ground level to 4m bgl.
Risk Pathway	Given the type of munitions that might be present on Site, all types of aggressive intrusive engineering activities may generate a significant risk pathway.
Risk Level	**Area A - LOW/MEDIUM** **Area B - MEDIUM/HIGH**
Recommended Risk Mitigation	**For all activities on the Study Site:** 1. **Operational UXO Risk Management Plan;** appropriate site management documentation should be held on site to plan for and guide upon the actions to be carried out in the event of a suspected or real UXO discovery. 2. **UXO Safety & Awareness Briefings;** the briefings are essential when there is a possibility of explosive ordnance encounter and are a vital part of the general safety requirement. **In addition to the above, for Area B (areas where significant bomb damage was recorded):** 3. **Specialist UXO Banksman Support;** all ground works should be supervised by a specialist UXO banksman to identify and dispose of any items of UXO.

ASSESSMENT METHODOLOGY

Approach	6 Alpha Associates are independent, specialist risk management consultants and the UXO related risk on the Site has been assessed using the process advocated by both the *Construction Industry Research & Information Association* (CIRIA) best practice guide (C681) and by the *Health & Safety Executive* (HSE). Therefore, any risk levels identified in the assessments are objective, quantifiable and not simply designed to generate "follow on survey or contracting work"; any mitigation solution is recommended *only* because it delivers the Client a risk reduced to As Low As Reasonably Practicable (ALARP) at best value. Potential UXO hazards have been identified through investigation of Local and National archives covering the Site, *Ministry of Defense* (MoD) archives, local historical sources, historical mapping as well as contemporaneous aerial photography (as and if, it is available). Potential hazards have only been recorded if there is specific information that could reasonably place them within the boundaries of the Site. Key source material is referenced within this document, whilst data of lesser relevance (which may have been properly considered and discounted by 6 Alpha), is available upon request. The assessment of UXO risk is a measure of ***probability*** *of encounter* and ***consequence*** *of encounter*; the former being a function of the identified hazard and proposed development methodology; the latter being a function of the type of hazard and the proximity of personnel (and/or other "sensitive receptors"), to the hazard at the moment of encounter. Should a measurable UXO risk be identified (in this case, assessed as **LOW/MEDIUM to MEDIUM/HIGH** across the Site), the methods of mitigation recommended are reasonably and sufficiently robust to reduce these to As Low As Reasonably Practicable (ALARP). We believe that the adoption of the legal ALARP principle is a key factor in efficiently and effectively ameliorating UXO risks. It also provides a ready means for assessing the client's tolerability of UXO risk. In essence the principle states that if the cost of reducing a risk significantly outweighs the benefit, then the risk may be considered tolerable. Clearly this does not mean that there is no requirement for UXO risk mitigation, but any mitigation must demonstrate that it is beneficial. Any additional mitigation that delivers diminishing benefits **and** that consume disproportionate time, money and effort are considered *de minimis* and thus unnecessary. Because of this principle unexploded bomb (UXB) risks will rarely be reduced to zero (nor need they be).
Important Notes	Although this report is up to date and accurate, our databases are continually being populated as and when additional information becomes available. Nonetheless, 6 Alpha have exercised all reasonable care, skill and due diligence in providing this service and producing this report. The assessment levels are based upon our professional opinion and have been supported by our interpretation of historical records and third party data sources. Wherever possible, 6 Alpha has sought to corroborate and to verify the accuracy of all data we have employed, but we are not accountable for any inherent errors that may be contained in third party data sets (e.g. National Archive or other library sources), and over which 6 Alpha can exercise no control.

STAGE ONE – SITE LOCATION AND DESCRIPTION	
Study Site	The Client has specified the Study Site as "*Tybalds Estate, Camden, London*". The Site is located at National Grid Reference 530523, 181903. See *Figures 1* and *2* for the Site location.
Location Description	The Site is partially situated within the *Bloomsbury Conservation Area,* located between *King's Cross* and *Holborn.* The Study Site is an irregular shape covering approximately 2.4 hectares (Ha). It is located within a city block bounded by four streets, namely *Great Ormond Street* to the north, *Lamb Conduit Street* to the east, *Theobalds Street* to the south and *Old Gloucester Street* to the west. This area comprises of numerous residential blocks and commercial buildings. See *Figure 3* for a current aerial view of the region.
Proposed Works	The Client has specified that detailed development plans are currently unavailable, although a summery of the three concepts broadly outlining the development intentions are as follows: **Example 1**: "79 N°. New Build Units and 16 N°. Conversion Units. Residential conversions to *Falcon, Springwater* and *Richbell* Houses. Community and ancillary use conversion to *Bleumundsbury* and *Windmill* Houses. Washrooms converted to homes in *Bleumundsbury*, *Windmill* and *Falcon* Houses. MultiUse Games Area (MUGA) located beneath central open space. Combined Heat and Power (CHP) unit to the base of *Chancellor's Court*. New pod flats to rooftop of *Bleumundsbury House*. New looped street around perimeter of site. 10 Storey new build element proposed to east of *Bleumundsbury*. Sub-option 1a indicated in corner of includes additional 8 units on 2 storeys, which sits above the underground MUGA". **Example 2**: "67 N°. New Build Units and 11 N°. Conversion Units. Residential conversion to *Falcon, Springwater* and *Richbell* Houses. Community and ancillary use conversion to *Bleumundsbury* and *Windmill* Houses. Residential conversion of washrooms in *Bleumundsbury*, *Windmill* and *Falcon* Houses. MUGA located underground and adjacent to *Bleumundsbury* House. CHP unit to the base of *Chancellor's Court*. New looped street around perimeter of site. New 6 storey build element to east of *Bleumundsbury House"*. **Example 3**: "44 N°. New Build Units and 16 N°. Conversion Units. Residential conversion to *Falcon, Springwater, Richbell* Houses and *Bleumundsbury* Houses. Conversion of community and storage in basement of *Windmill House*. No residential conversion of washrooms proposed. Games court at ground level located adjacent to *Chancellor's Court*. New street, which is accessible to all dwellings. New 5-storey build element proposed to the east of *Bleumundsbury* House". For completeness of the risk assessment process, 6 Alpha will also assume a number of generic engineering methodologies within this document, including trial pits, trenching, bulk excavations, boreholes and piled foundations.

STAGE ONE – SITE LOCATION AND DESCRIPTION (…continued)

Ground Conditions

The Client has supplied ground conditions for this particular Site as a table summarising the geology from boreholes conducted across the Study Site;

Thickness (m)	Type	Description
0.90 – 2.40	Made Ground	Brown slightly clayey fine to coarse sand with some brick and sandstone gravel.
1.80 – 3.50	Lynch Hill Gravel	Medium dense brown silty fine to coarse sand.
14.60 – 16.00	London Clay	Stiff, becoming very stiff with depth, grey fissured silty clay.
7.00 proven	Lambeth Group	Very stiff multi-coloured mottled fissured clay over pale grey silty fine sand underlain by blue clay.

It is important to establish the ground conditions within this report to determine both the maximum German UXB bomb penetration depth (BPD) as well as the potential for other types of munitions to be buried on this Site.

STAGE TWO – REVIEW OF HISTORICAL DATASETS	
Sources of Information Consulted	The following primary information sources have been used in order to establish the background UXO threat: 1. Home Office WWII Bomb Census Maps; 2. WWII & post-WWII Aerial Photography; 3. Official Abandoned Bomb Register; 4. National Archives in Kew; 5. Internet based research; 6. Geoenvironmental, Drainage and Flood Risk Desk Top Study *Campbell Reith*; 7. 33 Engineer Regiment (Explosive Ordnance Disposal) at Carver Barracks, Wimbish. Military providers have extremely long lead times for the delivery of information (typically extending to months), and at the time of reporting project specific data has not been received. If any relevant data is subsequently received that changes the risk assessment and/or the risk mitigation methodology, 6 Alpha will contact the client.
Site History	According to the County Series (CS) & Ordnance Survey (OS) historical mapping, the following site history can be recorded: **1896 to 1896 CS Mapping –** The Study Site is located within an area bounded by *Great "Ormond Street"* to the north, *"Lamb's Conduit Street"* to the east, *"Theobalds Road"* to the south and *"Gloucester Street"* to the west. The Site is predominantly residential housing located around *"Ormond Yard"* to the north, *"Orde Hall Street"* to the northeast, *"East Street"* and *"Harpur Street"* to the southeast, *"Boswell Close"* centrally and *"Devonshire Street"* and *"Gloucester Street"* to the west. Four structures are identified within the Study Site, a "*Mission Hall*" to the north and a "Public House" centrally within "*Ormond Yard*", a further two public houses are located at the junctions of "*Boswell Court*" and "*New North Street*" and "*Gloucester Street*" and "*Cross Street*"; **1916 CS Mapping –** There have been numerous structures removed from within the Study Site, which were located within the east (centrally) of "*Ormond Yard*", to the southwest of "*New North Street*", and to the southwest of "*Gloucester Street*". The remainder of the Site is unchanged; **1938 CS Mapping** – No noticeable change; **1949 OS Mapping –** There has been significant development within the Site, and numerous streets renamed including "*Ormond Close*" (formerly *Ormond Yard*), "*Dombey Street*" (formerly *East Street*), "*Boswell Street*" (formerly *Devonshire Street*) and "*Old Gloucester Street*"(formerly *Gloucester Street*). There is evidence that numerous properties have been removed from the southern portion of the Site (south of "*Dombey Street"*) from "*Lamb's Conduit Street"* to "*Old Gloucester Street*"; **1953 to 1954 OS Mapping** – The northern portion of the Site in the location of "*Ormond Close*" remains unchanged. The southern portion has undergone significant redevelopment, which consists predominantly of high rise residential flats; **1965 to 1968 OS Mapping –** No noticeable change within the southern portion of the Study Site. There has been significant redevelopment within the north, "Ormond Close" is no longer evident, and has been replaced with two high-rise residential buildings. These are identified as "*Chancellor Court"* to the east and "*Babington Court*" to the west; **1972 to 1974 OS Mapping –** No noticeable change; **1991 to 1995 OS Mapping –** No noticeable change;
Deductions	Prior to WWII, there had been an extensive residential development. Following, what appears to be the result of WWII bomb damage, the southern portion of the Study Site sustained widespread destruction with all structures south of *Dombey Street* removed from OS mapping. The area to the north of *Dombey Street* remained relatively unaffected, remaining virtually unchanged. Post WWII development has occurred throughout the Site, whilst not to the same density as prior to WWII.

STAGE TWO – REVIEW OF HISTORICAL DATASETS (…continued)	
WWII Bombing of London	The most intensive period of bombing over *London* was the nine months between October 1940 and May 1941, known as "the Blitz". During this period, the *Luftwaffe* attempted to overwhelm *Britain's* air defenses, destroy key military and industrial facilities as well as logistical capabilities, prior to invasion. A total of 18,000 tons of bombs were dropped on *London* between 1940 and 1945. Thousands of civilians were killed and many more injured; many buildings, both residential and commercial, were completely or partially destroyed. Public services also sustained intensive targeting with gas, electricity and water supplies often cut-off following damage to either the installation themselves or to the supply infrastructure.
WWII Site Use	The CS mapping from 1937 identifies the Study Site as a densely developed, predominantly residential area located within the *Holborn Metropolitan Borough* of *London*. The surrounding area consists of a mixture of commercial, residential and industrial properties. Great Ormond Street Children's Hospital is located approximately 40m to the north of the Study Site.
WWII Luftwaffe Bombing Targets (*Figure 4*)	During WWII, the Study Site was located within the *Holborn Metropolitan Borough.* Many areas of London where indiscriminately bombed by the *Luftwaffe*, particularly areas containing primary bombing targets. There has been one primary bombing target identified from *Luftwaffe* aerial photography (TN1611), which identifies the "Water Works, filter beds and pumping station" located 950m to the northeast of the Study Site. In addition, the Luftwaffe considered railway infrastructure a viable target during WWII, in an attempt to disrupt the supply and transportation of troops and materials vital for the war effort. There are two railway stations in proximity to the Study Site, *St Pancras Station and Goods Yard* (950mm to the north) and *Euston Station* (1,180m to the northwest).
WWII Anti-Aircraft Artillery (AAA) location	Anti-Aircraft Artillery (AAA) batteries were located in and around *London* as an integral defence mechanism against the *Luftwaffe* bombers. Typically, the *Royal Artillery* would man such defences. The AAA defence around *London* consisted of predominantly of 4.5" Heavy AAA gun batteries and 3.7" AAA batteries. The significance of these defensive positions located near to the Site, is that the *Luftwaffe* often targeted them in an attempt to reduce losses. *British* AAA sites were located at *Hyde Park and Regent's Park*, approximately 2.6km southwest and 1.7 northwest respectively from the Study Site throughout WWII
WWII HE Bomb Strikes (*Figure 5)*	Air Raid Precaution (ARP) mapping identifies two HE bomb strikes from between October 1940 to July 1941, located within the Study Site. One is located between *Devonshire Street* and *Gloucester Street,* the other is located southeast of *Ormond Close*. In addition, eight further HE bomb strikes are recorded within 25m of the Site boundary, two to the north, two to the south and one to the east. There are no recorded V1 or V2 strikes recorded within 100m of the Study Site. It is important to note that incendiary bombs were not generally recorded as they fell in such high numbers that accurate record keeping was impossible.
WWII Bomb Damage (*Figure 6*)	The *London County Council* (LCC) bomb damage maps have identified significant damage was sustained by all structures located within the Study Site boundary south of *Dombey Street* and west of *Devonshire Street*. This ranges from "seriously damaged – doubtful if repairable" to "total destruction". The northern portion of the Site sustained a much lesser degree of damage, with only five buildings in total sustaining any damage. These are identified as four structures located between *Orde Hall Street* and *Ormond Close* and one structure located to the east of *Devonshire Street*, which sustained damage described as "seriously damaged – doubtful if repairable. Given this variable degree of damage, the Study Site will be divided into two defined areas and assessed accordingly; **Area "A"** (north) and **Area "B"** (south).
WWII High Explosive Bomb Density (*Figure 7*)	The study site was located within *Holborn Metropolitan Borough*, which recorded 863 HE bombs per 1,000 acres. This figure does not include incendiary devices, as they were often released in such large numbers that they were seldom recorded.
Abandoned Bombs	There are no abandoned bombs recorded within the Study Site, or within the immediate vicinity.

STAGE THREE – DATA ANALYSIS	
Was the ground undeveloped during WWII?	No; OS mapping from 1937 identifies the Study Site as a densely developed area of commercial and residential use, located approximately 40m south of *Great Ormond Street Children's Hospital.*
Is there a reason to suspect that the immediate area was a bombing target during WWII?	Yes; there is one primary *Luftwaffe* target located within 950m of the Study Site, with the addition of two further "opportunistic" bombing targets located within the region including railway infrastructure, which is located approximately 950m to the northeast and 1,180m to the northwest.
Is there firm evidence that ordnance landed on Site?	Yes; ARP records identify two HE bomb strikes within the Study Site's boundary, one in Area "A" and one in Area "B". An additional five bomb strikes recorded within 25m of the Study Site boundary, two to the north and three to the south. Whilst incendiary bombs may have fallen within the Site boundary, these were dropped in such large numbers they were rarely recorded.
Is there evidence of damage sustained on Site?	Yes; the LCC bomb damage maps identify that significant damage was sustained within the southern and western portions of the Site (Area "B"). The damage sustained by the majority of buildings located within these areas is described as "damaged beyond repair" to "total destruction". The remaining structures located to the north of *Dombey Street* (Area "A") sustained localised damage, which was sustained by five properties in total. Four of these were located between *Orde Hall Street* and *Ormond Close* and the other was a single structure located to the east of *Devonshire Street*. The damage sustained by these five structures is described as"seriously damaged – doubtful if repairable".
Would an UXB entry hole have been observed and reported during WWII?	Yes; numerous buildings used both for business and residential purposes occupied the Study Site, any UXB entering the Study Site whilst engaged in this level of development and occupancy are almost certain to have been witnessed. However, following the scale of destruction sustained within Area "B" between 1940 and 1941, any UXB entering the Site at this time or subsequently, is likely to have gone unrecorded or witnessed. It is possible that UXB's from later air raids may have entered the Site, which may have been masked by debris from these earlier raids.
Is there any reason to suspect that Live Firing or military training may have occurred at this location?	No; there is no supporting evidence to suggest that guns or associated artillery munitions were ever stored, located or fired from this Site.
What is the expected UXO contamination?	The most likely source of UXO contamination is from *German* aerial delivered ordnance, which ranges from small incendiary bombs through to large HE bombs (of which the latter forms the principal threat). There is an additional threat posed by *British* AAA ordnance.
Would previous earthworks have removed the potential for UXO to be present?	Possibly, following the large-scale destruction within Area "B" of Site during WWII, which was redeveloped post WWII. It is possible that the development of these structures built during the 1960s may have removed items of UXO within the footprint of these structures depending on the scale and depth of ground works. However, there remains a possibility for UXO to be present within the footprint of the structures, given the high bomb-density in the area and lack of data on the scale of previous works.
Does the potential for a UXO encounter vary across the site? ***(Figure 8)***	Yes, the Study Site can be divided into two specific areas (Area "A" to the north and Area "B" to the south) based on the scale and severity of WWII bomb damage. Given the widespread damage sustained within the south of the Site, the potential for a UXO discovery is significantly increased within this southern area, when compared to the north, which escaped relatively unscathed.

STAGE FOUR – RISK ASSESSMENT	
Threat Items	The threat is predominately posed by WWII *German* HE bombs and Incendiary Bombs and *British* AAA projectiles (the latter were used to defend against German bombing raids).
Maximum Penetration	Considering the detailed ground conditions (highlighted in Stage 1), the most likely Bomb Penetration Depth (BPD) for a 250kg bomb is assessed to be 4m (bgl). Whilst the *Luftwaffe* used larger bombs, their deployment was so few and only used against notable targets, to use them within this risk assessment would not be justified. The expected threat horizon for the Site is shallow. Due to ground cover present during WWII, bomb penetration depths are expected to be shallow. The structures present on Site during WWII would significantly retard the penetration ability of an item of UXO.
Risk Pathway	Given the type of munitions that might be present on Site, all types of aggressive intrusive engineering activities (i.e. groundwork) may generate a significant risk pathway. Whilst not all munitions encountered aggressively will initiate upon contact, such a discovery could lead to serious impact on the project, especially in terms of delay and blight.
Consequence	Consequences of UXO initiation include: 1. Kill and/or critically injure personnel; 2. Severe damage to plant and equipment; 3. Blast damage to nearby buildings; 4. Rupture and damage underground services. Consequences of UXO discovery include: 1. Delay the project; 2. Disruption to local community/infrastructure; 3. Incurring of additional costs.
UXO RISK CALCULATION	
Site Activities	A number of construction methodologies have been identified for analysis on this Site. There is a large amount of variation in the probability of encountering, or initiating items of UXO when conducting different activities on Site. Additionally the consequences of initiating UXO vary greatly depending on how the item of UXO was initiated on Site. For this reason, 6 Alpha has determined to conduct separate Risk Rating calculations for each construction methodology that may be used on Site.
Threat Items	The most probable UXO threat items for this Site are *German* HE bombs, incendiary bombs and *British* AAA projectiles. The consequences of initiating *German* HE bombs are more severe than initiating incendiary bombs or *British* AAA projectiles and thus they pose the greatest threat to the Site.
Risk Rating Calculation	6 Alpha's Semi-Quantitative Risk Assessment identifies the Risk Rating posed by the most probable threat items when conducting a number of different construction activities on the Site. Risk Rating is determined by calculating the probability of encountering UXO and the consequences of initiating it.

STAGE FOUR - RISK ASSESSMENT (…continued)				
Area "A" (northern)				
UXO RISK CALCULATION TABLE				
Activity	**Threat Item**	**Probability** (SHxEM=P)	**Consequence** (DxPSR=C)	**Risk Rating** (PxC=RR)
Trial Pits and Window Sampling	HE Bombs	1x1=1	3x2=6	1x6=6
	Incendiary Bombs	1x1=1	3x1=3	1x3=3
	AAA Projectiles	1x1=1	3x1=3	1x3=3
Trenching	HE Bombs	1x1=1	3x2=6	1x6=6
	Incendiary Bombs	1x1=1	3x1=3	1x3=3
	AAA Projectiles	1x1=1	3x1=3	1x3=3
Bulk Excavations	HE Bombs	1x2=2	2x2=4	2x4=8
	Incendiary Bombs	1x2=2	2x1=2	2x2=4
	AAA Projectiles	1x2=2	2x1=2	2x2=4
Boreholes	HE Bombs	1x2=2	2x2=4	2x4=8
	Incendiary Bombs	1x2=2	2x1=2	2x2=4
	AAA Projectiles	1x2=2	2x1=2	2x2=4
Piled Foundations	HE Bombs	1x3=3	2x2=4	3x4=12
	Incendiary Bombs	1x3=3	2x1=2	3x2=6
	AAA Projectiles	1x3=3	2x1=2	3x2=6
Abbreviations – Site History (SH), Engineering Methodology (EM), Probability (P), Depth (D), Consequence (C), Proximity to Sensitive Receptors (PSR) and Risk Rating (RR).				

STAGE FOUR - RISK ASSESSMENT (…continued)				
Area "B" (southern)				
UXO RISK CALCULATION TABLE				
Activity	**Threat Item**	**Probability** (SHxEM=P)	**Consequence** (DxPSR=C)	**Risk Rating** (PxC=RR)
Trial Pits and Window Sampling	HE Bombs	2x1=2	3x2=6	2x6=12
	Incendiary Bombs	1x1=1	3x1=3	1x3=3
	AAA Projectiles	1x1=1	3x1=3	1x3=3
Trenching	HE Bombs	2x1=2	3x2=6	2x6=12
	Incendiary Bombs	1x1=1	3x1=3	1x3=3
	AAA Projectiles	1x1=1	3x1=3	1x3=3
Bulk Excavations	HE Bombs	2x2=4	2x2=4	4x4=16
	Incendiary Bombs	1x2=2	2x1=2	2x2=4
	AAA Projectiles	1x2=2	2x1=2	2x2=4
Boreholes	HE Bombs	2x2=4	2x2=4	4x4=16
	Incendiary Bombs	1x2=2	2x1=2	2x2=4
	AAA Projectiles	1x2=2	2x1=2	2x2=4
Piled Foundations	HE Bombs	2x3=6	2x2=4	6x4=24
	Incendiary Bombs	1x3=3	2x1=2	3x2=6
	AAA Projectiles	1x3=3	2x1=2	3x2=6
Abbreviations – Site History (SH), Engineering Methodology (EM), Probability (P), Depth (D), Consequence (C), Proximity to Sensitive Receptors (PSR) and Risk Rating (RR).				

STAGE FIVE – RECOMMENDED RISK MITIGATION MEASURES WITH RESULTING RISK RATING	
If a geophysical survey is required are the ground conditions an issue?	**Non-Intrusive Methods of Mitigation** – Not possible, as any magnetometer results are highly likely to be affected by ferro-magnetic contamination due to previous construction activities and Made Ground/fill material contained within the Study Site. **Intrusive Methods of Mitigation** – Intrusive magnetometry is expected to be possible (although limited) on this Site, prior to, or during piling and bore holing operations. As ferro-contamination of the made ground/fill material, is likely to adversely affect detection capability of the equipment, as it passes through the fill layer particularly. Additionally, it is likely that UXO threat items will be contained within the made ground/fill material.

MITIGATION MEASURES TO REDUCE RISK TO 'ALARP'		
Activity	**Risk Mitigation Measures**	**Final Risk Rating**
All Activities in Area "A"	1. **Operational UXO Risk Management Plan;** appropriate site management documentation should be held on site to plan for and guide upon the actions to be carried out in the event of a suspected or real UXO discovery. 2. **UXO Safety & Awareness Briefings;** the briefings are essential when there is a possibility of explosive ordnance encounter and are a vital part of the general safety requirement. All personnel working on the site should receive a general briefing on the identification of UXB, what actions they should take to keep people and equipment away from the hazard and to alert site management. Posters and information of the general nature of the UXB threat should be held in the site office for reference and as a reminder. The safety awareness briefing is an essential part of the Health & Safety Plan for the site and conforms to the CDM regulations 2007.	LOW ALARP
All Activities in Area "B"	**In addition to the mitigation measures indicated above, the following measures should be implemented in Area B (the southern area of the Site).** **3. Specialist UXO Banksman Support;** all works should be supervised by a specialist UXO banksman to identify and dispose of any items of UXO. Whilst an intrusive survey would be possible, a Specialist UXO Banksman Support would be the most cost effective solution for this particular Site.	
This assessment has been conducted based on the information provide by the Client, should the proposed works change then 6 Alpha should be re-engaged to refine this risk assessment.		

Report Figures

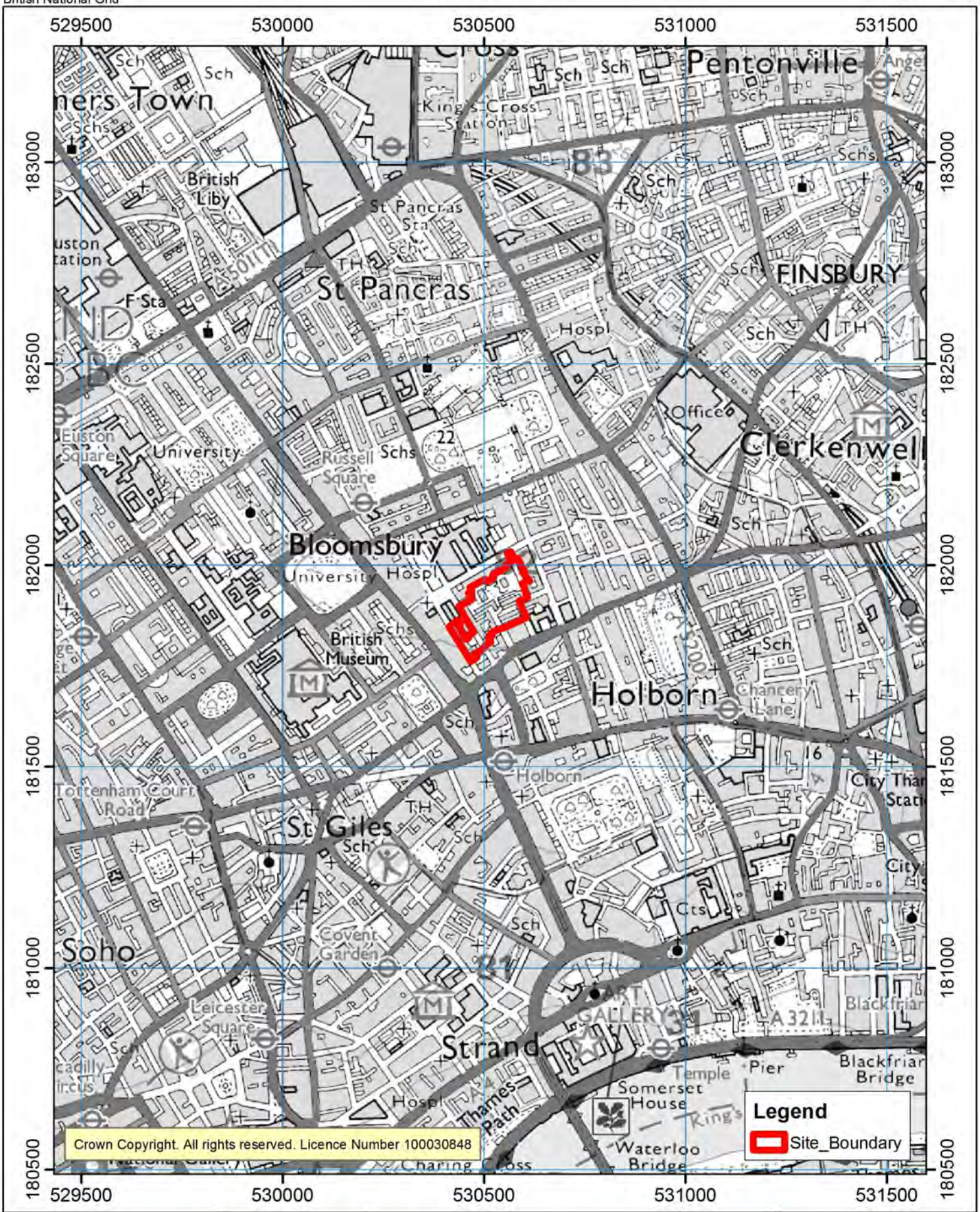
Figure One

Site Location

Tybalds Close Estate, Camden, London
Site Location

Figure 1

British National Grid



BOMB SEARCH

6 Alpha Associates Ltd.
Quatro House
Frimley Road
Camberley
Surrey GU16 7ER
United Kingdom
www.6alpha.com
0203 371 3900

0 50 100 200 300 400 500 Meters

N

Produced by and Copyright to 6 Alpha Associates Ltd.
Users noting any errors please forward to 6 Alpha.
Background data supplied by Ordnance Survey under licence.

Project Number: P2771

Drawn By: Dominique René

Checked by: Lee Gooderham

Date: 23rd February 2012

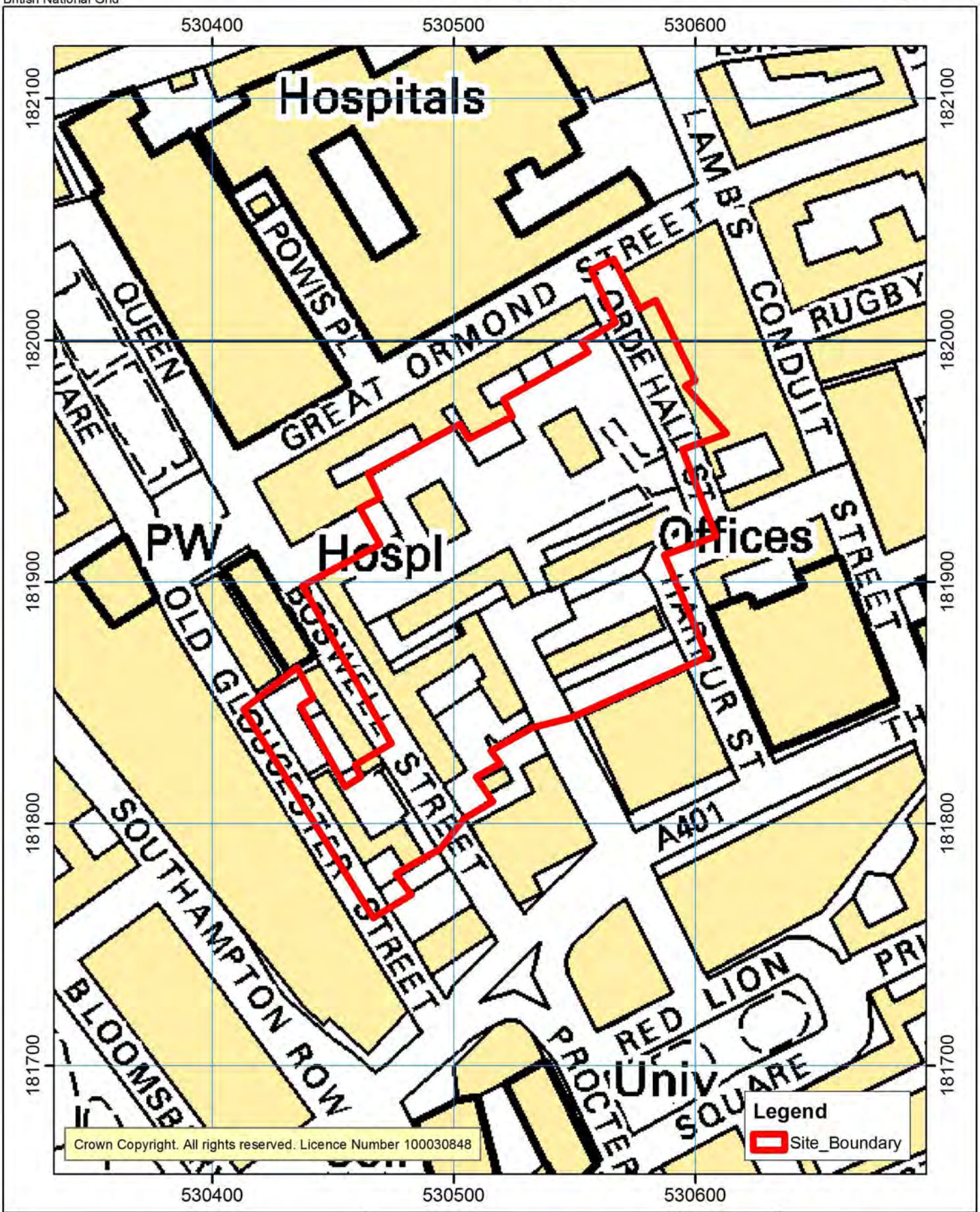
Figure Two

Site Boundary

Tybalds Close Estate, Camden, London
Site Boundary

Figure 2

British National Grid



BOMB SEARCH

6 Alpha Associates Ltd.
Quatro House
Frimley Road
Camberley
Surrey GU16 7ER
United Kingdom
www.6alpha.com
0203 371 3900

0 10 20 40 60 80 100 Meters

N

Produced by and Copyright to 6 Alpha Associates Ltd.
Users noting any errors please forward to 6 Alpha.
Background data supplied by Ordnance Survey under licence.

Project Number: P2771

Drawn By: Dominique René

Checked by: Lee Gooderham

Date: 23rd February 2012

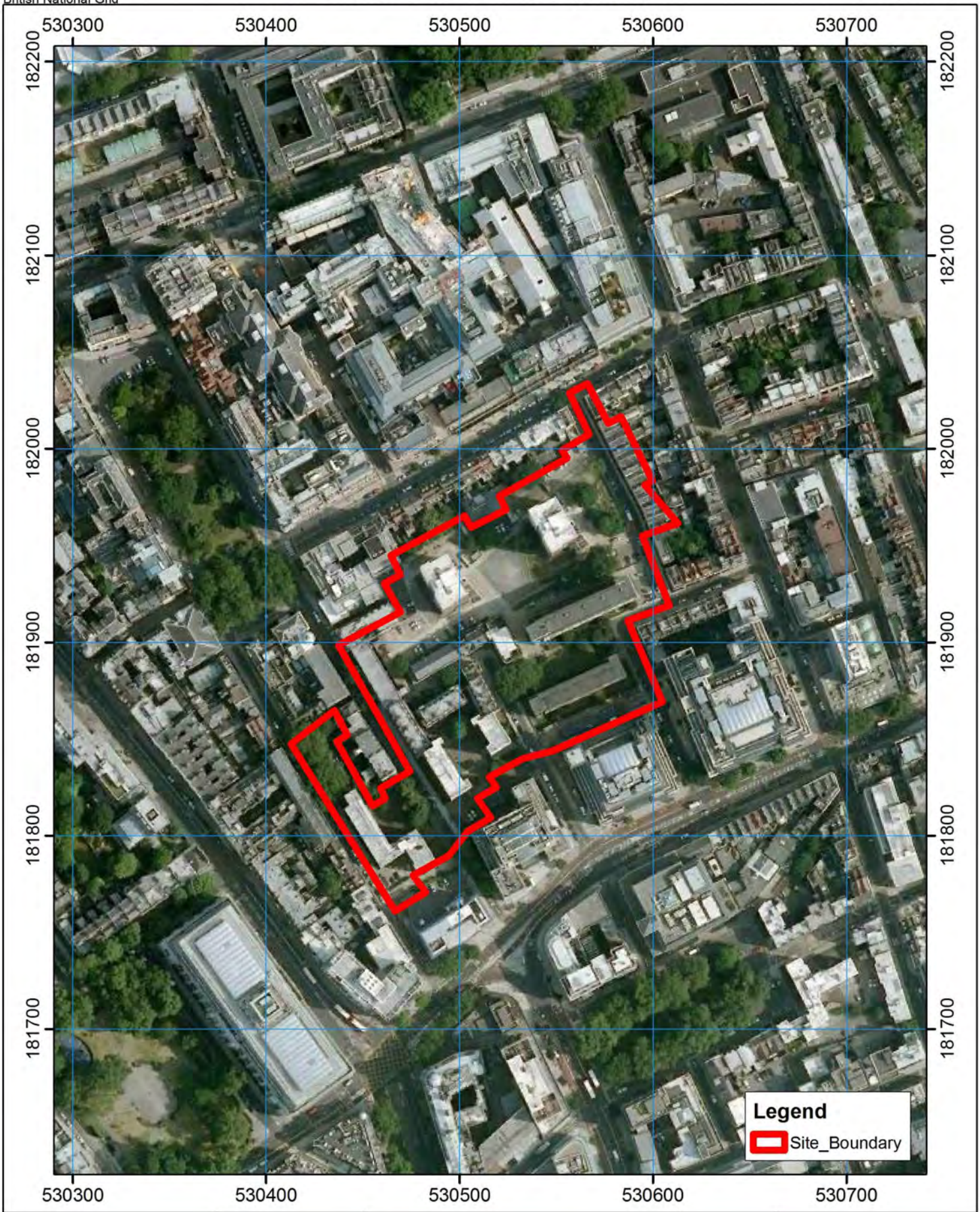
Figure Three

Current Aerial Photography

Tybalds Close Estate, Camden, London
Current Aerial Photography

Figure 3

British National Grid



BOMB SEARCH

6 Alpha Associates Ltd.
Quatro House
Frimley Road
Camberley
Surrey GU16 7ER
United Kingdom
www.6alpha.com
0203 371 3900

0 10 20 40 60 80 100 Meters

N

Produced by and Copyright to 6 Alpha Associates Ltd.
Users noting any errors please forward to 6 Alpha.
Background data supplied by Ordnance Survey under licence.

Project Number: P2771

Drawn By: Dominique René

Checked by: Lee Gooderham

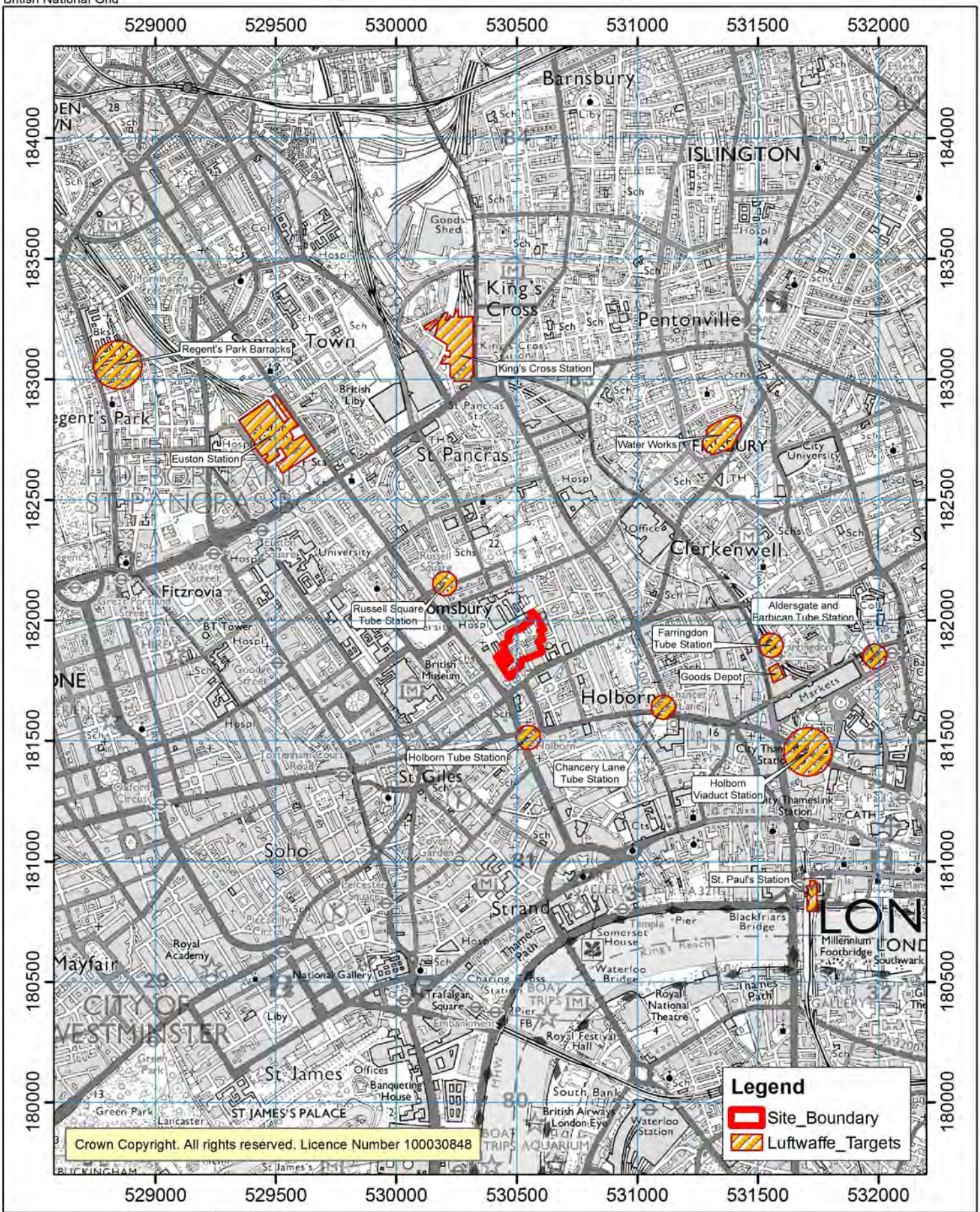
Date: 28th February 2012

Figure Four

WWII Luftwaffe Bombing Targets

Tybalds Close Estate, Camden, London
WWII Luftwaffe Bomb Targets

Figure 4



BOMB SEARCH

6 Alpha Associates Ltd.
Quatro House
Frimley Road
Camberley
Surrey GU16 7ER
United Kingdom
www.6alpha.com
0203 371 3900

0 100 200 400 600 800 1,000 Meters

N

Project Number: P2771

Drawn By: Dominique René

Checked by: Lee Gooderham

Date: 23rd February 2012

Produced by and Copyright to 6 Alpha Associates Ltd.
Users noting any errors please forward to 6 Alpha.
Background data supplied by Ordnance Survey under licence.

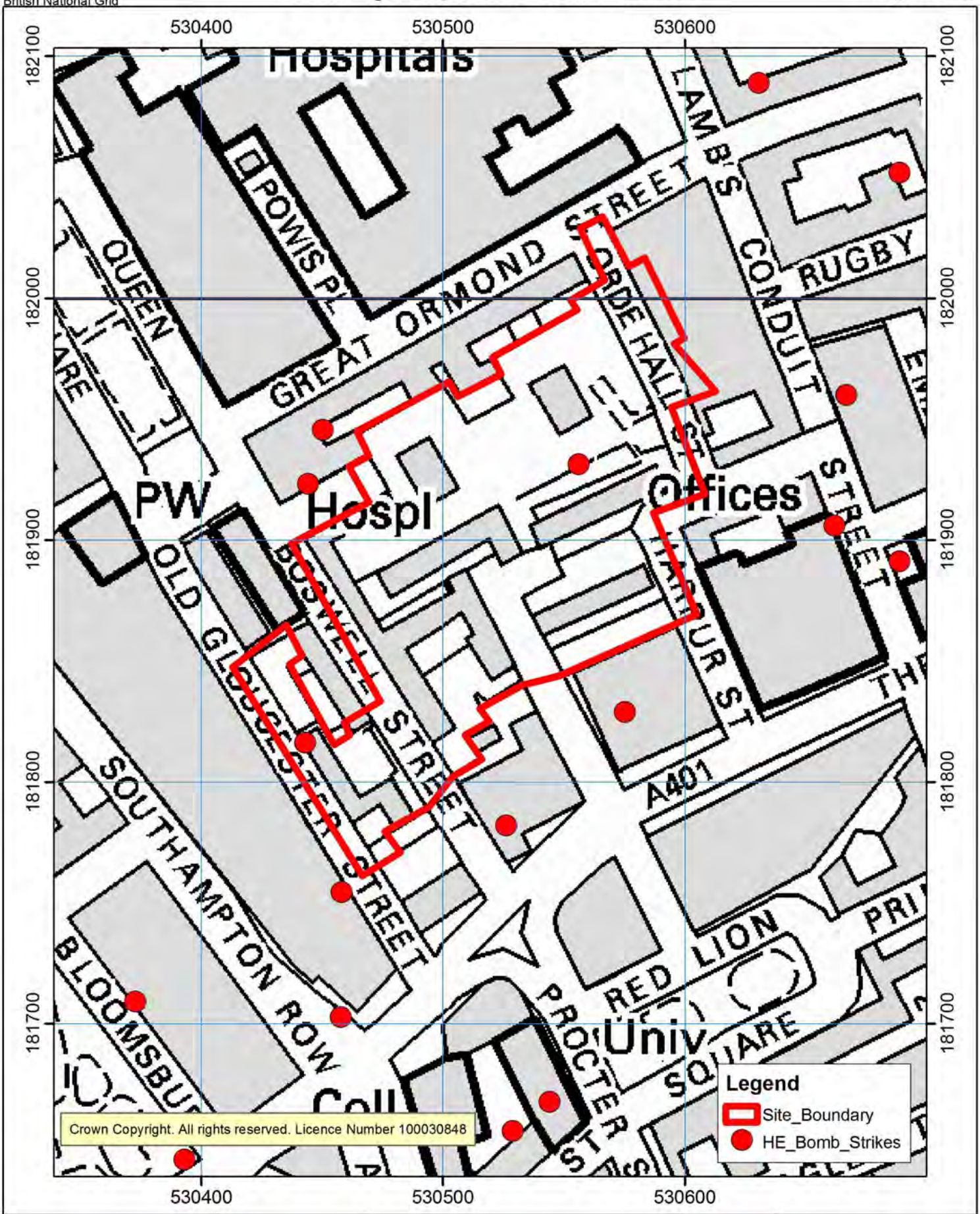
Figure Five

WWII High Explosive Bomb Strikes

Tybalds Close Estate, Camden, London
WWII High Explosive Bomb Strikes

Figure 5

British National Grid



BOMB SEARCH

6 Alpha Associates Ltd.
Quatro House
Frimley Road
Camberley
Surrey GU16 7ER
United Kingdom
www.6alpha.com
0203 371 3900

0 10 20 40 60 80 100 Meters

N

Project Number: P2771

Drawn By: Dominique René

Checked by: Lee Gooderham

Date: 23rd February 2012

Produced by and Copyright to 6 Alpha Associates Ltd.
Users noting any errors please forward to 6 Alpha.
Background data supplied by Ordnance Survey under licence.

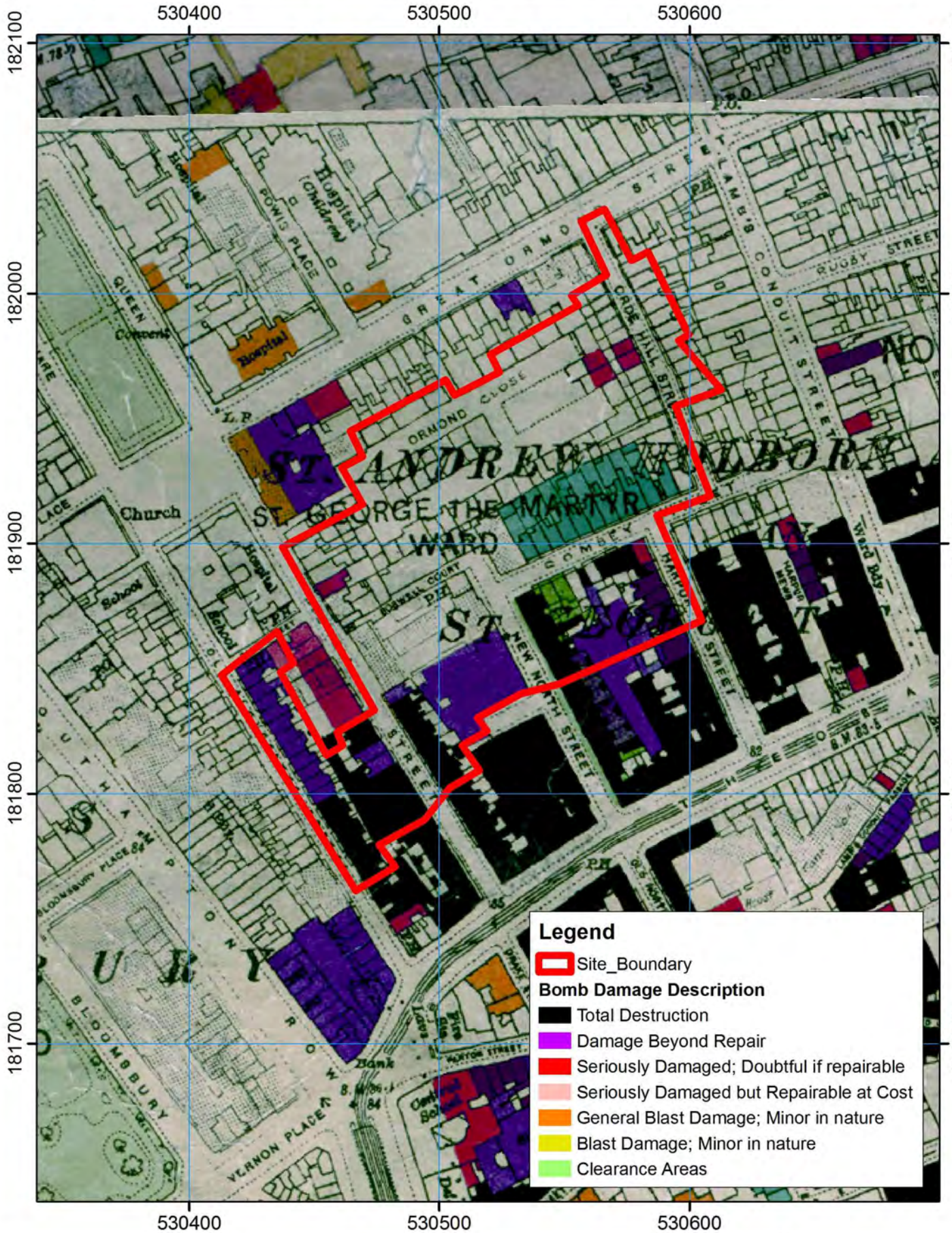
Figure Six

London County Council (LCC)
Bomb Damage Maps

Tybalds Close Estate, Camden, London
London County Council Bomb Damage Maps

Figure 6

British National Grid



BOMB SEARCH

6 Alpha Associates Ltd.
Quatro House
Frimley Road
Camberley
Surrey GU16 7ER
United Kingdom
www.6alpha.com
0203 371 3900

0 10 20 40 60 80 100 Meters

N

Project Number: P2771

Drawn By: Dominique René

Checked by: Lee Gooderham

Date: 23rd February 2012

Produced by and Copyright to 6 Alpha Associates Ltd.
Users noting any errors please forward to 6 Alpha.
Background data supplied by Ordnance Survey under licence.

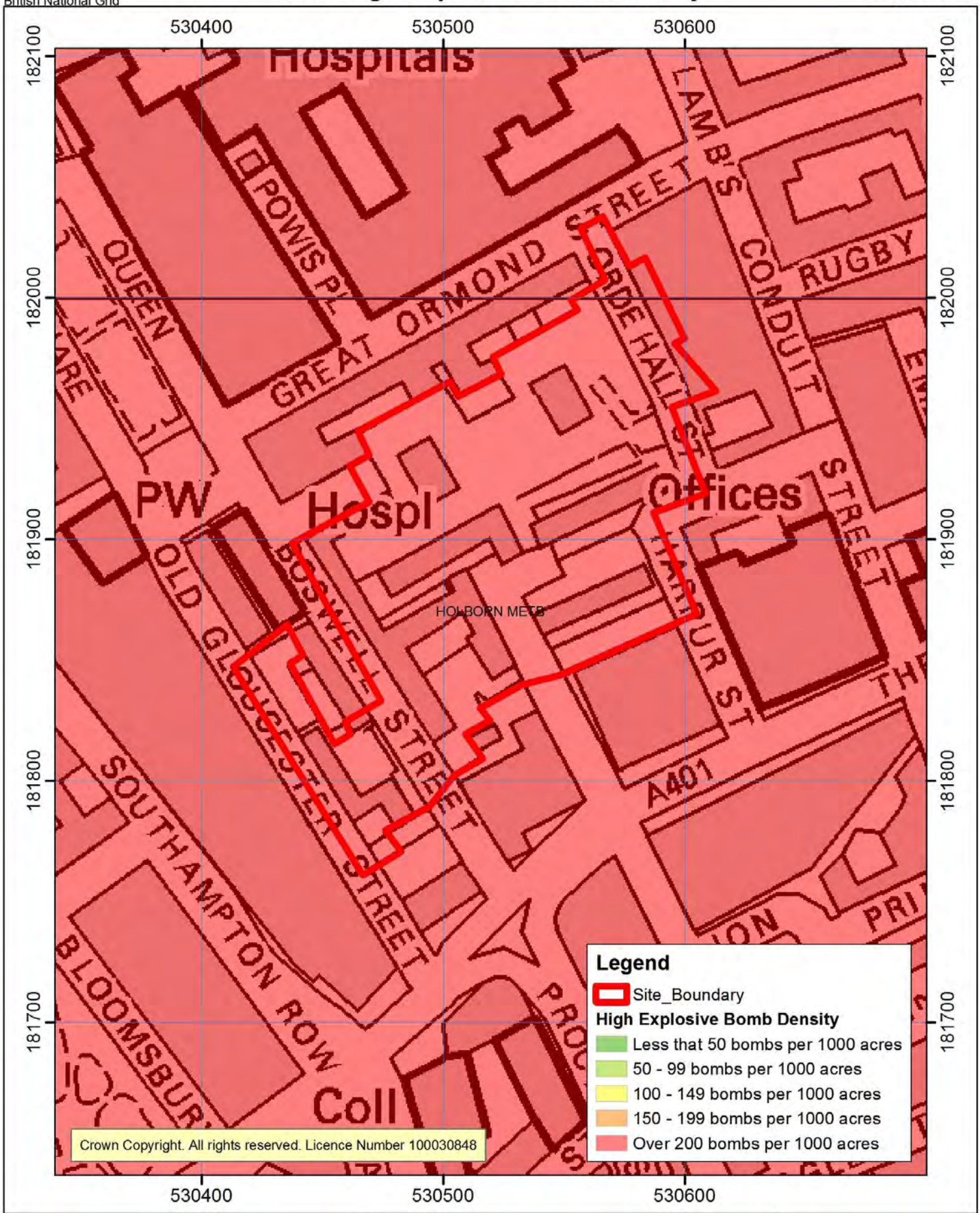
Figure Seven

WWII High Explosive Bomb Density

Tybalds Close Estate, Camden, London
WWII High Explosive Bomb Density

Figure 7

British National Grid



BOMB SEARCH

6 Alpha Associates Ltd.
Quatro House
Frimley Road
Camberley
Surrey GU16 7ER
United Kingdom
www.6alpha.com
0203 371 3900

0 10 20 40 60 80 100 Meters

N

Project Number: P2771

Drawn By: Dominique René

Checked by: Lee Gooderham

Date: 23rd February 2012

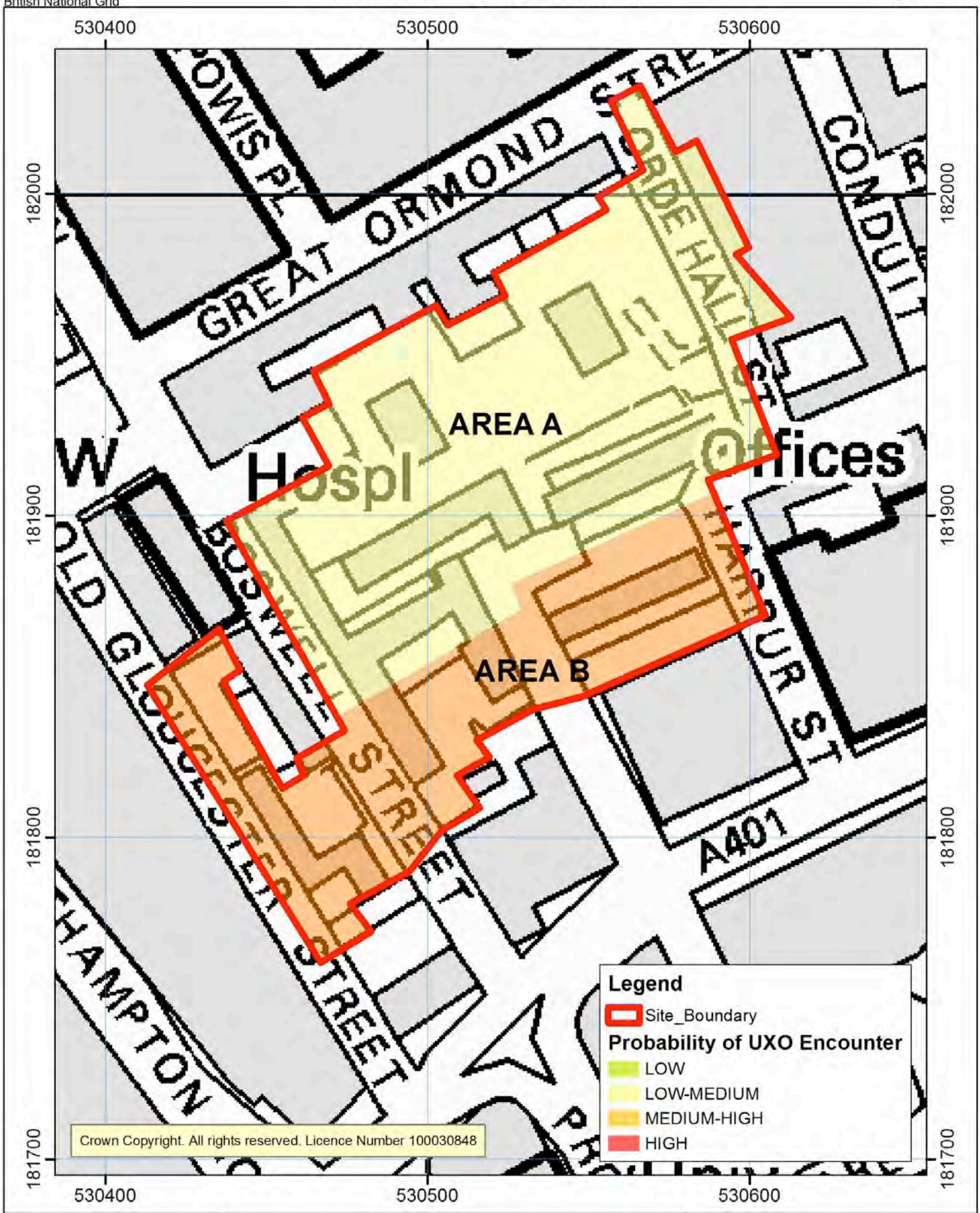
Produced by and Copyright to 6 Alpha Associates Ltd.
Users noting any errors please forward to 6 Alpha.
Background data supplied by Ordnance Survey under licence.

Figure Eight

Threat of UXO Encounter

Tybalds Close Estate, Camden, London
Threat from UXO Encounter

Figure 8



BOMB SEARCH

6 Alpha Associates Ltd.
Quatro House
Frimley Road
Camberley
Surrey GU16 7ER
United Kingdom
www.6alpha.com
0203 371 3900

0 10 20 40 60 80 Meters

N

Project Number: P2771

Drawn By: Dominique René

Checked by: Lee Gooderham

Date: 23rd February 2012

Produced by and Copyright to 6 Alpha Associates Ltd.
Users noting any errors please forward to 6 Alpha.
Background data supplied by Ordnance Survey under licence.

Annexes

Annex One

Risk Assessment Explanation

Contents

1 Detailed UXO Risk Assessment

1.1 Objective

The Detailed UXO Risk Assessment takes site-specific information indicating the potential for UXO encounter. It applies a semi-quantitative assessment in order to establish a risk level for the site (given the identified UXO hazard and the proposed intrusive engineering works required), and provide site-specific conclusions and recommendations for the management of the identified risk.

1.2 The Approach

Only experienced UXO consultants analyse the site information, before delivering conclusions and recommendations for the management of the identified risk. The Phase 2 assessment is not automatically generated; the consultant undertaking the assessment applies the risk levels based on the identified hazards, the site history, the probable depth of UXO encounter and the proposed intrusive earthworks. 6 Alpha Associates do not deliver the Phase 4 on-site UXO survey, nor do they advocate particular UXO contractors, ensuring that the risk levels stated objectively reflect those for the site.

1.3 The Product

While there may be additional source material reviewed within the assessment, it will be referred to or referenced and may not be included within the Phase 2 report. This is to ensure the reports are concise and user-friendly for industry professionals. The aim of this product is not to be an “expensive history lesson”. This is done in order to maintain the focus of the report and present the relevant information clearly and succinctly.

1.4 Report Structure

The report template has been developed to provide a succinct document for the client. In outline each report has the following structure:

- **Stage 1** – **Site Location** – to include coordinates, report notes, description of each location and proposed construction methodologies;
- **Stage 2** – **Review of Dataset** – identifying information sources used, site history, ground conditions and historical WWII data, bomb plot mapping and bomb damage maps;
- **Stage 3** – **Data Analysis/Interpretation** – of the data sets relative to the site;

- **Stage 4** – **Site Specific Risk Assessment** – using semi-quantitative techniques to identify Risk;
- **Stage 5** – **Recommended Risk Mitigation Measures** – with Residual Risk Rating to successfully reduce risks to conform to the ALARP (as low as reasonably practicable) principle.

This five-stage process clearly identifies the threats and associated risks faced by contractors and provide guidance on the mitigation measures that should be incorporated at a client's site.

1.5 Implications and Uses of the Detailed UXO Risk Assessment

When a risk level has been applied there are appropriate mitigation measures available, which can be applied as part of a scaled mitigation effort delivering a safe development environment. These measures are outlined within the recommendations of the Phase 2 report. The SQRA is designed to be in line with existing best practice from the Environmental industry; acknowledging the fact that UXO hazard should be approached as any other environmental hazard.

As stated, the majority of sites will be able to effectively manage any identified UXO risk through a series of procedural and documented measures. Where more significant risk is identified, a formal Phase 3 mitigation plan would be recommended, where the "ALARP" (As Low As Reasonably Practicable), principle guides the design. Phase 3 provides a specification to which the client invites tenders from UXO contractors; this "3rd Party" or consultant approach to mitigation design, ensures that any Phase 4 on-site UXO survey work includes only what is appropriate and cost effective in the delivery of a safe site for development.

2 Semi-Quantitative Risk Assessment Process

2.1 Risk Relationships

Risk (R) is calculated as a function of Probability (P) and Consequence (C), thus (P x C = R). In UXO terms these components can themselves be shown to be dependent on a number of additional sub-factors. The relationships are depicted in *Figure 1*.

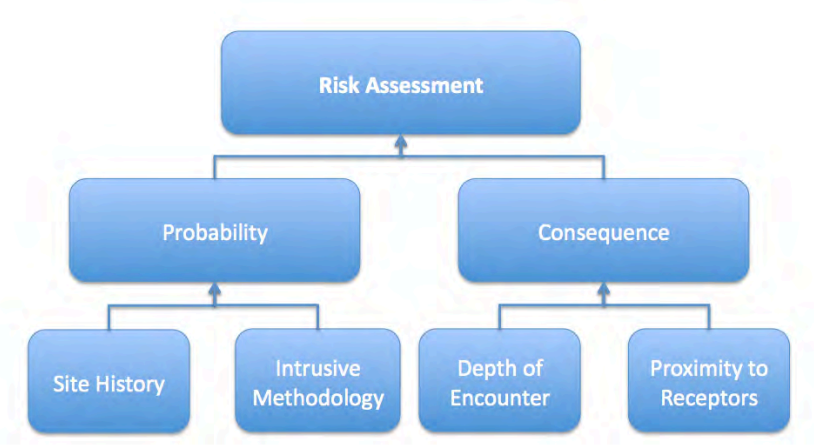


Figure 1 – Risk Assessment Relationships

2.2 Probability Calculation

Probability (P), a measure of the likelihood of UXO being discovered and then initiated, depends on the probability of an item of UXO being present as a result of the Site History (SH) and in the event that it is encountered, the probability of detonation which will be related to the Investigation Methodology (IM), thus (P = SH x IM).

This can be calculated using the historical information and statistics that are available for the site concerned. As part of this calculation; bombing density, ordnance failure rates, the probability of UXO being identified during WWII and the site area are all taken into account.

The potential that an item of UXO would detonate, if encountered, relies on a number of variable factors. There are no empirical means of accurately and reasonably calculating the probability of an UXO detonation during intrusive site activities. During the semi-quantitative risk assessment process, SH and IM are scored from 1 to 3 with 1 = Low, 2 = Medium and 3 = High. Probability is therefore scored 1 to 9.

		Intrusive Methodology (IM)		
		Benign (1)	Medium (2)	Aggressive (3)
Site History (SH)	Low (1)	1	2	3
	Medium (2)	2	4	6
	High (3)	3	6	9

Table 1 – Probability Matrix

2.3 Consequence Calculation

Consequence (C), the severity of a UXO incident (both from a Health & Safety and disruption point of view) is considered to be a factor of firstly, the Depth (D) at which an item of UXO is encountered and secondly, how much potential damage would be inflicted both in terms of collateral, physical and financial cost of damage. This element of the risk process is termed as the Proximity of Sensitive Receptors (PSR). Consequence is therefore dependant on the Depth and the PSR, thus (C = D x PSR). As with Probability, D and PSR are scored from 1 to 3 with 1 = Low, 2 = Medium and 3 = High. Consequence is therefore scored 1 to 9.

		Proximity to Sensitive Receptors (PSR)		
		Far (1)	Medium (2)	Close (3)
Depth (D)	Deep (1)	1	2	3
	Medium (2)	2	4	6
	Shallow (3)	3	6	9

Table 2 – Consequence Matrix

For boreholes and piled foundations, the consequence from a detonation may be reduced as natural overburdening geological material would suppress and potentially help contain the blast.

For activities nearer to the surface such as concrete coring and the excavation of trial pits, any blast would have little or no containment and thus presents a far greater risk.

It should be noted that “Depth” also takes into account any information relating to the potential size of an item particular attention to the NEQ that may be present.

2.4 Risk Rating Calculation

By combining Probability and Consequence in the above relationship (P x C = R) the Risk can be calculated. The Risk for this project is scored on a matrix below from 1 to 81; the matrix has associated risk categories.

		Probability					
		1	**2**	**3**	**4**	**6**	**9**
Consequence	**1**	1	2	3	4	6	9
	2	2	4	6	8	12	18
	3	3	6	9	12	18	27
	4	4	8	12	16	24	36
	6	6	12	18	24	36	54
	9	9	18	27	36	54	81

Table 3 – Risk Rating - Probability and Consequence

The risk to all intrusive activities at each location can then be deemed as Low, Low-Medium, Medium-High or High as seen in *Table 3*.

Where the Consequence or Probability is such that is as assessed as severe but the overall Risk score comes out as Medium, due to one of the component scores being Low, attention must be paid to these unique situations and consideration given to increasing the overall Risk rating. This will be conducted on a case-by-case basis and the merits of each individual site subsequently assessed.

Although a risk rating will be calculated for all intrusive engineering works, a final overall risk rating will be provided for the site. This will be achieved by making a holistic assessment of the entire site, methodologies and risk ratings.

3 Risk Mitigation

3.1 ALARP

6 Alpha approach is to ensure that risk mitigation measures are tied to ALARP in order to ensure that clients only spend reasonable and sufficient resource to mitigate the UXO risks that are most likely to present themselves.

The objective is to prevent a client spending a grossly disproportionate sum on unnecessarily reducing risks.

3.2 Risk Tolerability and Mitigation

In utilising the below, 6 Alpha can assess the risk tolerability and devise a suitable level of risk mitigation to meet ALARP.

Risk Rating (P x C)	Risk Level	Risk Tolerability	Action Required
1-4	Low	Partly Tolerable	Re-active measures should be employed such as UXO 'Tool Box' briefs, and a UXO 'on-call' service.
5-12	Low-Medium	Partly Tolerable	
13-27	Medium-High	Intolerable	Pro-active measures should be employed such as EOD Engineer Site Supervision and Magnetometer Surveys
28-81	High	Highly Intolerable	

Table 4 – Risk Scoring Categories

4 UXB Ground Penetration

4.1 Approach

When assessing the potential for UXB ground penetration it is essential not to rely solely on one particular empirical, statistical and arithmetical formula.

Whilst there have been numerous theoretical studies and models on this particular subject, they always appear to be very conservative and suggest deep bomb penetration i.e. in excess of 10m below ground level. In reality UXBs are rarely ever found at such depths. An explanation for this over estimation may be that generic models and calculations assume “homogenous standard” geological conditions, without the WWII coverage of water, made ground or hard standing. In addition the bomb penetration assessments typically use all the conditions and factors that are favourable for deeper and worst case penetration.

Experience has shown that a realistic depth is gained by considering the theoretical models and tables (such as Christopherson 1945, CONWEP TM5-855-1 and JSP 364) supplemented by accounts of Bomb Disposal Officer tasks in the area.

4.2 Benchmark Weapons

For this assessment 6 Alpha typically use the 500kg SC as a benchmark for the maximum bomb penetration, although a 250kg SC was selected for other areas based on the historical data. Generally, these two variants were the largest of the common bombs used by the Germans against London.