8.15 EXPLOSIVE ORDNANCE THREAT ASSESSMENT

EXPLOSIVE ORDNANCE (EO) THREAT ASSESSMENT (EOTA)

MARBLE HILL HOUSE, RICHMOND ROAD, TWICKENHAM, TW1 2NL

This assessment draws together all of the available information with regards to the site of concern in regard to potential Explosive Ordnance (EO) Contamination. It assigns an Explosive Ordnance Threat Level and proposes an appropriate Risk Management Strategy to reduce any associated risks.

This assessment has been produced in compliance with the Construction Industry Research and Information Association guidelines (Report CIRIA 681, dated Dec 08) for the preparation of detailed Risk Assessments in the management of UXO risks in the construction industry, for which PLANIT was an instrumental driver for improved UXO risk management and transparency.

BUILDER'S PROFILE

smas worksafe contractor as recognised by SSIP SAFETY SCHEMES IN PROCUREMENT

PLANIT RESTORING BALANCE

CHAS CONTRACTORS HEALTH & SAFETY ASSESSMENT SCHEME Accredited Contractor www.chas.co.uk

safecontractor APPROVED

CLIENT CONTACT DETAILS

Client Company:	**CET Structures Ltd** Northdown House Ashford Road Harrietsham Nr Maidstone, Kent ME17 1QW
Tel:	Mob: +44 (0) 7795 389980
POC:	James Appleby BSc MSc CSci MIEnvSc Principal Environmental Scientist
Email:	James.Appleby@cet-uk.com

OUR CONTACT DETAILS

Company:	**PLANIT UXB Limited**
Address:	PO BOX 285 Nunburnholme York YO42 9AU
Tel:	08000 588 747
Email:	help@planit-international.com

DOCUMENT CONTROL

Copy No.	Recipient
1	PLANIT FILE
2	CLIENT E-COPY
3	CLIENT HARDCOPY (NOT ISSUED)

Document Reference:	
Date of Issue:	**12 January 2017**
Copy No:	**2 of 2**

Document Review	Name	Signature
Author Review:	Daniel WHELAN	
Peer Review:	Andrew HAMILTON	

EXECUTIVE SUMMARY

SITE DESCRIPTION	The site is located north of the River Thames between the districts of Isleworth to the north and Twickenham within the London Borough of Richmond upon Thames – It sits in the centre of Marble Hill Park. National Grid Reference is centred on **TQ 172736** and the nearest Post Code is **TW1 2NL**.
POTENTIAL THREAT SOURCE	The following items of ordnance are potentially present under the southern part of the site of concern: • German 50Kg, 250Kg and 500Kg HE Bombs. • British AA Projectiles.
THREAT PATHWAY	For the purposes of this assessment, it has been assumed that development works would include piled foundations and excavations beyond WW2 ground levels. It is anticipated that personnel or key equipment may complete the risk pathway during excavation operations that may bring them into physical contact with potential threat items.
KEY FINDINGS	• There is evidence that the site of concern (with the notable exception of the immediate environs of the House itself) was affected by bombing during WW2. • The potential for British AA projectiles to present a potential threat cannot be reasonably ruled out. • It is unlikely that other ordnance contamination events occurred at the site of concern. • There are no Abandoned Bombs or UXBs recorded that would affect the site of concern. • The Ordnance Threat Level does not vary across the site of concern.
THREAT LEVEL	Ground volumes that have been excavated post-War may be considered effectively free from the threat of Explosive Ordnance (EO). The ordnance Threat Level for these ground volumes is **NEGLIGIBLE**. the EO Threat Levels for volumes of ground that have either not been subjected to significant intrusive engineering (excavation and/ or piling) or are below existing engineered structures (including foundations) and shallower than the estimated Bomb Penetration Depth (BPD) are assessed as: British AAA, German 50kg, 250Kg and 500Kg HE Bombs — **MEDIUM**
THREAT MITIGATION	Considering the findings of this assessment, a UXO Threat Mitigation Strategy **IS REQUIRED** to be in place prior to intrusive engineering works at this site of concern.
THREAT REVIEW	A review of these recommendations must be undertaken considering any additional, relevant information being provided. Such a review may, if the EO Threat Level is deemed to have altered, make alternative recommendations from those made above to implement work safely.
AIM & METHODOLOGY	The aim of this assessment is to identify any threats that may be posed by EO during the proposed engineering works at the site of concern and, where a threat is identified, to recommend a risk mitigation strategy that will reduce this threat to acceptable levels. This assessment follows the CIRIA 681 Guidelines, which were compiled using, as a main driver of change, PLANIT's innovative approach to EO risk assessment.

	The following key considerations are addressed in this assessment: • The risk that the site of concern was contaminated by EO. • The risk that EO remains on site. • The risk that EO may be encountered during the proposed engineering works. • The risk that EO may be initiated by proposed engineering works. • The consequences of encountering or initiating EO. If the likelihood of encountering EO is significant, information about the types and natures of that EO and the expected levels of contamination is considered within the source-pathway-receptor context of contamination. Should a confirmed pathway exist, the information is entered into our proprietary Threat Assessment Matrices in order to arrive at a valid and transparent Threat Level. The Threat Level allows relevant conclusions to be made about the EO Risk at the site of concern, which in turn allows an appropriate Risk Mitigation Strategy to be developed. The Threat Mitigation Strategy is intended to give the Client a best-fit, safe solution that will allow the level of risk from EO to be reduced to an acceptable level; providing maximum project planning flexibility. PLANITs approach to EO threat assessment has been fundamental in driving change throughout the UK Commercial EOD Industry and was instrumental in the drafting of CIRIA 681. PLANITs approach provides transparency to our EO risk assessment process allowing the Client to make valid decisions on what is a specialist activity; empowering them to maintain control over this vital aspect of their project - Where necessary, appropriate EO risk mitigation measures will be recommended. This assessment considers general and site specific factors, including: • Historical use of the site in relation to ordnance manufacturing, storage and disposal. • Historical use of the site in relation to Military training and related facilities. • Evidence of offensive aerial and naval bombardment during WW1 and WW2. • Evidence of Unexploded Bombs (UXBs). • Previous EO incidents and/or EO survey/clearance activities. • Extent of post-war redevelopment. • Proposed engineering works.
RELIABILITY OF HISTORICAL RECORDS	This assessment is drawn from detailed research into the available historical evidence. Every effort is made to gather all the relevant material; however, PLANIT cannot be held responsible for any changes to the assessed level of risk or proposed risk mitigation strategies due to subsequent information that may come to light later. The accuracy and detail of wartime historical records is difficult to verify, not least of which is due to the conditions under which much of this information was gathered and recorded. Additionally, recording of information was less formalised in the early days of the German air campaign against the UK mainland (Pre-Bomb Census Record) and much information recorded early on was lost during subsequent air raids. Records for rural, sparsely populated areas are not always reliable, being based on second-hand information in many cases; records of attacks on military installations was often recorded independently from general records and many such archives have been lost or remain undisclosed to the public. Consequently, the exact location, quantity and nature of the EO threat cannot be definitive but rather remains subjective and is based on the careful analysis by experts of the available information. PLANIT cannot accept liability for any gaps in the historical record.

CONTENTS

SITE LOCATION & DESCRIPTION	
SITE OF CONCERN	The site is located north of the River Thames between the districts of Isleworth to the north and Twickenham within the London Borough of Richmond upon Thames – It sits in the centre of Marble Hill Park. Marble Hill House itself is a Palladian villa built between 1724 and 1729. The compact design soon became famous and furnished a standard model for the Georgian English villa and for plantation houses in the American colonies. National Grid Reference is centred on **TQ 172736** and the nearest Post Code is **TW1 2NL**. Maps showing the site location and layout are at Annex A.
SCOPE OF PROPOSED WORKS	The development works are thought to comprise an extension to the existing café facilities at the house itself. In addition, there will be new drainage and service trenches being installed (to some 1-2m bgl) as well as some tree removal and planting (1-2m bgl). It is anticipated that any redevelopment works are likely to involve deep engineering works including bulk excavation and piling below WW2 ground levels.
GEOLOGICAL ENVIRONMENT	London occupies part of the Thames Basin, a broad syncline of chalk filled in the centre with Tertiary sands and clays. Per the British Geological Survey, the site of concern is underlain by a degree of Made Ground for some 0.4m over sandy-clays (Langley Silt Members) to some 3.0m overlaying the Kempton Park Gravel Formation (fine to coarse sandy gravel).
REVIEW OF RELEVANT DATASETS	
SOURCES OF INFORMATION	PLANIT ensures that Explosive Ordnance Threat Assessments (EOTAs) are as comprehensive as possible and detailed research is undertaken to collate all the available EO-related information that relates to the site of concern. Information sources may include, but are not restricted to: • National Historic Archives. • Local Authority & Council Archives. • English Heritage National Monuments Record. • Ministry of Defence Archives • PLANITs extensive archives drawn from many years of detailed research and operational experience of UXO Risk Management activities in the UK and abroad. • Joint Service EOD Centre (JSEOD). • Historic Mapping and Aerial Photography. • Specific UXO-related documents such as military bombing and casualty records. • Local libraries and history groups. • Open sources such as published books and internet searches. • Anecdotal evidence from eye witnesses. *NB: The MoD information office that deals with requests for information relevant to EO clearance operations completed by the MoD is currently facing significant delays. Although a request has been submitted, any information that may be relevant has not yet been forwarded for timely inclusion in this assessment. However, if any relevant information comes to light from this source that affects the threat assessment, this will be notified to the client as a matter of urgency.*
SITE HISTORY	The earliest available mapping of **1865** shows Marble House sitting within well-defined grounds following the house's completion in **1729**. Although the areas surrounding the house and grounds, especially to the north, have been transformed by urban expansion and the development of light industry since that time, the site has remained essentially unchanged from this time to the present day. Marble Hill Park is first noted in the map record in **1912**.

ORDNANCE MANUFACTURE & STORAGE	During WW1 and WW2, London housed some 48 facilities involved in the manufacture, storage, filling and testing ordnance, but none that posed a potential threat to the site of concern. (The closest Royal Ordnance Factory (ROF) that produced munitions was at Yeading near Hayes, an explosives factory producing small arms ammunition.)
MILITARY HISTORY	There is no evidence to indicate that the site was ever used for military purposes.
CIVIL DEFENCE	London possessed a peak of 199 Heavy Anti-Aircraft Batteries during WW2, including 4.5, 3.7 and 3-inch Anti-Aircraft (AA) guns, sited in some 70 separate locations. None of these were sited on or near to the site of concern to have created a direct source of potential ordnance contamination. Due to the relatively high failure rate of Anti-Aircraft Ammunition (AAA) during this time, there remains the possibility that such ordnance fell back to earth creating additional UXO hazards. This type of ordnance had the potential to penetrate the ground to significant depths and cannot be entirely discounted as a potential threat source although its potential presence is impossible to determine with any quantifiable degree of certainty. As would be expected, Greater London had several Civil Defence ('Starfish') sites designed to protect London from aerial attack. London's Starfish Sites were located at: • Richmond Park. • Farleigh. • Rainham Marshes. • Lambourne End. • Lullingstone. • Hampstead Heath. • Kenn Woods. None of these sites would indicate the possibility that erroneous Luftwaffe bombing would have produced a consequent UXO risk on the site of concern.
WW1	Great Britain suffered several 'Zeppelin' aerial bombardments and aerial attacks by Gotha and Giant Bombers during WW1 as well as several naval bombardments from the sea. However, none of these are known to have dropped bombs near the site of concern and further, due to the limited number of bombs dropped then, the risks from WW1 unexploded ordnance from this source are negligible.
WW2 – GERMAN AERIAL BOMBING CAMPAIGN	At the outbreak of WW2, the site sat close to several viable Luftwaffe targets such as Railway lines, Docks, Manufacturing and other heavy industry; all infrastructure targets for the Luftwaffe with the local areas affected by several raids. In addition, the River Thames was used by enemy bombers of the time to navigate in and out of London and unused bombs were routinely jettisoned whilst returning to base following an unsuccessful raid. The high-altitude area bombing during this period was notoriously inaccurate with areas surrounding specific targets suffering during attacks on the targets themselves. The site was placed within Region 5 (London) Group 6D for Civil Defence purposes and the figures for bombs falling in the area are well recorded. Region 5 (all Greater London and The City) received some **15, 107.5 Tonnes of HE bombs**. The site itself sat within an area recorded as receiving **17 to 32 Bombs per Sq Km** from the outbreak of hostilities to Oct 1941 and between **50 - 99 bombs per 1000 acres** between 1939 and '45. A summary of the bombs that fell on Region 5 Group 6D throughout WW2 is shown below:

Ordnance Type	No of Bombs	% of Total HE
High Explosive (HE)		
50Kg HE	143 (17)	39
250Kg HE	111 (4)	28
500Kg HE	51 (13)	16
1000Kg HE	25 (9)	8
1400Kg HE	(2)	0.5
1800Kg HE	3 (1)	1
Parachute Mine	23 (2)	6
V1 'Doodlebug'	107	
V2 Long Range Rocket Bomb	10	
Anti-Personnel Bomb		
Incendiary		
50kg Phosphorus	44 (90)	
Small IBs		
Fire Pot	6	
Oil Bomb	132 (2)	
Containers	48 (2)	
Unclassified	3513 (99)	

By May 1941, concentrated aerial attacks were diverted elsewhere and only sporadic bombing of London and the Southeast of England occurred.

UNEXPLODED BOMBS (UXBs)

Between 1940 and 1945, Bomb Disposal (BD) Teams cleared over 50,000 items of German air-dropped ordnance of 50Kg or larger, 7 000 anti-aircraft (AA) projectiles and more than 30 000 beach mines – This work claimed the lives of 394 Officer's and men. The War Office at the time stated that over 200 000 HE bombs exploded in Britain during WW2 with some 25 195 remaining a threat as UXBs i.e. 11%. Some 93% of all UXBs were 50Kg HE and 250Kg HE aerial bombs.

The types of ordnance discovered as UXBs give an indicator of the type of ordnance that may be encountered on or near the site of concern. There are no records of UXBs on or immediately adjacent to the site of concern.

ABANDONED BOMBS

A post-air raid search of damaged buildings and facilities would have included a specific search for bomb entry holes. If such evidence was discovered, then BD Teams would have been tasked (in order of strict priority from Category A, the highest priority, to category D, the lowest) to assess the potential UXB and to recommend a course of action. UXBs that were deemed to be a high enough priority, were tackled by the BD Teams who made strenuous efforts to recover and dispose of these items. However, it was not always possible to recover such bombs either through physical constraints, a lack of resources or a change in priority. Such UXBs were noted as 'Abandoned'.

Due to the low priority of abandoned bombs, records that detail them are sketchy and sometimes contradictory. Others were subsequently recovered after the War when time and resources permitted and others remain 'abandoned'. It is worth remembering that 'abandoned' bombs may also include suspected UXBs that were reported but not confirmed, but simply efforts to locate the 'bomb' were exhausted.

The following Abandoned Bombs are recorded in the wider vicinity of the site of concern:

- Folio 56, Ser No. 6D/269 – nr. Fairfax level crossing, Twickenham, 1 x 50kg (Bomb Register R5/1/52 and R5/2/1610).
- Folio 45, Ser No.9/513 - Mid-Surrey Golf Course, In ditch between fairway and River Thames, 1 x Unknown (Bomb Register R5/1/40).
- Folio 34, Ser No.6D/438 - D C Page's Nurseries, Hampton, Twickenham, 1 x 50kg.
- Folio 35, Ser No.6D/358 – Hounslow Cemetery, Twickenham, 1 x 50kg incendiary.

These are not considered to present a potential threat to the site of concern.

BOMB CENSUS MAPS	The site of concern is not covered by the London County Council (LCC) Bomb Damage Maps from WW2. Bomb Census maps are available which do record at least five large, air-dropped, high-explosive bomb strikes within the grounds of Marble Hill Park but not on the House itself or its immediate surrounding area. The relevant Bomb Census Summaries are at Annex B.
HISTORICAL STREEP MAPS	Historical street plans of the period are a useful indicator of whether an area may have suffered bomb damage. The street layout prior to WW2 is the start state and major changes to street layouts or building boundaries may indicate that the change was due to bomb damage. In this instance, there are no significant changes to the site layout between 1938 and 1948. The relevant Historical Street Plans are at Annex C.
HISTORICAL AERIAL PHOTOGRAPHY	The same rational applies with historic aerial photography as it does when examining historical street plans – changes between pre-war and post-war images may indicate the possibility of damage caused by bombs falling on the site. Sometimes, detail is such that it allows bomb damage to be seen directly on sites of concern. In this instance, only the RAF post-War c.1945 historical aerial photography is available so no 'before and after' comparison can be made. However, the image does not show any clear evidence of bomb damage to the site itself or its surrounding areas. The relevant Historical Aerial Photography is at Annex D.
THREAT ANALYSIS	
IS THERE EVIDENCE THAT THE SITE WAS AFFECTED BY ANY EXPLOSIVE ORDNANCE CONTAMINATION EVENTS?	**Yes.** The historical record is acknowledged as being incomplete from a National perspective but there is good evidence to show that the site of concern was directly affected by bombing during WW2; including large air-dropped bombs, and potentially including smaller anti-personnel bombs and/or incendiary bombs. The potential for large, air-dropped bombs to have landed on the site and remain unexploded underground cannot be ignored especially considering the mostly open, parkland nature of the site within which a UXB entry hole could easily have been overlooked considering their diminutive size and the area of the park. The potential for British anti-aircraft artillery falling back to earth as UXBs and remaining on the site undiscovered cannot be entirely ruled out although it is very unlikely. The potential for *ad hoc* military or criminal activity to have generated explosive ordnance contamination at any site is generally unquantifiable but cannot be entirely ruled out although this possibility is very unlikely.
IF ENCOUNTERED, WHAT ORDNANCE TYPES ARE ANTICIPATED?	Of all the large bombs that were recorded as falling in Region 5, Group 6D; 15% were 1000kg or larger, 16% were 500kg and of the remaining 69%, 58% were 50kg HE Bombs. We must also consider the possibility, however remote, that Anti-Aircraft Artillery (AAA) projectiles or Explosive Ordnance (EO) because of military training could remain as a potential threat to the site from both WW1 and WW2. Therefore, the following items of EO may be anticipated to be potentially present on the site of concern:

	• Large, air-dropped, German HE Bombs including 50, 250, 500 and 1,000kg bombs (of WW2 vintage). • British AAA projectiles. • Small Incendiary and anti-personnel bombs. • *Ad hoc* legacy EO.
WHAT IS THE POTENTIAL EO/ UXB ENCOUNTER DEPTH?	**Ministry of Homeland Defence Security Bomb Penetration Studies**. A major study was completed by the Ministry of Homeland Security during WW2, during which the penetration depths of 1 328 air-dropped bombs (as reported by the BD Sections of the day and mostly in the Birmingham area) were recorded. It was concluded, not surprisingly, that the penetration depths of different sized bombs varied according to the geology into which they fell. The average Bomb Penetration Depth (BPD) of 430 x 50Kg HE bombs in London Clay was found to be 4.6m and that for a 250Kg bomb 6.1m. Also, they concluded that a 500Kg bomb, the largest common bomb dropped during the War, had a likely penetration depth of 6m in sand and 8.7m in clay – the maximum observed for a 500Kg was 10.2m and for a 1000Kg bomb was 12.7m. It should be remembered that these depths were achieved unencumbered by obstacles to penetration such as buildings, concrete and brickwork. **The 'J' Curve**. The 'J-curve' describes the path of a bomb (dropped from a normal altitude of about 5 000m) into homogenous ground will continue its line of flight (unless deflected by a substantial obstacle) but then turn upwards towards the surface before it stops. The horizontal distance (the 'offset') between the point of entry and final resting position was typically 1/3 of the ultimate penetration depth for a bomb. Therefore, if a bomb fell close to the exterior of a building or site and did not explode, the path that the bomb subsequently travelled beneath the ground, the "J-Curve", may have delivered it beneath the building or site footprint. The J-curve is often misunderstood, and used to describe the path taken by a bomb dropped from low flying aircraft to which it should not be applied. The final penetration depth of an air-dropped depends upon several factors; the velocity (as a function of the mass and speed) of the bomb, – PLANIT uses a standard velocity of 267m/s for assessment purposes – the angle of penetration of the bomb, the physical features through which the bomb travelled prior to impact with the ground, and the geology of the ground into which it entered - Generally, the softer the ground, the deeper the expected penetration depth of the bomb. Peat, alluvium and soft clays are easier to penetrate than gravels and/or sand and water content also plays a part. In addition, it must be remembered that 'barrier geology' such as very dense gravels or bedrock i.e. geology dense enough to stop the progress of a bomb underground, is an important factor in determining the median BPD. The physical characteristics of the site in this instance, would not act to retard the progress of UXBs underground by reducing their overall velocity prior to impact and therefore the maximum potential bomb penetration depths must be applied. The following UXO encounter depths *from WW2 ground levels* are estimated: • Small Incendiary and AP bombs – Surface (WW2 ground level) • Ad hoc legacy EO – Surface (WW2 ground level) • British AAA projectiles – 2m • 50kg HE – 4.5m • 250kg HE – 6m and • 500kg HE – 9m • 1000kg HE – 12m It must be remembered that UXBs can be found *at any depth* from WW2 ground level down to their maximum estimated depths.
HOW COULD AN UNCONTROLLED DETONATION BE BROUGHT ABOUT?	Unexploded Bombs rarely spontaneously explode. High Explosive (HE) requires a great deal of energy to create the necessary conditions for detonation to occur. In the case of WWII German bombs being disturbed during intrusive ground works, there are several scenarios to be considered:

	• **Direct impact onto the main body of the bomb**. Although this is a possibility, there is little chance of generating enough energy to detonate the explosive fill unless the fuse itself is directly struck. • **Re-starting the mechanical clock-timer in a bomb fuse**. This is a possibility. It is probable that environmental conditions have corroded the fuse sufficiently to prevent clockwork mechanisms from functioning. However, under some conditions, fuse elements will be in a good condition and additional movement of a bomb fuse may be sufficient to restart a previously 'jammed' mechanical clockwork mechanism. • **Induction of a static charge, creating a sufficient current to initiate an electric fuse**. This is an unlikely event. Environmental conditions are likely to have corroded the fuse, degrading its components sufficiently to prevent them from functioning. Any elements of the fuse capable of holding a charge would have dissipated in the time since the bomb failed to function. • **Friction impact initiating fuse elements causing bombs to detonate**. Although remote, this is the most likely scenario that may result in a bomb detonating. Weathering within the fuse pocket can cause the explosives within the fuse to breakdown, crystallize and exude from the fuse itself. Violent physical disturbance of this exuded material carries the remote possibility of initiating the fuse mechanism which in turn will initiate the bomb.

WHAT WOULD THE EFFECTS OF SUCH A DETONATION BE TO THE SITE?	The effects of WWII German bombs detonating have been the subject of several well recorded studies. The general effect of an explosive detonation will depend upon:
	
	• The size of the bomb and its Net Explosive Quantity (NEQ) (i.e. how much explosive material it contains).
	• The type of fill in the bomb (i.e. high explosive, incendiary, photoflash).
	• The physical location of the bomb. Whether it is:
	
	  ○ On the surface.
	  ○ Partially buried.
	  ○ Buried (A bomb can be considered 'buried' when it is more than 2½ times its own length below ground level *and* covered).
	
	• The locations of the bomb in relation to other structures.
	• The strength and design of structures near to the seat of an explosion.
	• The nature of the ground (i.e. sand, gravel, clay, marsh etc.).
	• The location of the bomb in relation to human and animal populations.
	
	There would be the potential for ground shock to damage important underground structures including sewers, communication cables, and foundations.
	
	The potential Damage Radii to various underground structures has been assessed by extrapolating from the Joint Service Publication 364 which is the MOD Manual for assessing bomb damage. Potential damage radii for underground structures are assessed as:
	
	• Brick Walls - 30m
	• Foundations - 60m
	• Cast Iron/ Concrete Pipes - 15m
	• Earthenware/ brisk Sewers - 25m
	• Electric Cables/ Steel Pipes - 12m

WOULD THE SITE CONDITIONS AFFECT THE BOMB FAILURE RATE?	There is no evidence to suggest that bomb failure rate at the site of concern would have been any different from that routinely experienced, i.e. **10-15% of all bombs dropped**.

WOULD UXBs HAVE BEEN DISCOVERED DURING WW2?	**Density of Bombing.** Hounslow received a low density of bombing in WW2 and we know that the site itself received direct bomb strikes. This fact would have made data gathering at the time easier and the likelihood of overlooking UXBs lower. However, the physical scale of the site is imposing and therefore it is very conceivable that its entire area would never have been searched effectively. **Frequency of Access.** The site appears to have been occupied by very few, if any, significant buildings at the time of the aerial bombing being mostly dominated by open land albeit turned over to sewage treatment. As a large utility with a key strategic value, it is likely that it would have been subject to post-air raid survey and clearance. Given this fact and that the site itself was affected by bombing, any post-raid survey activities would have been particularly thorough. This would have made the likelihood of identifying smaller items of EO (such as Incendiaries and AP bomblets) quite high whilst larger UXBs would have been more readily identified, even when you consider that UXB entry holes are diminutive. **Ground Cover.** The site of concern was predominantly covered by essentially open land, assumed to be underlain by clay over peat. Given the large, open expanse of the site (considering the diminutive size of UXB entry holes), a UXB remaining underground could have easily been overlooked. **Peripheral Bomb Damage.** We know that the site of concern was subject to direct bomb strikes during the War although, given the nature of the site, bomb damage would have been limited in terms of destruction. This decreases the possibility of post-air raid operations failing to identify entry holes of potential UXBs.
DOES THE SITE'S DEVELOPMENT HISTORY AFFECT THE POTENTIAL FOR UXO ENCOUNTER?	**No.** The fact that no significant degree of post-War redevelopment has taken place at the site is worthy of note. Redevelopment of the immediate area and the site itself over the years would likely have encountered shallow UXO contamination at the time, which would have been dealt with – This has not happened in this instance. It is worth noting that historical development either immediately post-War or in the 1960/ 70 and 80s would not have taken any account of the potential for UXBs at the site of concern nor would any effective technology be available to detect such potential threat items at depth. Modern structures tend to have foundation designs that go deeper than historic buildings and risk encountering UXBs at depths beyond existing historic foundation levels that were not detected by excavation or bomb survey. Remember, 'at risk' ground volumes may remain beneath post-War structures, between the maximum engineering depth achieved by the structure when built down the estimated maximum Bomb Penetration Depth (BPD) of 12m bgl. In addition, bombs may be found anywhere from the surface ***down to*** the estimated maximum BPD).
DOES THE UXO THREAT VARY ACROSS THE SITE?	**No.** Volumes of ground within the site already subjected to extensive redevelopment involving the displacement of earth, may be considered free from the threat of UXO/EO ***within the volumes of ground excavated/disturbed***. This would include excavated lagoons, settlement tanks, foundations for post-War, multi-storey buildings and underground utility runs. Volumes of ground within the site already subjected to historical piling may be considered a lower potential risk, ***within the ground volume occupied by the piles***, from large, air-dropped bombs than areas that have not been subjected to the same degree of intrusive engineering. ***This is not true for the remainder of the site or for ground volumes that are potentially at risk underneath modern structures***.

THREAT ASSESSMENT

POTENTIAL EXPLOSIVE ORDNANCE THREAT ITEMS	Given the lack of post-War redevelopment, it is unlikely that UXBs with very shallow penetration depths such as small incendiary and anti-personnel bombs would have been disturbed and discovered by now, if present. By the same token, any Explosive Ordnance (EO) because of *ad hoc* military activity is unlikely to have been discovered, if present, either. However, there is no good evidence that any of these contamination events occurred and it is reasonable, therefore, to discount these potential threat items as likely to be present on the site of concern today. The potential for larger items of explosive ordnance to remain as UXBs does exist across the wider site, given that we know the site was bombed in WW2 and it has barely been disturbed since. The exception is the house itself since, given its occupancy during the War and its status as a 'Grand House', it is inconceivable that the immediate environs of the House were not checked thoroughly post-raid and the likelihood that a UXB came to rest under the existing structure is very unlikely. Particularly to then go unremarked if such an incident had occurred. With that in mind, for the wider site, except for the House and its immediate surrounds, the following items of explosive ordnance are thought to potentially be present within undisturbed ground volumes across the site of concern: • German, 50-500kg, air-dropped, high explosive bombs. • British anti-aircraft artillery projectiles.
ENGINEERING WORKS	The following engineering processes are thought to be planned: • Site investigation. • Piled foundations (to 10m bgl). • Service/ drainage installation, tree planting/ removal (to 1-2m bgl).
RISK PATHWAY	For the purposes of this assessment, it has been assumed that development works could include excavations beyond WW2 ground levels. It is anticipated that personnel or key equipment may complete the risk pathway during intrusive engineering operations that may bring them into physical contact with potential threat items. As the piled foundations are within the immediate environs of the existing house, this process alone will not create the potential UXB encounter despite its intrusive nature. Therefore, the following activities are thought to potentially complete the risk pathway to a potential UXB encounter: • Site investigation. • Service/ drainage installation, tree planting/ removal (to 1-2m bgl).
CURRENT EXPLOSIVE ORDNANCE THREAT LEVELS	Volumes of ground within the site already subjected to extensive redevelopment involving the displacement of earth, may be considered free from the threat of UXO/EO within the volumes of ground excavated or disturbed. The ordnance Threat Level for these ground volumes is **NEGLIGIBLE**. The Ordnance Threat Levels for the remainder of the site of concern from the Threat Assessment Matrices are assessed as: British AAA, 50kg, 250Kg and 500Kg HE Bombs — **MEDIUM**
WHAT ARE THE CONSEQUENCES OF AN	The following consequences of an uncontrolled detonation are anticipated: For British AAA & 250kg HE Bombs: • People - Lost time injury <7 days

UNCONTROLLED DETONATION?	• Plant - Item write off • Property - Major damage • Environment - Localised effect For 50 & 500kg HE Bombs: • People - Lost time injury >7 days • Plant - Unit level damage • Property - Major wider damage • Environment - Major effect

THREAT MATRICES

ORDNANCE CATEGORY

The 'Ordnance Category' is assessed for the different types of ordnance in terms of the 'Damage Radii' that may result were the ordnance subject to an uncontrolled explosion and is a function of the calibre of the ordnance and whether it is encountered on the 'surface' or 'buried'.

Ordnance Category	Ordnance Category Description	Danger Radii (m)	Potential Threat Item
0	No Explosive Ordnance (EO) suspected to be present	NA	NA
1	Landmines, Anti-Personnel, HE; HE in Bulk <5Kg; Pyrotechnics	< 75	NA
2	Projectiles, HE <75mm calibre; Projectiles, Mortar, HE 50mm to < 75mm calibre; Grenades, Hand, HE; Grenades, Rifle, HE.	< 100	**British AAA Projectiles**
3	Projectiles, HE < 125mm calibre; Rockets, HE, Anti-Tank (HEAT); Bombs PIAT, HE; Arial Bombs, HE, 50-250Kg (Surface & Buried); Aerial Bombs, Blast, HE & Sea Mines 20-250Kg; Aerial Bomb, HE, 250-500Kg (Buried)	< 250	**50 & 250kg HE Bombs**
4	Bombs, Mortar, HE <105mm calibre; Bombs, Mortar, Spigot, HE; Landmines, Anti-Tank, HE; Aerial Bombs, HE, 250-500Kg (Surface)	< 300	**500kg HE Bombs**
5	Projectile, HE > 125mm calibre; Aerial Bombs, HE, 1500-2500Kg (Surface); Aerial Bomb, Blast, HE & Sea Mines 500-1500Kg (Surface)	< 500	NA
6	Aerial Bombs, HE, 2000-10000Kg (Buried); Aerial Bombs, Blast, HE & Sea Mines 1500-4000Kg (Surface)	< 800	NA

ORDNANCE THREAT

This table assigns the 'Ordnance Threat', which is a function of the Ordnance Category and the anticipated encounter depth. i.e. the smaller and deeper the ordnance the less threat is present to people and property at the surface.

	ORDNANCE CATEGORY						Depth of Encounter (m)
0	1	2	3	4	5	6	
	ORDNANCE THREAT						
							>10
			250kg Bomb	500kg Bomb			**5<10**
		British AAA	50kg Bomb				**2.5<5**
							0.5<2.5
							0<0.5
							Surface

ORDNANCE THREAT LEVEL

The 'Ordnance Threat Level' is arrived at by comparing the 'Ordnance Risk' with the 'Likelihood of Encounter' of ordnance as a function of the level of expected ordnance contamination of a given type at a site of concern.

Ordnance Threat	ASSETS AFFECTED				LIKELIHOOD OF ENCOUNTER				
	People	Plant	Property	Environment	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
X	No effect								
	First aid injury	Slight damage	Slight damage	Slight Effect					
	Medical injury	Item repair	Minor damage	Minor Effect					
British AAA & 250kg Bomb	Lost time <7 days	Item write off	Major damage	Local Effect	AAA & British AAA				
50 & 500kg Bomb	Lost time injury >7 days	Unit level damage	Major wider damage	Major Effect	50kg & 500kg Bomb				
	Fatality	Multiple damage	Catastrophe	Massive Effect					
					ORDNANCE THREAT LEVEL				

No special measures required	**NEGLIGIBLE**	
Monitor & manage potential risks	**LOW**	
Review & emplace strict control measures if necessary	**MEDIUM**	**XXXX**
Control measures required to mitigate risks to acceptable levels	**HIGH**	
Intolerable Risk Level. Immediate control measures prior to any further works	**EXTREME**	

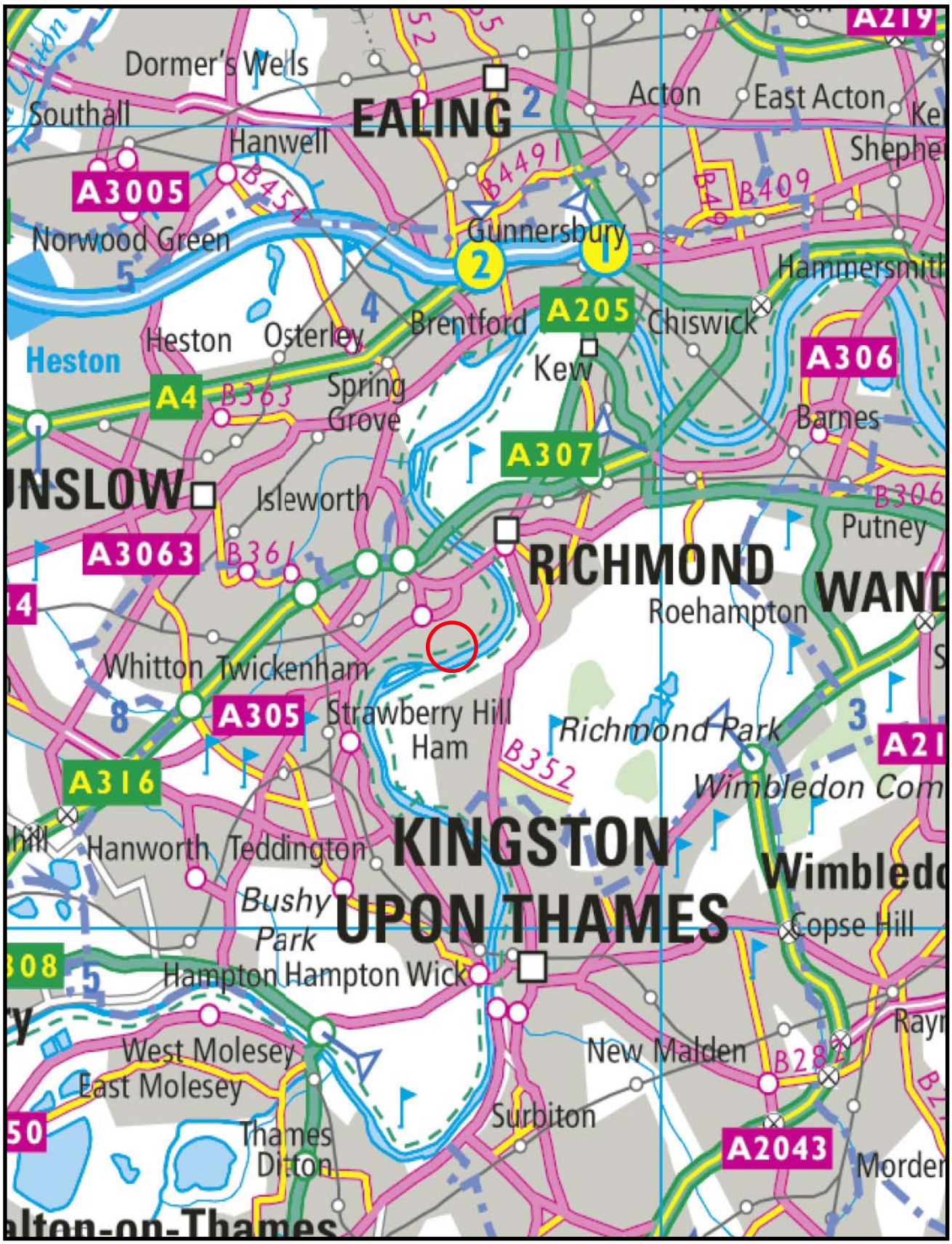
THREAT MITIGATION		
ACTIVITY	**THREAT MITIGATION MEASURES**	**FINAL THREAT LEVEL**
ALL ACTIVITIES	A threat management strategy **IS REQUIRED** to be in place prior to intrusive engineering works within the UXB Threat Zone for the site of concern. **Explosive Ordnance Safety Awareness Briefings.** An explosive ordnance Safety Briefing should be included as part of routine site health and safety training and form a key element of the Site Health & Safety Plan. This should be conducted by a trained specialist and would assist conformance with the CDM Regulations 2007. The briefing will instruct all personnel on the identification of EO hazards, actions to take in the event of an EO incident to protect personnel, key equipment, property and the general public. **Explosive Ordnance Site Safety Instructions.** Explosive Ordnance Site Safety Instructions should be drafted for inclusion in the site-specific health and safety manual and would include information on dealing with an EO incident safely and appropriately. These instructions would form part of the permanent site documentation and will be an aide memoire for identifying potential EO hazards, making a preliminary threat assessment as well as specific guidelines on what to do in the event of a confirmed incident.	**AS LOW AS REASONABLY PRACTICABLE (ALARP)**
SITE INVESTIGATION WORKS	Site investigation works should be supported by UXO survey as appropriate. Consideration should be given to whether the works are shallow or deep from the perspective of UXO Survey. 'Shallow' Survey is survey of the ground from 0.0m bgl to 6.5m bgl and 'Deep' UXO Survey is that beyond 6.5mbgl. • **Boreholes.** PLANIT can conduct a non-intrusive survey of a 5m x 5m box which will accurately allow your borehole to proceed into a volume of ground under which there are no ferrous obstructions. Several locations may be provided within a survey box, allowing maximum flexibility for positioning and preventing any boreholes being terminated as a result of encountering a potential threat item at depth. • **Trial Pits.** Using shallow non-intrusive survey, the area for your trial pit can quickly be surveyed and confirmed as free from ferrous anomalies/UXO. Data is interpreted on-site and therefore locations can be changed very efficiently in the event of a potential obstacle. • **Window Sampling.** Using shallow non-intrusive survey, the area for your window sample can quickly be surveyed and confirmed as free from ferrous anomalies/UXO. Data is interpreted on-site and therefore locations can be changed very efficiently in the event of a potential obstacle.	**AS LOW AS REASONABLY PRACTICABLE (ALARP)**

SHALLOW INTRUSIVE ENGINEERING WORKS	There are two options available to effectively deal with the EO Threat when conducting shallow intrusive ground works. **On-Site UXO Support.** On-site UXO Support for shallow ground works would involve the presence of an appropriately trained and experienced UXO Technician during this phase of construction. The role of the UXO Technician is to: • Conduct EO Safety Awareness Briefings as required. • Monitor all intrusive ground works using visual and instrument aided means to locate any EO that may be uncovered during site works. • Provide an immediate and expert assessment of any EO that may be discovered. • Assist in implementing an appropriate and safe response to an EO incident. • Design and emplace protective works as an immediate response to protect personnel, key equipment, property and the general public as may be required. • Advise on best safe working practice considering the perceived EO Threat. • Act as the liaison with the Authorities on behalf of the Client in the event of an EO incident. **Shallow Non-Intrusive UXO Survey**. PLANIT can deploy industry leading technology that will survey your site of concern non-intrusively (as long as ground conditions permit) in order to identify potential EO Threat Items. Any anomalies identified following the non-intrusive survey that may be EO should then be subject to Controlled Excavation to confirm them as EO and remove the threat or discount them. Once the non-intrusive survey and controlled excavation are complete, there is no further requirement for UXO Support at the site of concern since all EO Threats would have been identified and dealt with.	**AS LOW AS REASONABLY PRACTICABLE (ALARP)**
DEEP INTRUSIVE ENGINEERING	There are several options available to effectively deal with potential EO Threats when conducting deep intrusive ground works. Which approach is applicable will depend upon the ground conditions of the site of concern: **Deep Non-Intrusive UXO Survey.** PLANIT can deploy industry leading technology that will survey your site of concern non-intrusively (if ground conditions permit) in order to identify potential EO Threat Items at depth – UXO Survey should proceed to the expected UXB penetration depth or maximum depth of intrusive ground works, whichever is shallower. As a benchmark, PLANITs Deep Non-Intrusive Survey is capable of identifying a 500Kg HE bomb to some 8.0m bgl in average ground and larger bombs deeper. This approach is ideal for covering large areas quickly and can be employed to survey piling runs and borehole locations. Any anomalies identified following the non-intrusive survey that may be EO should then be subject to Controlled Excavation in order to confirm them as EO and remove the threat or discount them. Once the non-intrusive survey and controlled excavation are complete, there is no further requirement for UXO Support at the	**AS LOW AS REASONABLY PRACTICABLE (ALARP)**

	site of concern since all EO Threats would have been identified and dealt with. **Magcone UXB Survey.** PLANIT can deploy world class Magcone Survey Systems to survey either pile locations or small areas ahead of intrusive engineering including piling and drilling. The Magcone system is very versatile and can survey to great depths if required. **Down-Hole Magnetometer UXO Survey**. PLANIT can deploy down-borehole UXO Survey equipment that will clear ahead of a piling or borehole rig as it descends underground. The main drawbacks of this approach are that it is time consuming, 'blind' (insofar as the borehole may proceed for some depth before a potential threat item is identified, at which stage the borehole will have to be terminated and relocated, wasting time and money), equipment heavy and expensive. Any anomalies identified during this survey that may be EO should either be subject to Controlled Excavation in order to confirm them as EO and remove the threat or discount them or relocate the borehole or adjust the piling plan. UXO Survey should proceed to the expected UXB penetration depth or maximum depth of intrusive ground works, whichever is shallower.	

ANNEXES

A. Site Location & Layout.
B. Bomb Census Summary.
C. Historical Street Maps.
D. Historical Aerial Photography.

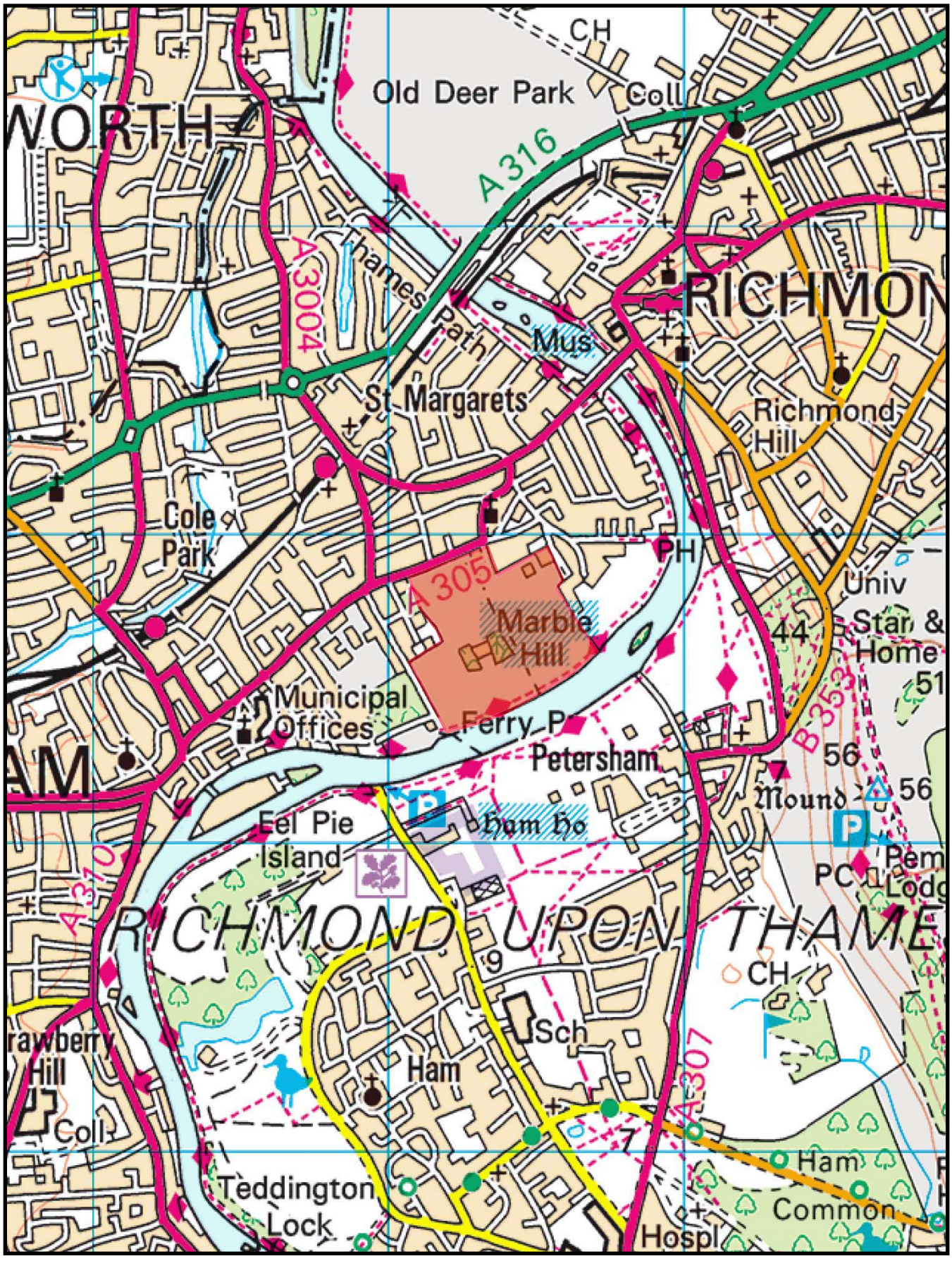


Annex A: Site Location
Client: CET
Project Ref: Marble Hill House
Doc Ref: 0123 EOTA Marble Hill 04/01/17

Key:

Site Location

PLANIT RESTORING BALANCE

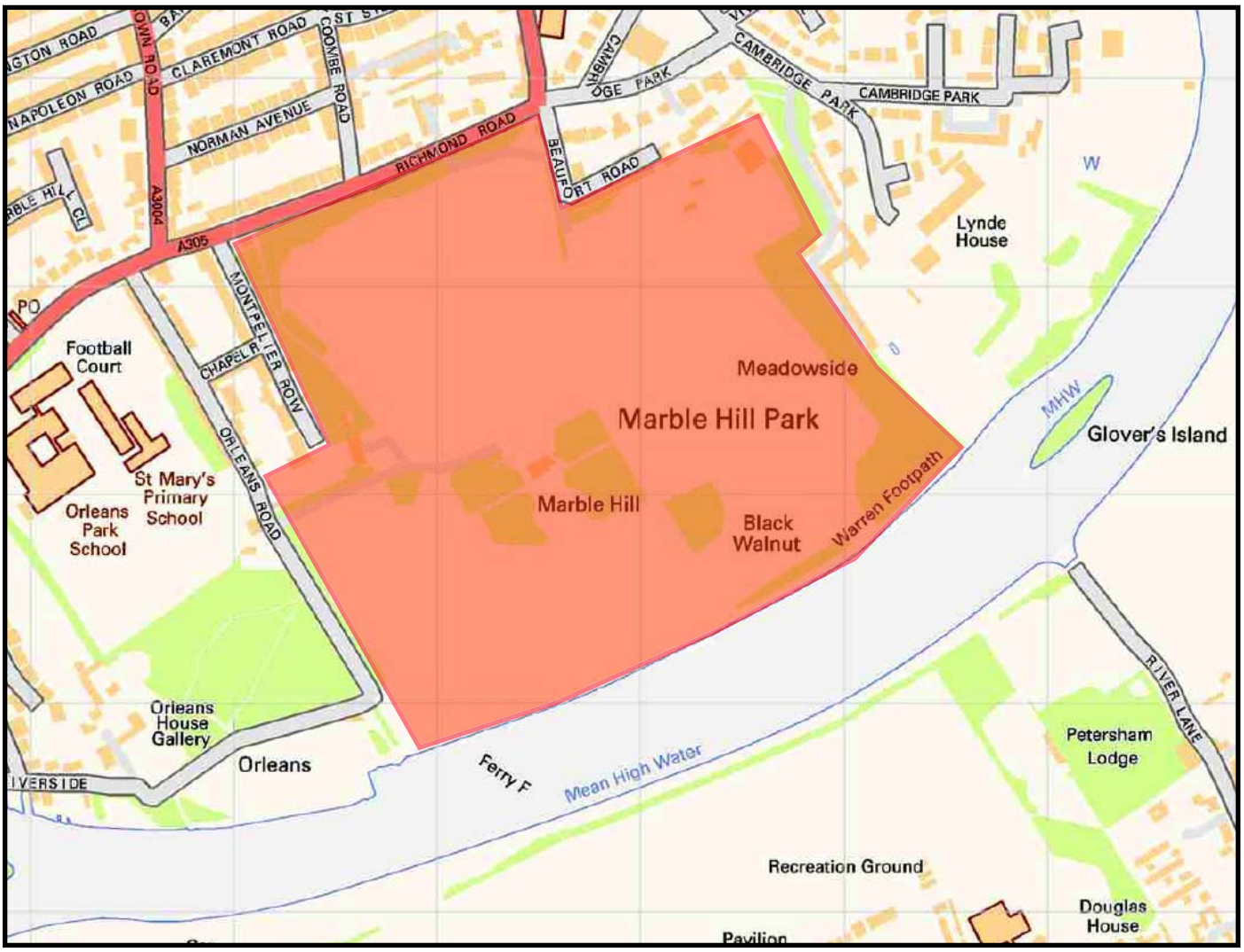


Annex A: Site Location
Client: CET
Project Ref: Marble Hill House
Doc Ref: 0123 EOTA Marble Hill 04/01/17

Key:

Site Location

PLANIT RESTORING BALANCE



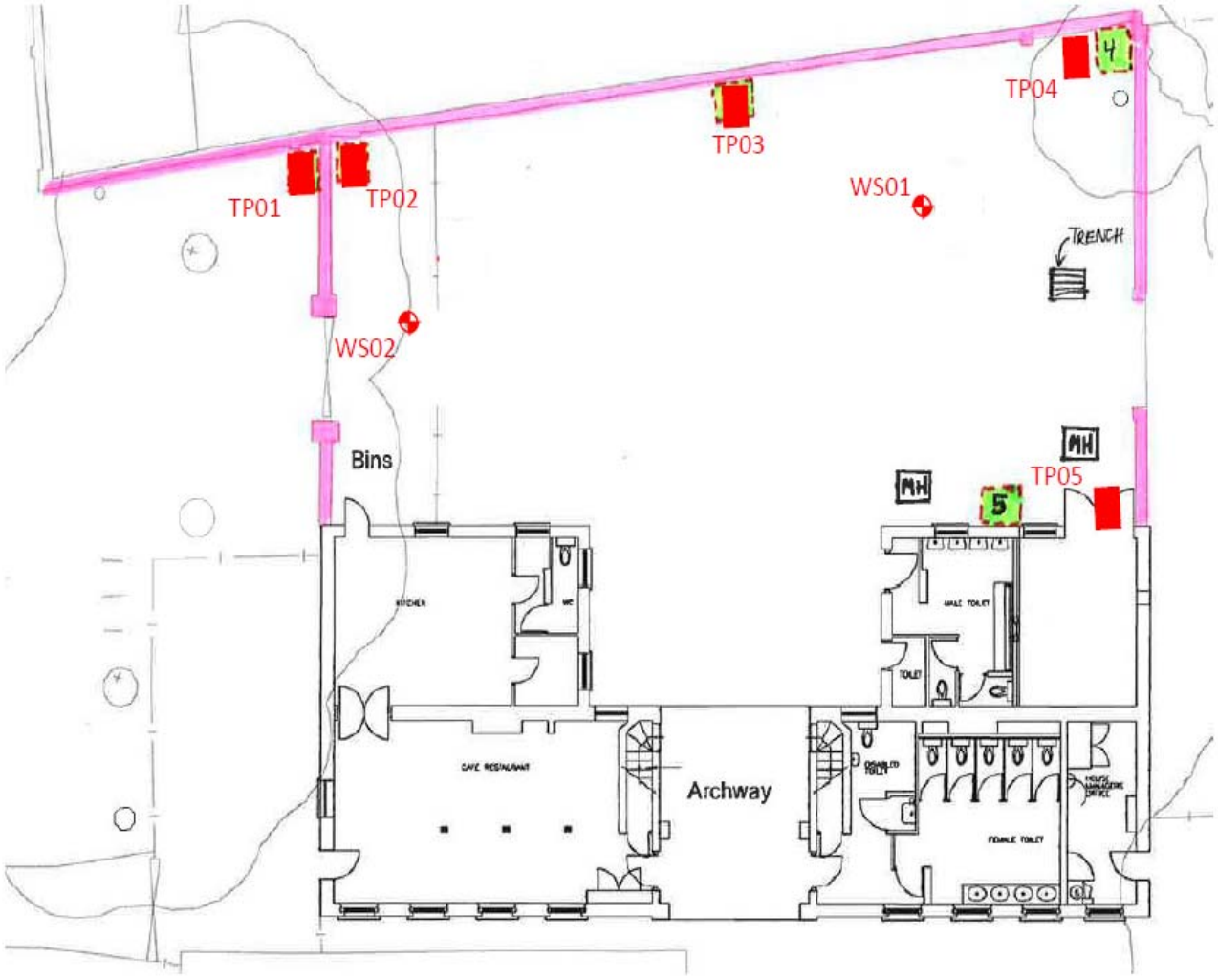
Annex A: Site Location
Client: CET
Project Ref: Marble Hill House
Doc Ref: 0123 EOTA Marble Hill 04/01/17

Key:

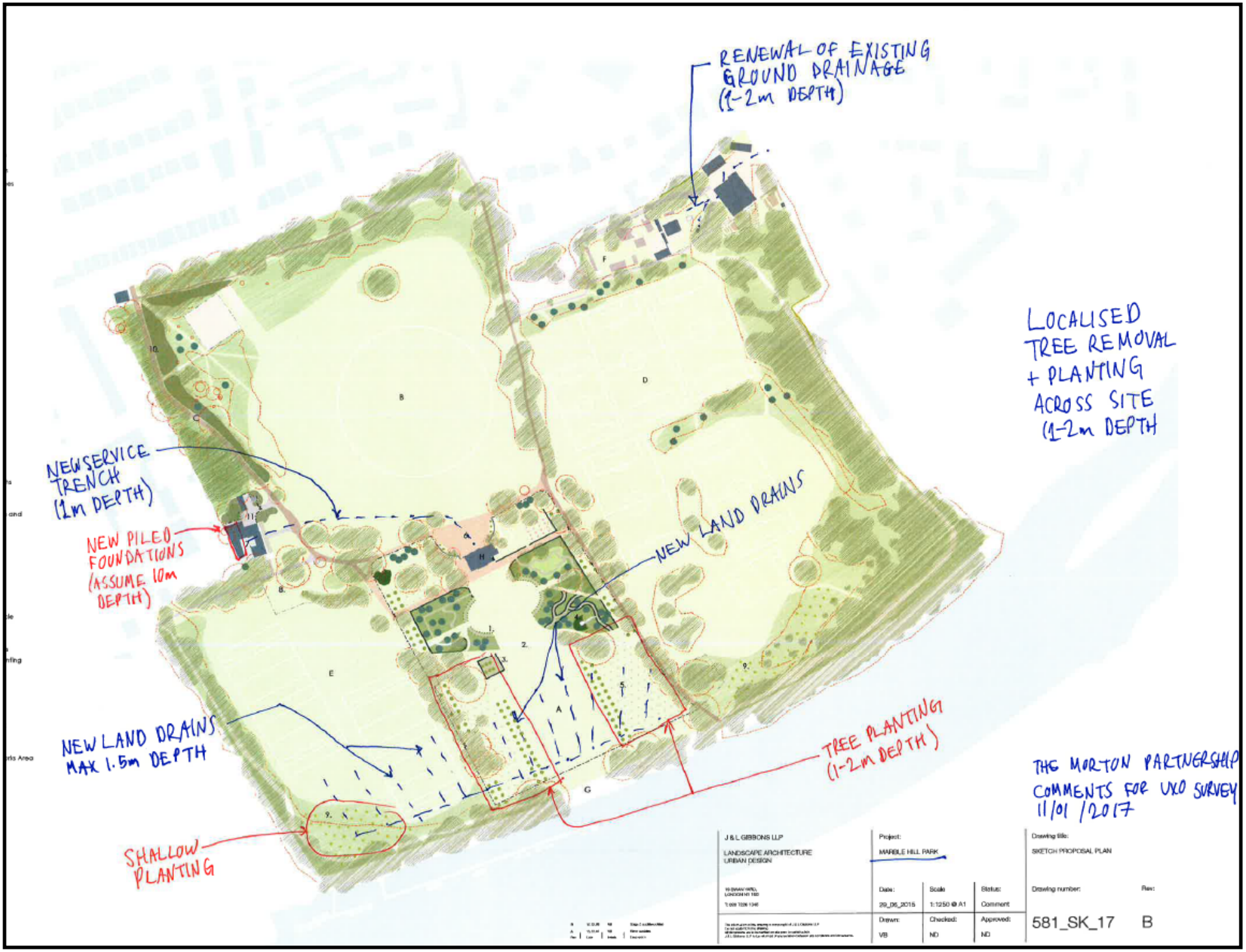
Site Location

PLANIT RESTORING BALANCE

Marble Hill House – Proposed Café Extension
299004



Annex A: Site Location
Client: CET
Project Ref: Marble Hill House
Doc Ref: 0123 EOTA Marble Hill 04/01/17


RENEWAL OF EXISTING GROUND DRAINAGE (1-2m DEPTH)
LOCALISED TREE REMOVAL + PLANTING ACROSS SITE (1-2m DEPTH
NEW SERVICE TRENCH (1m DEPTH)
NEW PILED FOUNDATIONS (ASSUME 10m DEPTH)
NEW LAND DRAINS
NEW LAND DRAINS MAX 1.5m DEPTH
TREE PLANTING (1-2m DEPTH)
SHALLOW PLANTING
THE MORTON PARTNERSHIP COMMENTS FOR UXO SURVEY 11/01/2017
J & L GIBBONS LLP
LANDSCAPE ARCHITECTURE
URBAN DESIGN
Project:
MARBLE HILL PARK
Drawing title:
SKETCH PROPOSAL PLAN
Date:
29_06_2015
Scale
1:1250 @ A1
Status:
Comment
Drawing number:
581_SK_17
Rev:
B
Drawn:
VB
Checked:
ND
Approved:
ND

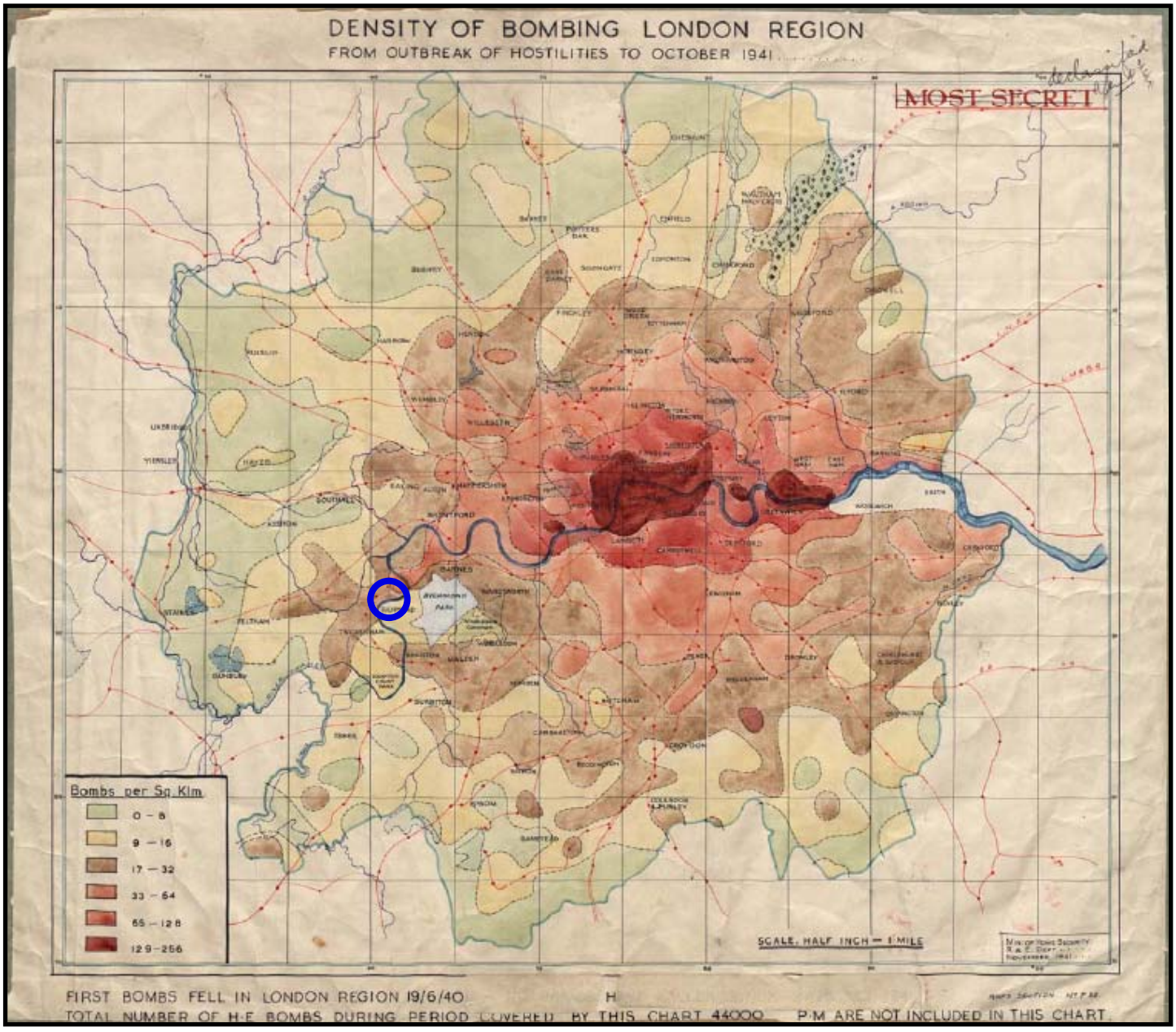
MODERN AERIAL PHOTOGRAPHY

Annex A: Site Location
Client: CET
Project Ref: Marble Hill House
Doc Ref: 0123 EOTA Marble Hill 04/01/17

Key:

Site Location

PLANIT RESTORING BALANCE

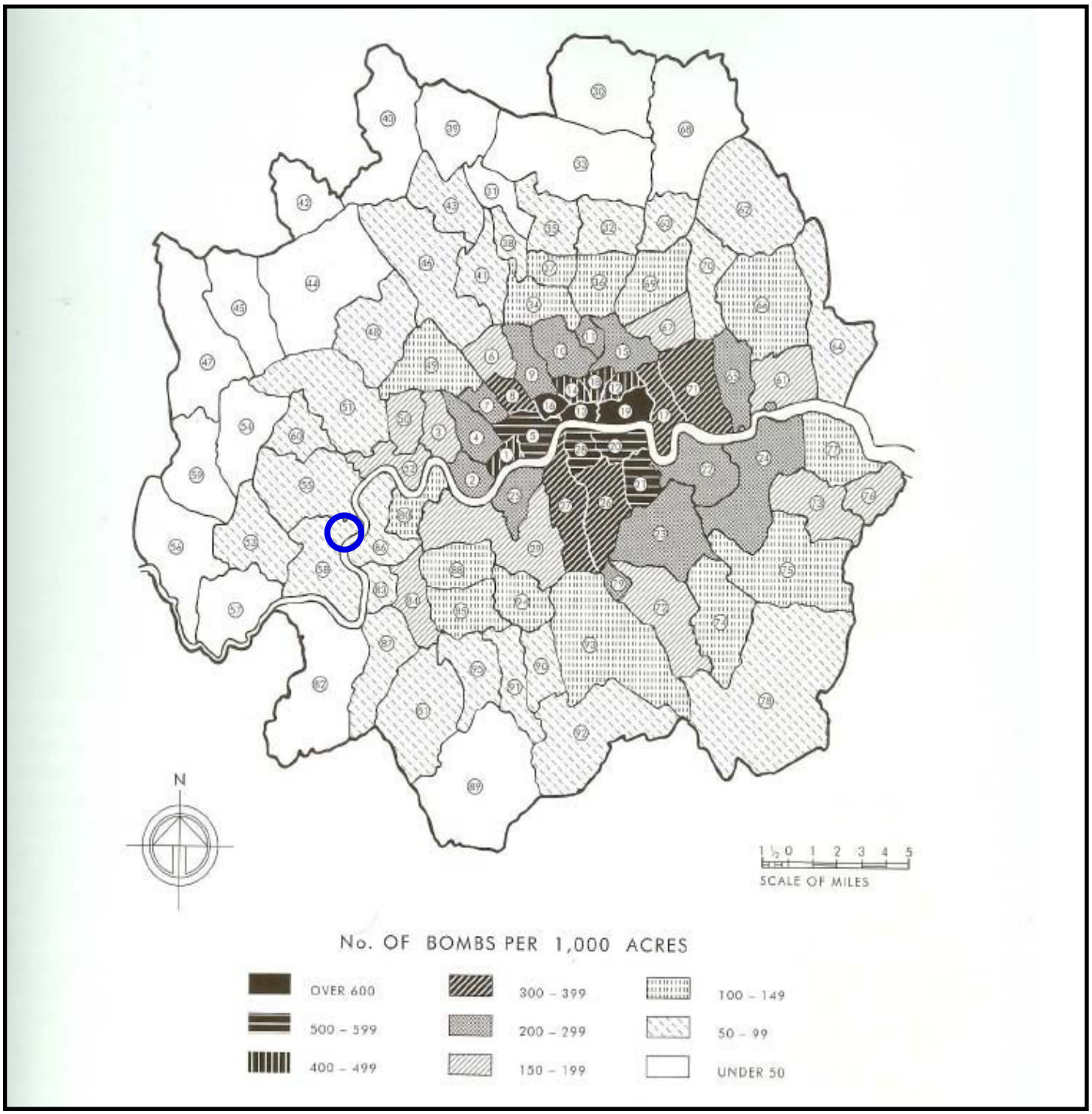


Annex B: Bomb Census Summary
Client: CET
Project Ref: Marble Hill House
Doc Ref: 0123 EOTA Marble Hill 04/01/17

Key:

Site Location

PLANIT
RESTORING BALANCE

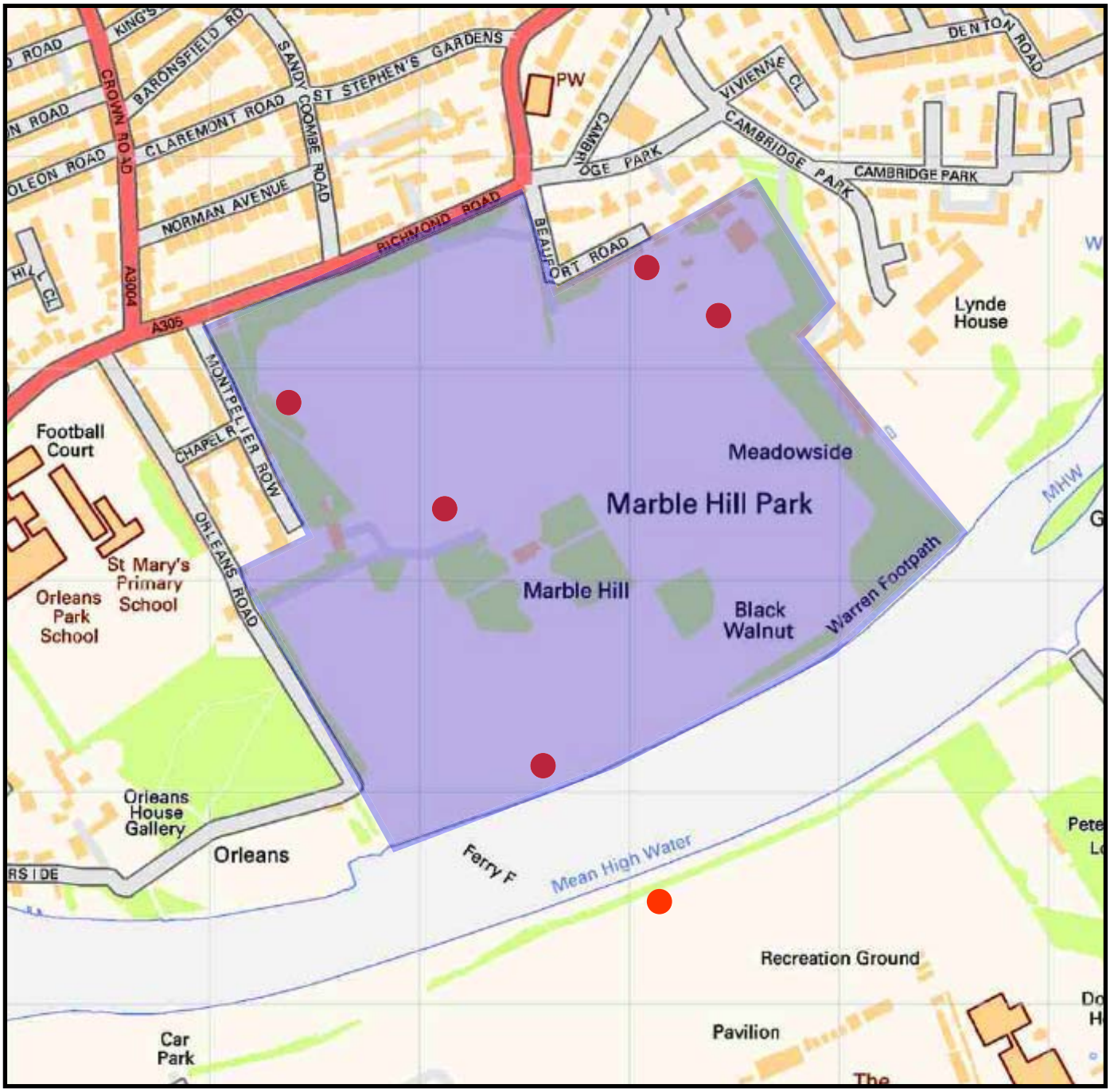


Annex B: Bomb Census Summary
Client: CET
Project Ref: Marble Hill House
Doc Ref: 0123 EOTA Marble Hill 04/01/17

Key:

Site Location

PLANIT RESTORING BALANCE



Annex B: Bomb Census Summary
Client: CET
Project Ref: Marble Hill House
Doc Ref: 0123 EOTA Marble Hill 04/01/17

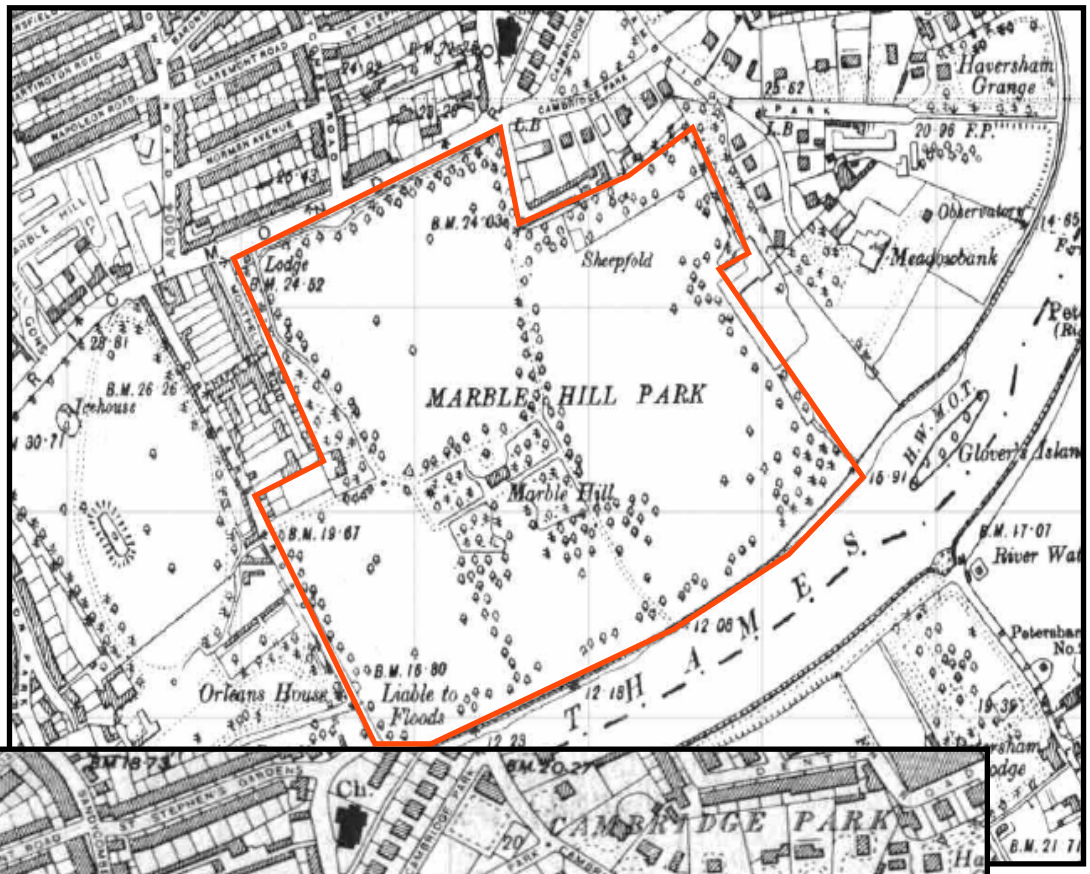
Key:

Site Location

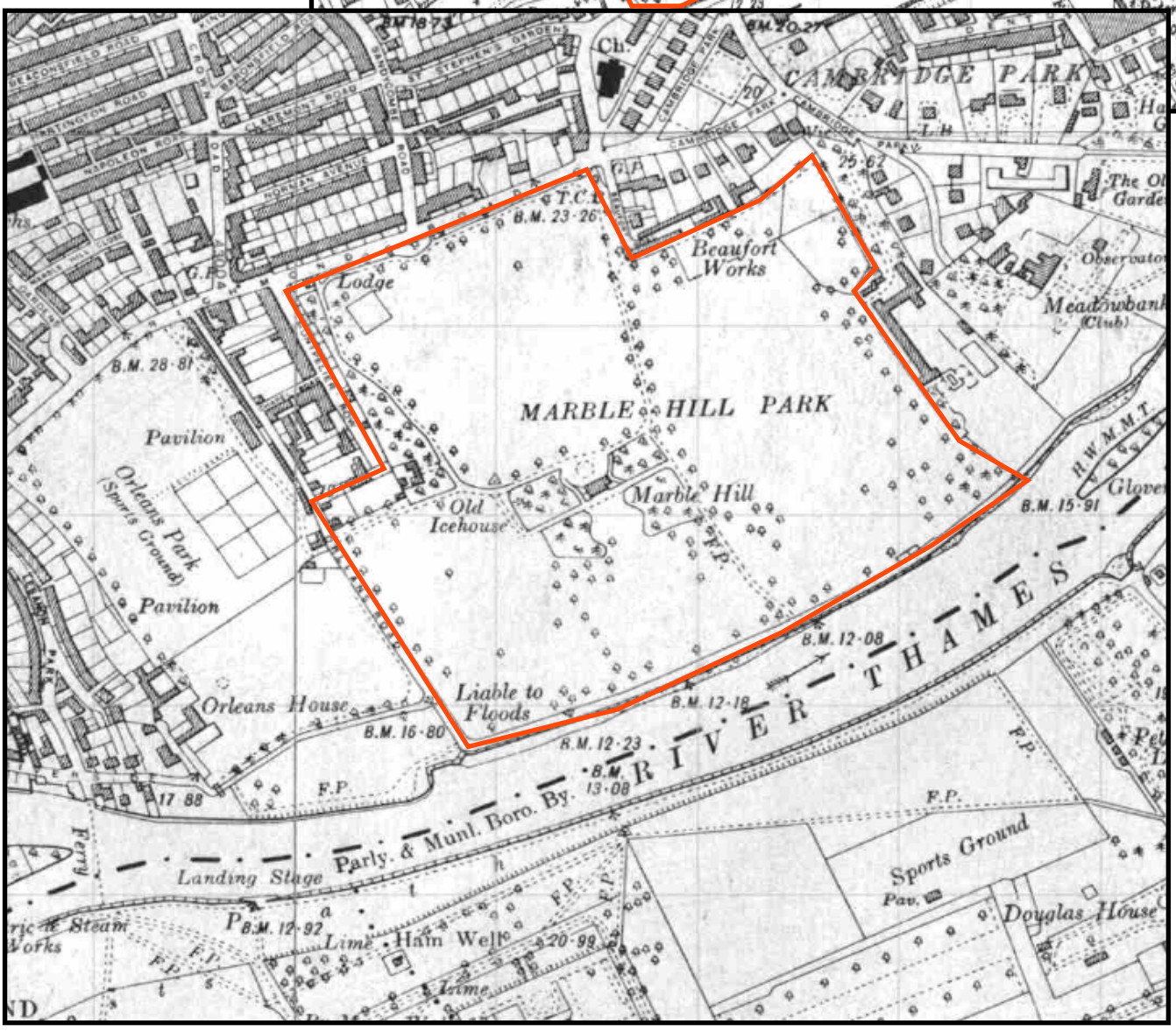
HE Bomb Strikes

PLANIT RESTORING BALANCE

1938



1948



Annex C: Historical Street Map
Client: CET
Project Ref: Marble Hill House
Doc Ref: 0123 EOTA Marble Hill 04/01/17

Key:

Site Location

PLANIT RESTORING BALANCE

N

RAF AERIAL PHOTOGRAPH c. 1945

Annex D: Historical Aerial Photography
Client: CET
Project Ref: Marble Hill House
Doc Ref: 0123 EOTA Marble Hill 04/01/17

Key:

Site Location

PLANIT RESTORING BALANCE