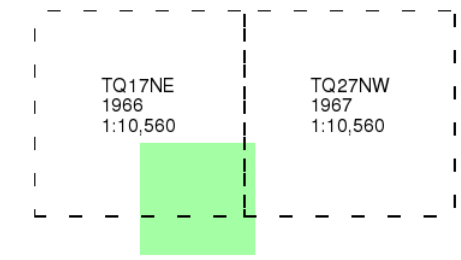


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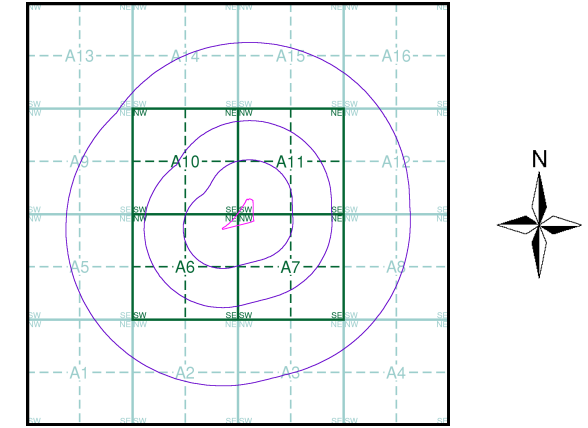
**Ordnance Survey Plan**  
**Published 1966 - 1967**  
**Source map scale - 1:10,000**

The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840's. In 1854 the 1:2,500 scale was adopted for mapping urban areas; these maps were used to update the 1:10,560 maps. The published date given therefore is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas. In the late 1940's, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

### Map Name(s) and Date(s)



### Historical Map - Slice A



### Order Details

Order Number: 142584674\_1\_1  
 Customer Ref: Homebase, Richmond  
 National Grid Reference: 518890, 175430  
 Slice: A  
 Site Area (Ha): 1.58  
 Search Buffer (m): 1000

### Site Details

Homebase Ltd, 84, Manor Road, RICHMOND, TW9 1YB



# FAIRHURST

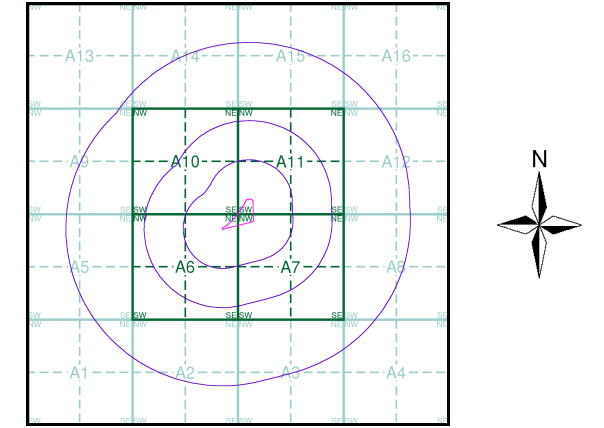
**Ordnance Survey Plan**  
**Published 1975 - 1976**  
**Source map scale - 1:10,000**

The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840's. In 1854 the 1:2,500 scale was adopted for mapping urban areas; these maps were used to update the 1:10,560 maps. The published date given therefore is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas. In the late 1940's, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

### Map Name(s) and Date(s)

|                            |                            |
|----------------------------|----------------------------|
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| TQ17SE<br>1975<br>1:10,000 | TQ27SW<br>1976<br>1:10,000 |

### Historical Map - Slice A



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# FAIRHURST

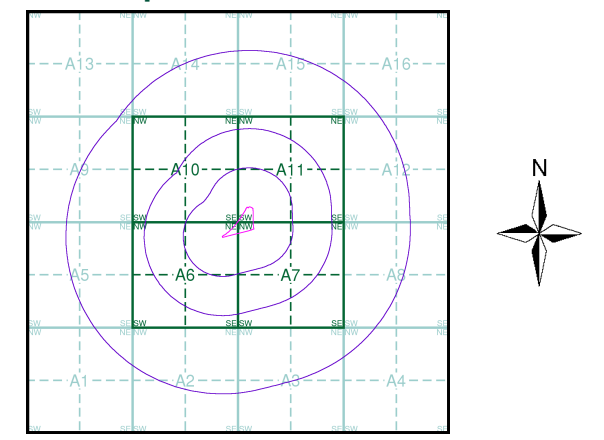
**London**  
**Published 1985**  
**Source map scale - 1:25,000**

These maps were produced by the Russian military during the Cold War between 1950 and 1997, and cover 103 towns and cities throughout the U.K. The maps are produced at 1:25,000, 1:10,000 and 1:5,000 scale, and show detailed land use, with colour-coded areas for development, green areas, and non-developed areas. Buildings are coloured black and important building uses (such as hospitals, post offices, factories etc.) are numbered, with a numbered key describing their use. They were produced by the Russians for the benefit of navigation, as well as strategic military sites and transport hubs, for use if they were to have invaded the U.K. The detailed information provided indicates that the areas were surveyed using land-based personnel, on the ground, in the cities that are mapped.

### Map Name(s) and Date(s)

|                          |                          |
|--------------------------|--------------------------|
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|--------------------------|--------------------------|

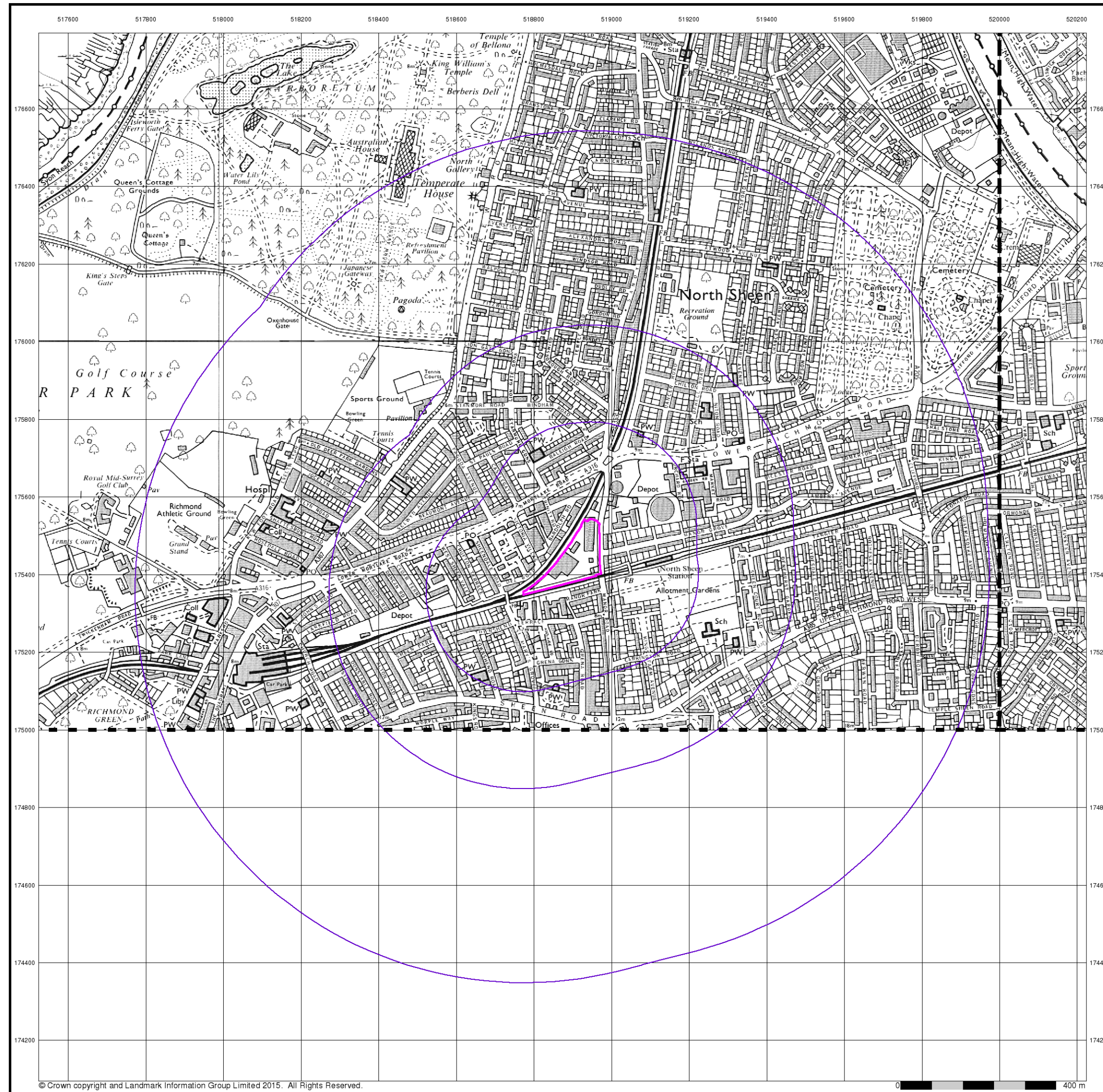
### Russian Map - Slice A



**Order Details**  
 Order Number: 142584674\_1\_1  
 Customer Ref: Homebase, Richmond  
 National Grid Reference: 518890, 175430  
 Slice: A  
 Site Area (Ha): 1.58  
 Search Buffer (m): 1000

**Site Details**  
 Homebase Ltd, 84, Manor Road, RICHMOND, TW9 1YB

**Landmark**  
 INFORMATION GROUP  
 Tel: 0844 844 9952  
 Fax: 0844 844 9951  
 Web: www.envirocheck.co.uk

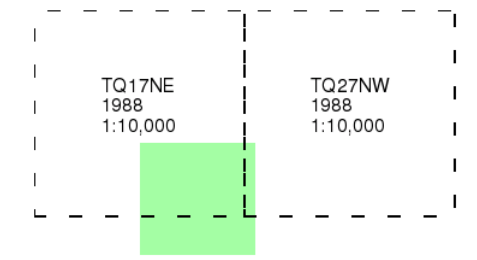


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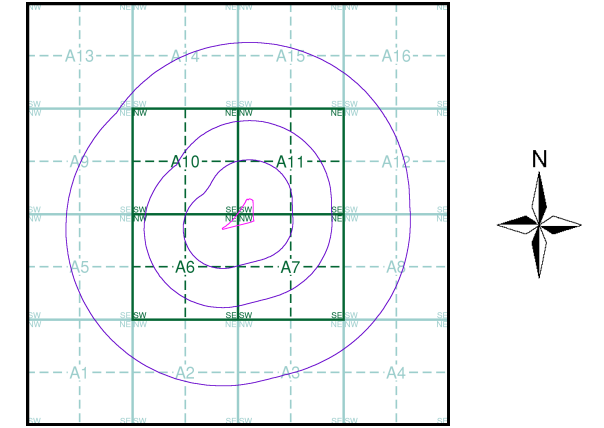
**Ordnance Survey Plan**  
**Published 1988**  
**Source map scale - 1:10,000**

The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840's. In 1854 the 1:2,500 scale was adopted for mapping urban areas; these maps were used to update the 1:10,560 maps. The published date given therefore is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas. In the late 1940's, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

### Map Name(s) and Date(s)



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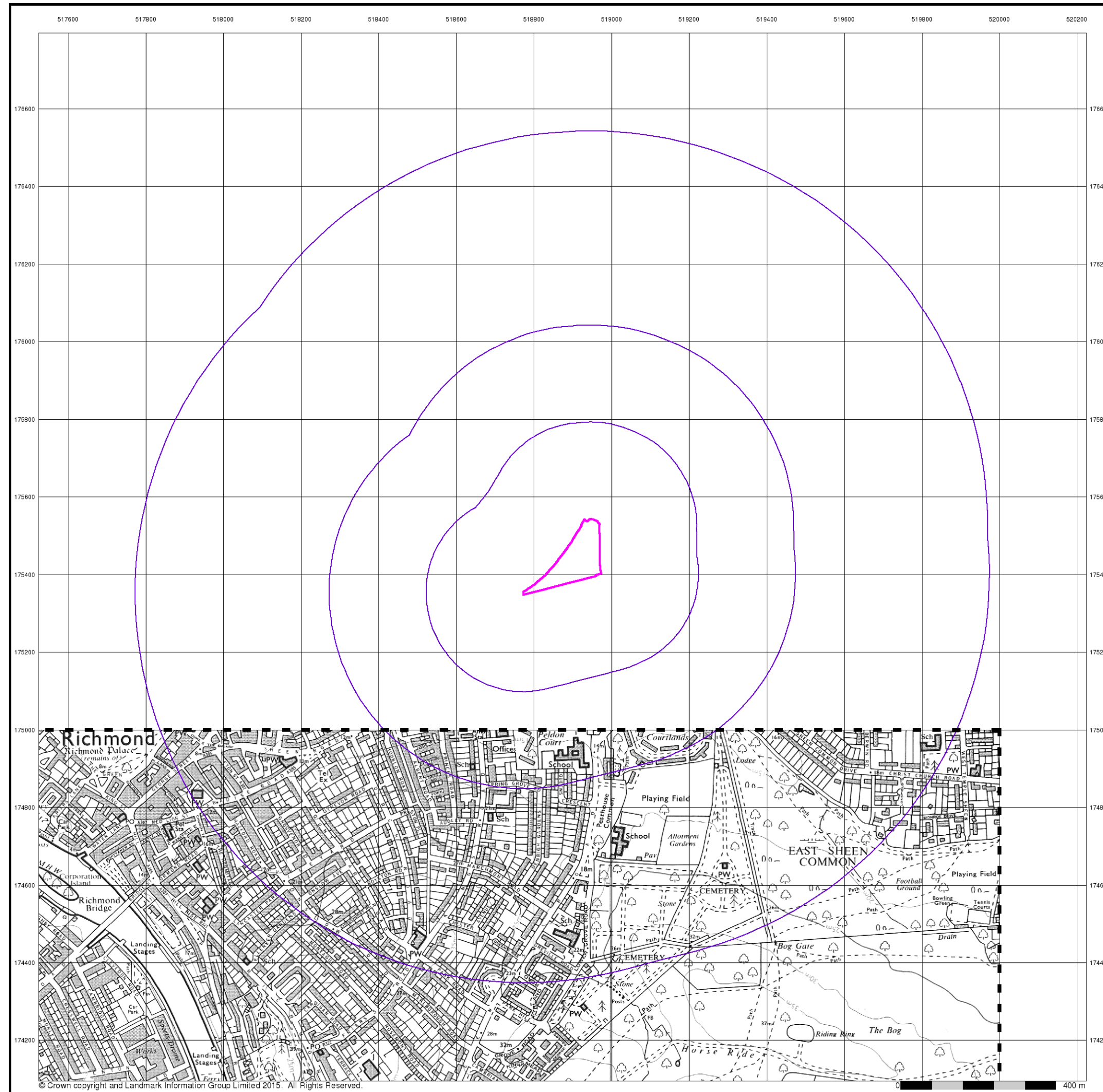


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Order Number: 142584674\_1\_1  
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 National Grid Reference: 518890, 175430  
 Slice: A  
 Site Area (Ha): 1.58  
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### Site Details

Homebase Ltd, 84, Manor Road, RICHMOND, TW9 1YB

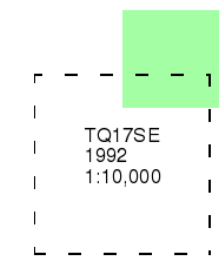


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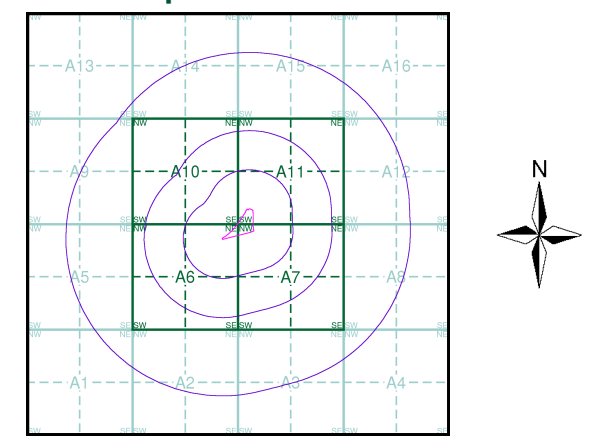
**Ordnance Survey Plan**  
**Published 1992**  
**Source map scale - 1:10,000**

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# FAIRHURST

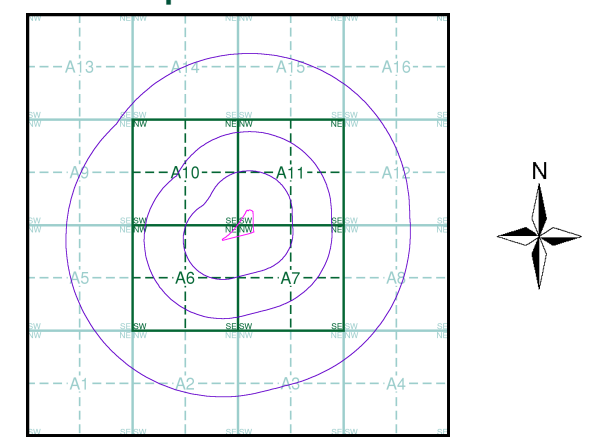
**10k Raster Mapping**  
**Published 1999**  
**Source map scale - 1:10,000**

The historical maps shown were produced from the Ordnance Survey's 1:10,000 colour raster mapping. These maps are derived from Landplan which replaced the old 1:10,000 maps originally published in 1970. The data is highly detailed showing buildings, fences and field boundaries as well as all roads, tracks and paths. Road names are also included together with the relevant road number and classification. Boundary information depiction includes county, unitary authority, district, civil parish and constituency.

### Map Name(s) and Date(s)

|          |          |
|----------|----------|
| TQ17NE   | TQ27NW   |
| 1999     | 1999     |
| 1:10,000 | 1:10,000 |
| TQ17SE   | TQ27SW   |
| 1999     | 1999     |
| 1:10,000 | 1:10,000 |

### Historical Map - Slice A



### Order Details

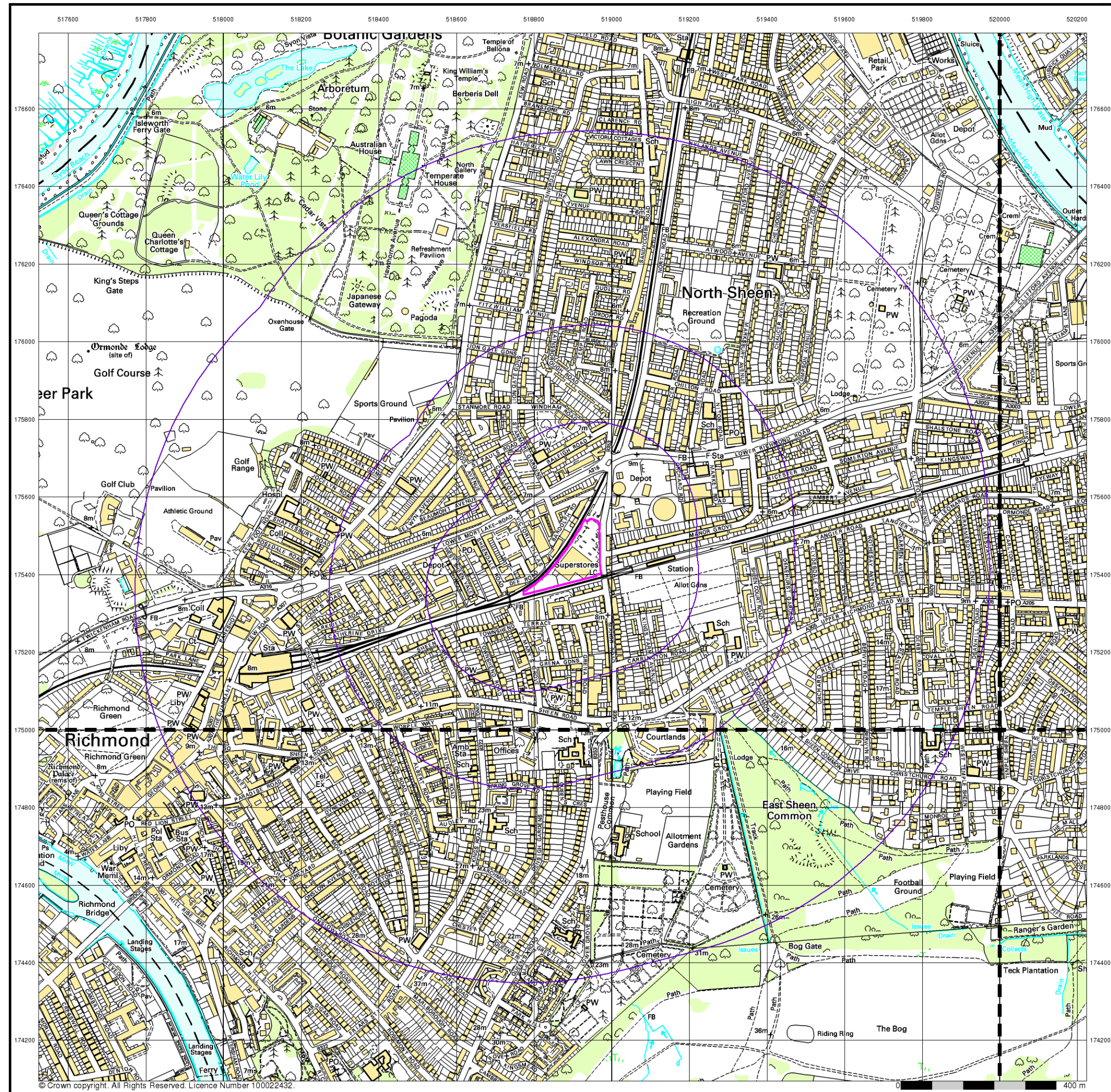
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 National Grid Reference: 518890, 175430  
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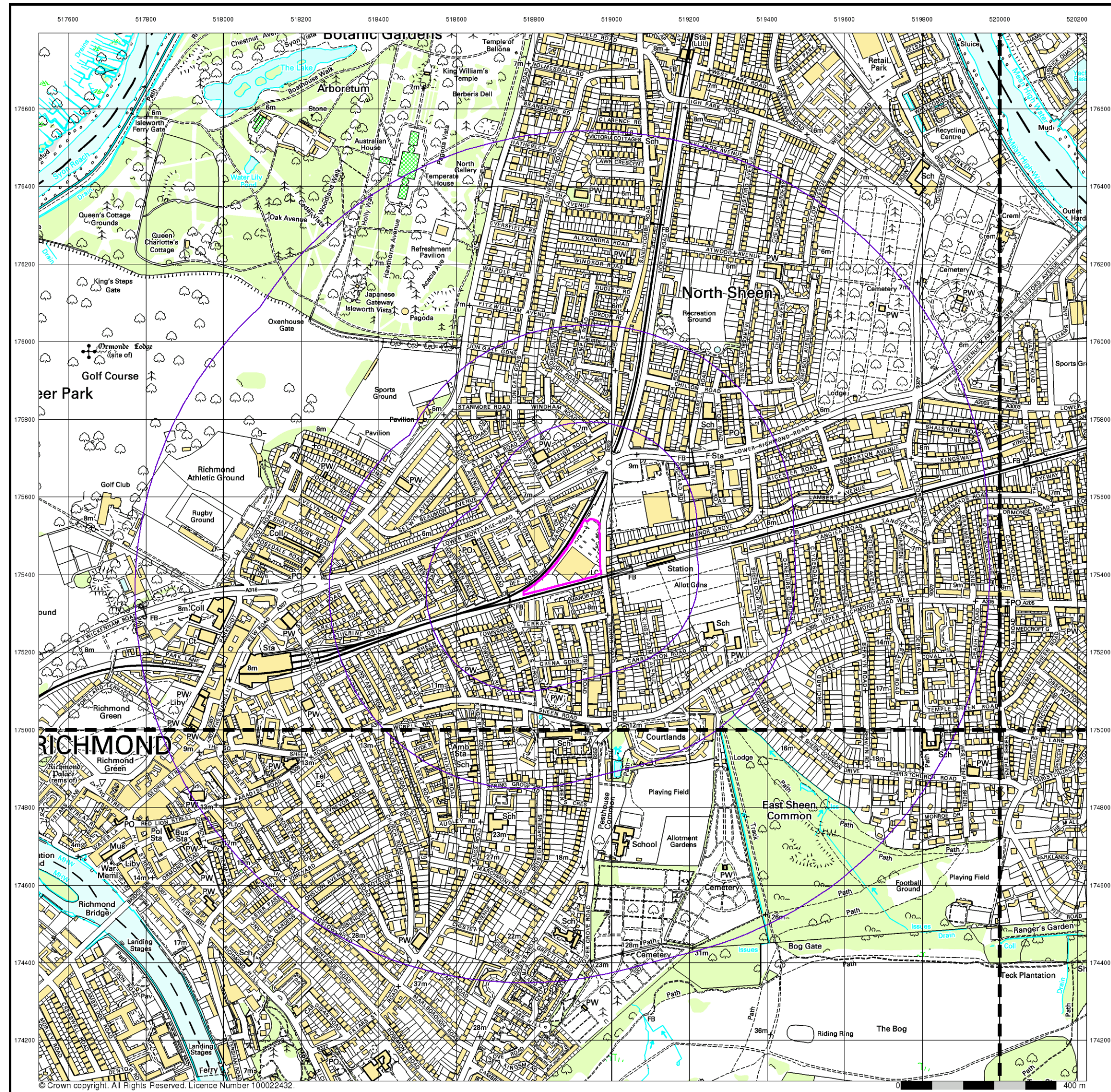
### Site Details

Homebase Ltd, 84, Manor Road, RICHMOND, TW9 1YB

**Landmark**  
 INFORMATION GROUP

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# FAIRHURST

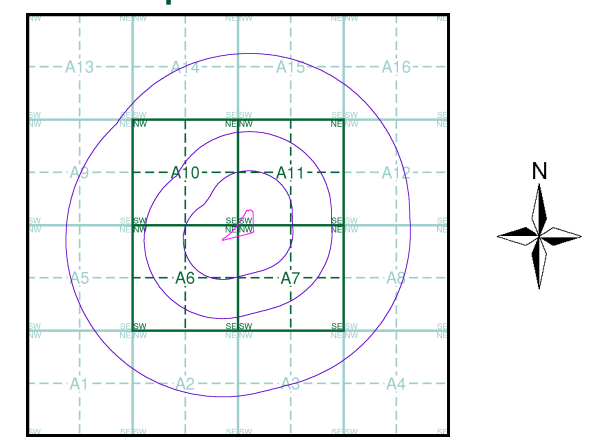
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**Published 2006**  
**Source map scale - 1:10,000**

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### Map Name(s) and Date(s)

|          |          |
|----------|----------|
| TQ17NE   | TQ27NW   |
| 2006     | 2006     |
| 1:10,000 | 1:10,000 |
| TQ17SE   | TQ27SW   |
| 2006     | 2006     |
| 1:10,000 | 1:10,000 |

### Historical Map - Slice A

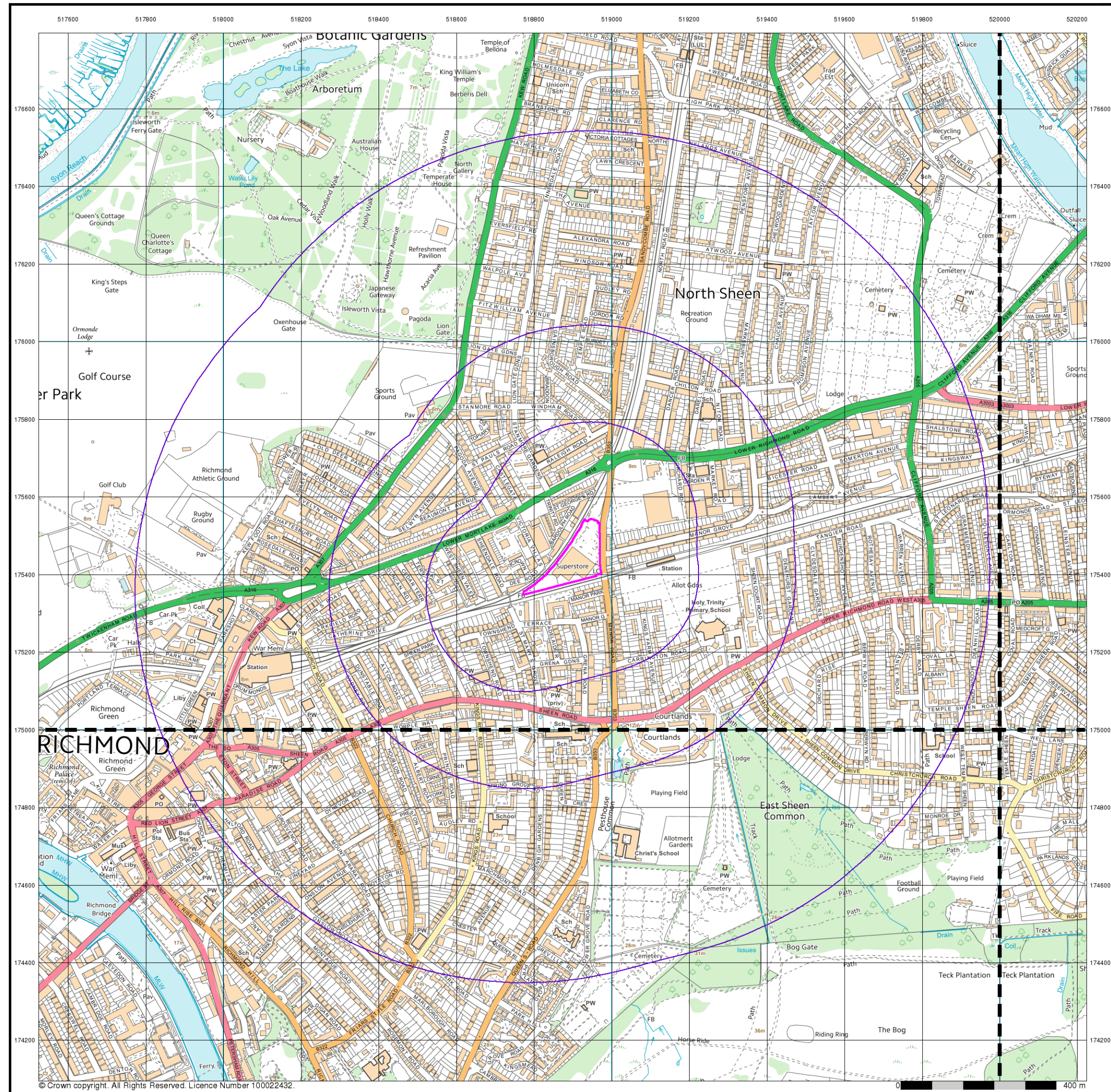


### Order Details

Order Number: 142584674\_1\_1  
 Customer Ref: Homebase, Richmond  
 National Grid Reference: 518890, 175430  
 Slice: A  
 Site Area (Ha): 1.58  
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# FAIRHURST

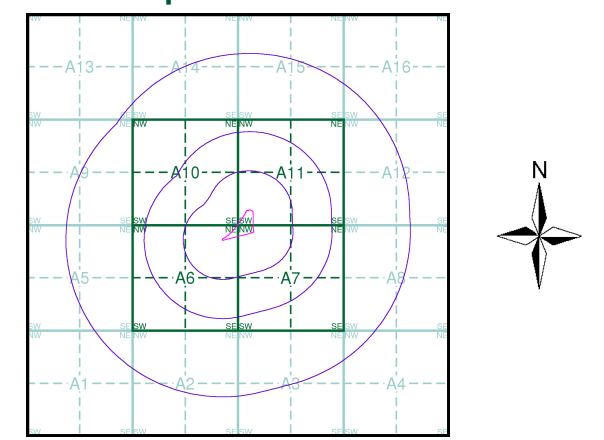
**VectorMap Local**  
**Published 2017**  
**Source map scale - 1:10,000**

VectorMap Local (Raster) is Ordnance Survey's highest detailed 'backdrop' mapping product. These maps are produced from OS's VectorMap Local, a simple vector dataset at a nominal scale of 1:10,000, covering the whole of Great Britain, that has been designed for creating graphical mapping. OS VectorMap Local is derived from large-scale information surveyed at 1:1250 scale (covering major towns and cities), 1:2500 scale (smaller towns, villages and developed rural areas), and 1:10 000 scale (mountain, moorland and river estuary areas).

### Map Name(s) and Date(s)

|                            |                            |
|----------------------------|----------------------------|
| TQ17NE<br>2017<br>Variable | TQ27NW<br>2017<br>Variable |
| TQ17SE<br>2017<br>Variable | TQ27SW<br>2017<br>Variable |

### Historical Map - Slice A



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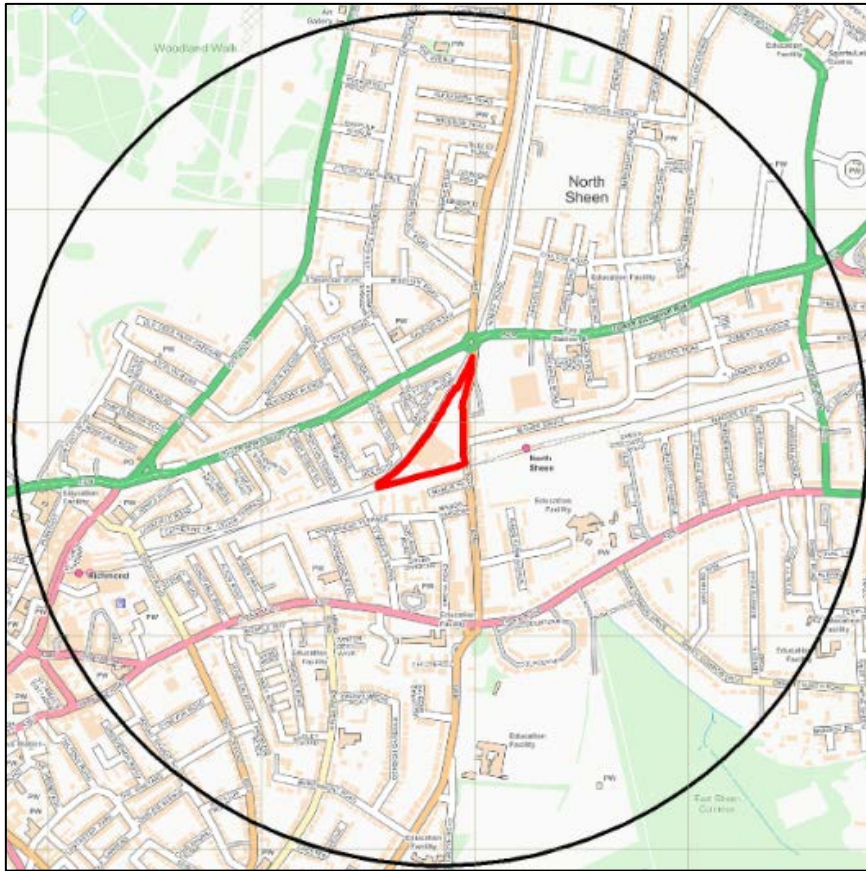


**APPENDIX C**

**Detailed Unexploded Ordnance (UXO) Threat and Risk Assessment**

# Detailed Unexploded Ordnance (UXO) Threat & Risk Assessment

Meeting the requirements of CIRIA C681 'Unexploded Ordnance (UXO)  
A guide for the Construction Industry' Risk Management Framework



|                               |  |                    |  |
|-------------------------------|--|--------------------|--|
| <b>6 ALPHA PROJECT NUMBER</b> | P7115  | <b>ORIGINATOR</b>  | S. Barratt                                   |
| <b>LANDMARK ORDER NUMBER</b>  | 190053937_1  | <b>REVIEWED BY</b> | B. Wilkinson (10 <sup>th</sup> January 2018) |
| <b>CLIENT REFERENCE</b>       | 126782   | <b>RELEASED BY</b> | R. Griffiths (11 <sup>th</sup> January 2018) |
| <b>SITE</b>                   | Homebase Ltd, 84, Manor Road, Richmond, TW9 1YB  |                    |  |
| <b>RATING</b>                 | <b>HIGH</b> - This Site requires further action to reduce risk to ALARP during intrusive activities. |                    |  |

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## Acronyms and Abbreviations

---

|       |   |           |  |
|-------|---|-----------|--|
| AA    | Anti-Aircraft   | NEQ       | Net Explosive Quantity                         |
| AAA   | Anti-Aircraft Ammunition                                      | NFF       | National Filling Factory                       |
| ALARP | As Low As Reasonably Practicable                              | NGR       | National Grid Reference                        |
| AOD   | Above Ordnance Datum  | OD        | Ordnance Datum                                 |
| ARP   | Air Raid Precaution   | OS        | Ordnance Survey                                |
| AXO   | Abandoned Explosive Ordnance                                  | PM        | Parachute Mine                                 |
| BD    | Bomb Disposal   | PoW       | Prisoner of War                                |
| BDO   | Bomb Disposal Officer   | RADAR     | Radio Detection And Ranging                    |
| bgl   | Below Ground Level  | RAF       | Royal Air Force                                |
| BGS   | British Geological Survey                                     | RN        | Royal Navy                                     |
| BH    | Borehole  | RNAS      | Royal Naval Air Service                        |
| BPD   | Bomb Penetration Depth  | ROF       | Royal Ordnance Factory                         |
| CDP   | Cast Driven Piles   | SAA       | Small Arms Ammunition                          |
| CFA   | Continuous Flight Auger                                       | TA        | Territorial Army                               |
| CIRIA | Construction Industry Research<br>and Information Association | TNT       | Trinitrotoluene                                |
| CPT   | Cone Penetration Testing                                      | UK        | United Kingdom                                 |
| CS    | County Series   | UN        | United Nations                                 |
| EO    | Explosive Ordnance  | USAAF     | United States Army Air Force                   |
| EOC   | Explosive Ordnance Clearance                                  | UXB       | Unexploded Bomb                                |
| EOD   | Explosive Ordnance Disposal                                   | UXO       | Unexploded Ordnance                            |
| GI    | Ground Investigation  | V Weapons | <i>Vergeltungswaffe</i> – Vengeance<br>Weapons |
| GIS   | Geographic Information Systems                                | WD        | War Department                                 |
| GL    | Ground Level  | WWI       | World War One                                  |
| GP    | General Purpose   | WWII      | World War Two                                  |
| GPS   | Global Positioning Systems                                    |           |  |
| HAA   | Heavy Anti-Aircraft   |           |  |
| HE    | High Explosive  |           |  |
| HO    | Home Office   |           |  |
| HSE   | Health and Safety Executive                                   |           |  |
| IB    | Incendiary Bomb   |           |  |
| kg    | Kilograms   |           |  |
| km    | Kilometres  |           |  |
| LAA   | Light Anti-Aircraft   |           |  |
| LCC   | London County Council   |           |  |
| LE    | Low Explosive   |           |  |
| LSA   | Land Service Ammunition                                       |           |  |
| m     | Metres  |           |  |
| MoD   | Ministry of Defence   |           |  |
| mm    | Millimetres   |           |  |

## EXECUTIVE SUMMARY

### Study Site

The Client has defined the Study Site as “Homebase Ltd, 84, Manor Road, Richmond, TW9 1YB”. The Site is located at NGR 518920, 175460.

### Risk Level

**HIGH**

### Potential Threat Sources

The most probable UXO threat is posed by WWII *German* HE bombs, whilst IBs and *British* AAA projectiles (which were used to defend against *German* bombing raids) pose a residual threat.

### Risk Pathway

Given the types of UXO that might be present on-site, all types of aggressive intrusive engineering activities may generate a significant risk pathway.

### Key Findings

During WWII, the Study Site was situated within *Richmond Municipal Borough*, which recorded 22 HE bomb strikes per 100 hectares, a low level of bombing.

*Luftwaffe* aerial reconnaissance photography associated with the Site did not identify any primary bombing targets located on-site or within 1,000m of the Site boundary.

ARP records associated with the Site did not note any HE bomb strikes within it however, six were recorded; 5m to the south, 50m to the north-west, 55m to the north-west, 70m to the south-west, 130m to the north-west and 155m to the east.

Official bomb damage mapping was not available. However, an analysis of post-war mapping identified “*Ruins*” 40m to the south and 65m to the south. In addition, photographic evidence and further research identified bomb damage along *Stanmore Gardens* located 180m north-west and *Peldon Avenue* located 345m to the south.

Pre-WWII mapping (1934 - 1936) and aerial photography (1945) associated with the Site shows that it was located within a densely developed urban area during WWII, with the Site itself consisting of a timber yard and several small structures. As a result, it is considered likely that employees from the timber yard may have observed and reported any UXB entry holes which would have been dealt with at the time. However, given the trajectory of incoming weapons this in fact may not have been the case.

The Site has undergone significant post-war redevelopment in some areas, with the construction and demolition of small structures between the late-1940s and late-1980s, prior to the development of the large superstore in the 1990s. Consequently, it is considered likely that any UXO within the structural foundations of post-war buildings would have been discovered and removed, however, the potential for deep buried UXO to be present within remaining areas is assessed to be extant. Given the immediate vicinity of the Site was subjected to bombing, the following risk mitigation measures are recommended as a minimum, in order to reduce risks ALARP, during intrusive works in all previously undisturbed ground i.e. that which has not previously been excavated, probed, drilled or otherwise intrusively disturbed since it had potentially become contaminated with UXO.

## EXECUTIVE SUMMARY (...continued)

### Recommended Risk Mitigation

#### All Groundworks in All Areas:

**1. Operational UXO Emergency Response Plan;** appropriate Site Management documentation should be held on-site to guide and plan for the actions which should be undertaken in the event of a suspected or confirmed UXO discovery (this plan can be supplied by *6 Alpha*);

**2. UXO Safety & Awareness Briefings;** the briefings are essential when there is a possibility of an-UXO / UXB encounter and are a vital part of the general safety requirement. All personnel working on the Site should receive a briefing on the identification of an UXO / UXB, what actions they should take to keep people and equipment away from such a hazard and to alert Site management. Information concerning the nature of the UXO / UXB threat should be held in the Site office and displayed for general information on notice boards, both for reference and as a reminder for ground workers. The Safety & Awareness briefing is an essential part of the *Health & Safety Plan* for the Site and helps to evidence conformity with the principles laid down in the *CDM* regulations 2015 (this briefing can be delivered directly, or in some cases remotely, by *6 Alpha*).

#### Excavations and Trial Pits into Previously Undisturbed Ground:

**3. EOD Banksman Support;** an EOD Engineer should be on-site, in the EOD Banksman role, to monitor all 'open' intrusive works into previously undisturbed ground as they progress and identify suspicious items which may or may not be UXO / UXB whilst also acting as the first point of contact for all UXO associated matters (this service can be provided by *6 Alpha*).

#### Cable Percussive Boreholes and Piling into Previously Undisturbed Ground:

**4. Intrusive UXO Survey;** Where 'blind' intrusive works into previously undisturbed ground are proposed, an intrusive UXO survey (employing down-hole magnetometer or MagCone techniques) is strongly recommended. Such a survey should extend to the *assessed average bomb penetration depth* or to the maximum depth of the works, whichever is encountered first, or until geology is encountered through which it is assessed a UXB would not penetrate, to identify for signs of sub-surface anomalies which may model as the target UXO in advance of said works. (this service can be provided by *6 Alpha*).

For further information, please contact Envirocheck:

Website: <http://www.envirocheck.co.uk>

Telephone: +44 (0)844 844 9952

Email: [customerservice@envirocheck.co.uk](mailto:customerservice@envirocheck.co.uk)

## ASSESSMENT METHODOLOGY

### Approach

6 Alpha Associates is an independent, specialist risk management consultancy practice, which has assessed the risk of encountering UXO (as well as buried bulk high explosives) at this Site, by employing a process advocated for this purpose by CIRIA. The CIRIA guide for managing UXO risks in the construction industry (C681) not only represents best practice but has also been endorsed by the HSE. Any risk mitigation solution is recommended *only* because it delivers the Client a risk reduced to ALARP at best value.

UXO hazards can be identified through the investigation of local and national archives associated with the Site, MoD archives, local historical sources, historical mapping as well as contemporaneous aerial photography (if it is available). Hazards will have only been recorded if there is specific information that could reasonably place them within the boundaries of the Site. The amalgamation of information is then assessed to enable the researcher to provide relevant and accurate risk mitigation practices.

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', such as equipment) to the hazard, at the moment of encounter.

If UXO risks are identified, the methods of mitigation we have recommended are considered reasonably and sufficiently robust to reduce them to ALARP. We advocate the adoption of the legal ALARP principle because it 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. This does not mean that there is never a requirement for UXO risk mitigation, but that 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, UXB and UXO risks will rarely be reduced to zero (nor need they be).

### Important Notes

Key source material is referenced within this document, whilst secondary/anecdotal information may be available upon request.

Although this report is up to date and accurate at the time of writing, 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 cannot exercise control.

## STAGE ONE – SITE LOCATION AND DESCRIPTION

### Study Site

The Client has defined the Study Site as “Homebase Ltd, 84, Manor Road, Richmond, TW9 1YB”. The Site is located at NGR 518920, 175460. The Site location and Site boundary are presented at *Figures 1* and *2* respectively.

### Location Description

The Study Site is situated within the *London Borough of Richmond-Upon-Thames* and covers an area of 1.8 hectares (ha).

Furthermore, the Site is bounded by:

- North-west: A railway line and industrial facilities;
- East: *Manor Road*;
- South: A railway line and residential houses.

### Aerial Photography (2018) (*Figure 3*)

Aerial photography (2018) corroborates the information above and shows that the Site is situated within a densely developed urban area. The Study Site itself consists of a large industrial building, hard-standing and a large Hard-standing car park.

### Proposed Works

The Client has described the following:

- “*Medium Trial Pit between 1m and 5m below ground level*;
- *Cable percussive boreholes up to 25m bgl*;
- *Basement and piling anticipated*”.

### Ground Conditions

It is important to establish the specific ground conditions in order to determine the maximum *German* UXB penetration depth as well as the potential for other types of munitions to be buried.

If the Site investigations and/or construction methodologies change, and/or if a specific methodology is to be employed, and/or if the scope of work is focused upon a specific part of the Site, then *6 Alpha* are to be informed so that the prospective UXO risks and the associated risk mitigation methodology might be re-assessed. Certain ground conditions may also constrain certain types of UXO risk mitigative works e.g. magnetometer survey is adversely affected in mineralised and made ground.

It is important to establish the provenance of made ground, where this is recorded as being part of the site ground make-up, in order to accurately determine the ground levels at the time when the site may have become potentially contaminated with UXO and so as to accurately determine the average / maximum bomb penetration depths and make appropriate recommendations aimed at reducing the risk to ALARP.



## STAGE ONE – SITE LOCATION AND DESCRIPTION (...continued)

### Ground Conditions

BGS borehole log “TQ17NE436 – Victoria Villas Richmond Upon Thames 1” (located 25m to the west), recorded the following strata:

| Depth bgl (m)   | Strata      | Description  |
|-----------------|-------------|--|
| 0.00m to 0.10m  | Made Ground | Concrete   |
| 0.10m to 0.80m  | Made Ground | Brown clayey silty sand with some gravel of brick, flint, concrete and clinker and some lenses of soft to firm brown sandy clay with occasional brick cobbles (0.70m).   |
| 0.80m to 1.50m  | Clay        | Soft brown sandy clay (0.70m)... from 1.00m, some fine to medium flint gravel.   |
| 1.50m to 1.80m  | Sand        | Medium dense brown fine to coarse silty sand with some lenses of sandy clay and some fine to coarse subrounded to angular flint gravel (0.30m).  |
| 1.80m to 2.80m  | Sand/Gravel | Medium dense brown fine to coarse sand and fine to coarse angular to rounded flint gravel (1.00m).   |
| 2.80m to 3.00m  | Clay        | Soft grey sandy clay with a little flint gravel.   |
| 3.00m to 3.90m  | Sand        | Medium dense brown fine to coarse sand with some fine to medium angular to subrounded flint and quartzite gravel (0.90m).  |
| 3.90m to 6.00m  | Sand/Gravel | Medium dense brown slightly clayey silty fine to coarse sand and fine to coarse rounded to angular flint and quartzite gravel (2.10m)<br>...from 5.00m, very sandy gravel.   |
| 6.00m to 6.30m  | Clay        | Stiff grey clay with some brown sand and fine to coarse flint gravel (0.30m).  |
| 6.30m to 15.00m | Clay        | Stiff extremely closely fissured grey-brown clay with occasional black silt partings (8.70m).<br>...from 10.55m, very closely fissured.<br>...from 13.00m, very stiff<br>...from 13.45m, occasional black silty sand partings. |

## 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. *6 Alpha's Azimuth Database*;
2. *Home Office WWII Bomb Census Maps*;
3. WWII and post-WWII aerial photography;
4. Official Abandoned Bomb Register;
5. Information gathered from the *National Archives at Kew*;
6. Historic UXO information provided by *33 Engineer Regiment (Explosive Ordnance Disposal) at Carver Barracks, Wimbish*.

### Potential Sources of UXO Contamination

In general, there are several activities that might contaminate a site with UXO but the three most common ways are: legacy munitions from military training/exercises; deliberate or accidental dumping (AXO) and ordnance resulting from war fighting activities (also known as the Explosive Remnants of War (ERW)).

During WWII, the *Luftwaffe* undertook bombing campaigns all over the *UK*. The most common type of UXO discovered today is the aerially delivered high explosive (HE) bomb, which are comparatively thick-skinned and dropped from enemy aircraft. If the bomb did not detonate when it was dropped, the force of impact enabled the UXO to penetrate the ground, often leaving behind it a UXB entry hole. These entry holes were not always apparent and some went unreported, leaving the bomb buried and unrecorded. More rarely, additional forms of *German* UXO are occasionally discovered including *inter alia* V1 and V2 rockets, Incendiary Bombs (IBs), and Anti-personnel (AP) bomblets.

Although the *Luftwaffe* had designated primary bombing targets across the *UK*, their high-altitude night bombing was not accurate. As a result, thousands of buildings were damaged and civilian fatalities were common. Bombs were also jettisoned over opportunistic targets and residential areas were sometimes struck.

As the threat of invasion lingered over *Britain* during WWII, defensive actions were undertaken. The *British* and *Allied Forces* requisitioned large areas of land for military training and bomb storage (including HE bombs, naval shells, artillery and tank projectiles, explosives, LSA and SAA). Thousands of tonnes of these munitions were used for the *Allied Forces* weapon testing and military training alone. It has been estimated that at least 20 per cent of the *UK's* land has been used for military training at some point.

*The best practice guide for dealing with your UXO risks on land* (CIRIA publication C681) suggests that approximately 10 per cent of all munitions deployed failed to function as designed. ERW are therefore, still commonly encountered, especially whilst undertaking construction and civil engineering groundwork.

Furthermore, in exceptional circumstances, UXO is discovered unexpectedly and without apparent rational explanation. There are several ways this might occur:

- When *Luftwaffe* aircraft wished to swiftly escape e.g. from an aerial attack, they would jettison some or all of their bombs and flee. This is commonly referred to as *tip and run* and it has resulted in bombs being found in unexpected locations;
- Transportation of aggregate containing munitions to an area that was previously free of UXO, usually related to construction activities employing material dredged from a contaminated offshore borrow site;
- Poor precision during targeting (due to high altitude night bombing and/or poor visibility) resulted in bombs landing off target, but within the surrounding area.
- *British* decoy sites were also constructed to deliberately cause incorrect targeting. For obvious reasons, such sites were often built in remote and uninhabited areas.

## Site History

From an analysis of the CS and OS historical mapping associated with the Site, the following Site history can be deduced:

|                         |  |
|-------------------------|--|
| <b>1896 CS Map</b>      | The Study Site was labelled as a “ <i>Timber Yard</i> ” with railway lines in the south-western sector and several small structures located in the central and south-eastern sectors, and along the north-western border.        |
| <b>1913 CS Map</b>      | Some structures had been demolished and numerous small structures and railway lines were developed on-site.  |
| <b>1920 CS Map</b>      | Changes were not recorded at the Study Site.   |
| <b>1934-1936 CS Map</b> | Several small structures were demolished and others developed on-site.   |
| <b>1938 OC Map</b>      | A long linear structure was developed on-site in the central sector.   |
| <b>1949 OS Map</b>      | Changes were not recorded at the Study Site.   |
| <b>1960 OS Map</b>      | Several structures were demolished and others developed on-site.   |
| <b>1966 OS Map</b>      | Changes were not recorded at the Study Site.   |
| <b>1988 OS Map</b>      | All structures on-site including railway lines were demolished, and two large structures were developed in the central and western sectors with smaller structures developed in the northern, south-eastern and central sectors. |
| <b>1991 OS Map</b>      | Changes were not recorded at the Study Site.   |
| <b>1999 OS Map</b>      | All structures on-site were demolished, and a large “ <i>Superstore</i> ” was developed in replacement.  |
| <b>2006 OS Map</b>      | Changes were not recorded at the Study Site.   |
| <b>2018 OS Map</b>      | Changes were not recorded at the Study Site.   |

### Aerial Photography (1945) (Figure 4)

The aerial photography (1945) associated with the Site shows that it is located within a developed urban area, with the Site itself consisting of various industrial facilities. Nonetheless, the resolution of the photograph is insufficient to be able to identify accurately, the precise local features and/or type of structures, then within the curtilage of the Site.

### 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 defences, 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. Many residential, commercial and industrial buildings were targeted during air raids and sustained large scale damage. Public services were also affected, with gas, electricity and water supplies often cut-off following damage to either the installations themselves or to the supply infrastructure. In addition, thousands of civilians were killed and injured, and many were forced to evacuate as their homes were destroyed.

### WWII Luftwaffe Bombing Targets

Prior to WWII, the *Luftwaffe* conducted numerous aerial photographic reconnaissance missions over *Britain*, recording key military, industrial and commercial facilities for attack, in the event of war. In addition, logistics infrastructure and public services, such as railways, canals, power stations, reservoirs, water and gas works were also considered viable bombing targets.

*Luftwaffe* aerial reconnaissance photography associated with the Site did not identify any primary bombing targets located on-site or within 1,000m of the Site boundary.

## WWII HE Bomb Strikes (Figure 5)

During WWII, ARP wardens compiled detailed logs of bomb strikes across their respective districts. ARP records associated with the Site did not note any HE bomb strikes within it, however six HE bomb strikes were identified 5m to the south, 50m to the north-west, 55m to the north-west, 70m to the south-west, 130m to the north-west and 155m to the east. Furthermore, whilst IBs may have fallen within the Study Site, they fell in such large numbers that accurate record keeping was either non-existent or perfunctory therefore, their prospective presence cannot be either corroborated or discounted.

In addition to IBs and HE bomb strikes, during the latter part of the war when aerial bombing had significantly declined, the main threat came from V type weapons. The first recorded V1 strike on London was on the 13<sup>th</sup> June 1944, with the first recorded V2 strike on London on the 8<sup>th</sup> September 1944. V1 and V2 rockets were thin-skinned, unmanned and inaccurate weapons. Despite this, there is no evidence to suggest that the Site (or its immediate vicinity) was subjected to rockets strikes during WWII.

The potential penetration depth of an UXB was dependent on a number of factors including but not restricted to those prior to striking the ground e.g. velocity and orientation of the UXB which in turn will be influenced on factors such as the release altitude from the aircraft and encounters with infrastructure during its fall; those encountered at the point of impact i.e. was the impact on concrete, grass, water etc and finally, the below ground level conditions which were encountered such as infrastructure e.g. services, basements, foundations, and geology e.g. made ground, clay, sand, etc. Further, as the UXB penetrated the ground, it's velocity naturally slowed where, it either came to an abrupt stop e.g. against foundations or would continue for 10's of feet along a route of least resistance which often resulted in a curving of the trajectory back towards the surface. This is known as the "J Curve" effect and often resulted in a considerable horizontal off-set from the point of entry. This is often the reason why UXBs have been discovered against or under the foundations of buildings, which were present during WWII, or many meters from the point of impact.

## WWII Bomb Damage

Official bomb damage mapping was not available. However, an analysis of post-war mapping identified "Ruins" 40m to the south and 65m to the south. In addition, photographic evidence and further research identified bomb damage along *Stanmore Gardens* located 180m north-west and *Peldon Avenue* located 345m to the south.

## WWII HE Bomb Density (Figure 6)

The Study Site was located within the *Richmond Municipal Borough*, which recorded 22 HE bombs per 100 hectares, a low level of bombing.

## Abandoned Bombs

An examination of the official abandoned bomb records has not identified any abandoned bombs within 1,000m of the Site boundary.

## Records of WWII UXB Disposal Tasks

Civil defence records did not identify any UXB disposal tasks within *Richmond Municipal Borough* from 1940-45. However, it is known that these records are incomplete, some having been destroyed by enemy action during WWII.

## Records of Post-WWII UXB Disposal Tasks

An examination of the post-WWII BDO tasks associated with the area has not identified any BDO operations within 1,000m of the Study Site.

## WWII Site Use

The CS mapping prior to WWII (1934 - 1936), shows that the Study Site was located within a densely developed urban area, with the Study Site itself consisting of a timber yard and several small structures. Therefore, it is considered possible that an employee at the timber yard may have observed and reported any UXB entry holes which would have been dealt with at the time. However, given the trajectory of incoming weapons this in fact may not have been the case.

## Sources of UXO Contamination

The most likely source of UXO contamination is from *German* aerially delivered ordnance, which ranges from small IBs through to large HE bombs (the latter forms the principal threat). Additional residual contamination may be present from *British* AAA projectiles (which were used to defend the UK against *German* bombing raids).

## STAGE THREE – DATA ANALYSIS

| Variable   | Result | Comment  |
|--|--------|--|
| Was the area considered to be a primary bombing target?  | ✗      | No primary targets were identified within 1,000m.  |
| Was the Site or the immediate area bombed during WWII?   | ✓      | Six HE bomb strikes were recorded within 155m of the Site boundary; the closest being 5m south.  |
| Did the Site or the immediate area experience bomb damage?                                       | ✓      | An analysis of post-war mapping identified “Ruins” located 40m south and 65m south.  |
| Was the ground undeveloped during WWII?  | ✓      | The Site consisted of a timber yard and several small structures, however some areas were left undeveloped.  |
| Would the footfall have been high in the area?   | ✓      | Given that a timber yard was located on-site and was situated within a developed urban area, it is likely that footfall would have been high.  |
| Would a UXB entry hole have been observed during WWII?   | ✓      | Given that the footfall would have been high on-site, it is considered likely that a UXB entry hole would have been observed and reported. However, given the trajectory of incoming weapons this in fact may not have been the case.                    |
| Have military personnel ever occupied the Site?  | ✗      | No military facilities were identified within 1,000m.  |
| Would munitions have been manufactured, stored and/or fired from the Site?                       | ✗      | There is no evidence to suggest munitions were located or fired from this Site.  |
| Would previous intrusive works have removed the potential for UXO to be present?                 | ✗      | The Site has undergone significant post-war redevelopment in some areas, therefore it is likely that any UXO within the structural foundations of post-war buildings would have been discovered and removed, whilst the surrounding areas remain extant. |
| Are proposed intrusive works likely to extend into previously undisturbed ground?                | ✓      | Some small areas of the Site have remained undeveloped since WWII and therefore some proposed works may extend into previously undisturbed ground.   |
| Is there potential for an unplanned encounter with UXO to occur during proposed intrusive works? | ✓      | Given that the immediate vicinity was subjected to bomb strikes and bomb damage, combined with some areas of the Site not undergoing any significant post-war redevelopment, it is considered possible for an unplanned encounter with UXO to occur.     |
| Does the probability of UXO vary across the Site?  | ✓      | The probability of discovering UXO within the structural foundations of post-war buildings is considered to be remote, however, the probability of UXO discovery within all previously undisturbed areas of the Site is extant.                          |

## STAGE FOUR – RISK ASSESSMENT

### Threat Items

The most probable UXO threat items are *German* HE bombs, whilst IBs and *British* AAA projectiles pose a residual threat. The consequences of initiating *German* HE bombs are more severe than initiating IBs or AAA projectiles, and thus they pose the greatest prospective risk to intrusive works.

### Bomb Penetration Depth

Considering the ground conditions (highlighted in Stage 1), the average BPD for a 250kg *German* HE bomb is assessed to be approximately 5m bgl, with the maximum BPD considered to be approximately 15m bgl. Although it is possible that the *Luftwaffe* deployed larger bombs in the area, their deployment was infrequent, and to use such larger (or the largest) bombs for BPD calculations are not justifiable on either technical or risk management grounds.

WWII *German* bombs have a greater penetration depth when compared to IBs and AAA projectiles, which are unlikely to be encountered at depths greater than 1m bgl. However, due to the “J Curve” and the potential for structures to impede the penetration into the ground, HE bombs have been discovered at much shallower depths than the average.

### Risk Pathway

Given the types of UXO that might be present on-site, all types of aggressive intrusive engineering activities (i.e. excavations, trial pits, cable percussive boreholes and piling) may generate a significant risk pathway. Whilst not all UXO encountered aggressively will initiate upon contact, such a discovery could lead to serious impact on the project especially in terms of critical injury to personnel, damage to equipment and project delay.

### Prospective Consequences

Consequences of UXO initiation include:

1. Fatally injure personnel;
2. Severe damage to plant and equipment;
3. Deliver blast and fragmentation damage to nearby buildings;
4. Rupture and damage underground utilities/services.

Consequences of UXO discovery include:

1. Delay to the project and blight;
2. Disruption to local community/infrastructure;
3. The expenditure of additional risk mitigation resources and EOD clearance;
4. Incurring additional time and cost.

## UXO RISK CALCULATION

### Site Activities

Although there is some variation in the probability of encountering and initiating items of UXO when conducting different types of intrusive activities, excavations, trial pits, cable percussive boreholes and piling have been described for analysis at this Site. The consequences of initiating UXO vary greatly, depending upon, *inter alia* the mass of HE in the UXO and how aggressively it might be encountered. For this reason, *6 Alpha* has conducted separate risk rating calculations for each trial pits, cable percussive boreholes and piling.

### Risk Rating Calculation

*6 Alpha's* Semi-Quantitative Risk Assessment assesses and rates the risks posed by the most probable threat items when conducting a number of different activities on the Site. Risk Rating is determined by calculating the probability of encountering UXO and the consequences of initiating it.

**UXO Risk Calculation Table – All Areas**

| Activity                                     | Threat Item     | Probability<br>(SH+EM=P) | Consequence<br>(D+PSR=C) | Risk Rating<br>(PXC=RR) |
|--|-----------------|--------------------------|--------------------------|-------------------------|
| <b>Excavations</b>                           | HE Bombs        | 2+2=4                    | 3+3=6                    | 4x6=24                  |
|  | AAA Projectiles | 1+2=3                    | 3+1=4                    | 3x4=12                  |
|  | IBs             | 1+2=3                    | 3+1=4                    | 3x4=12                  |
| <b>Trial Pits</b><br>(between 1m and 5m bgl) | HE Bombs        | 2+2=4                    | 3+3=6                    | 4x6=24                  |
|  | AAA Projectiles | 1+2=3                    | 3+1=4                    | 3x4=12                  |
|  | IBs             | 1+2=3                    | 3+1=4                    | 3x4=12                  |
| <b>Boreholes</b><br>(25 m bgl)               | HE Bombs        | 2+3=5                    | 3+2=5                    | 5x5=25                  |
|  | AAA Projectiles | 1+3=4                    | 3+1=4                    | 4x4=16                  |
|  | IBs             | 1+3=4                    | 3+1=4                    | 4x4=16                  |
| <b>Piling</b>                                | HE Bombs        | 2+3=5                    | 3+2=5                    | 5x5=25                  |
|  | AAA Projectiles | 1+3=4                    | 3+1=4                    | 4x4=16                  |
|  | IBs             | 1+3=4                    | 3+1=4                    | 4x4=16                  |

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

### Do the ground conditions support a geophysical UXO survey?

**Non-Intrusive Methods of Mitigation** – Magnetometer results may be affected by ferro-magnetic contamination due to previous construction activities and made ground within the Site.

**Intrusive Methods of Mitigation** – Intrusive magnetometry may be effective on this Site, prior to boreholing and piling especially. However, any ferrous metal/red brick contamination in made ground/old foundations may affect the detection capability of the UXB survey equipment, as it passes through the contaminated layer especially. Nonetheless, beyond the contaminated strata such a survey should prove effective.

### Mitigation Measures to Reduce Risk to 'ALARP'

| Activity  | Risk Mitigation Measures   | Final Risk Rating   |
|---|--|---|
| <p><b>All Activities in All Areas</b></p>                                   | <p><b>1. Operational UXO Emergency Response Plan;</b> appropriate Site Management documentation should be held on-site to guide and plan for the actions which should be undertaken in the event of a suspected or real UXO discovery (this plan can be supplied by <i>6 Alpha</i>);</p> <p><b>2. UXO Safety &amp; Awareness Briefings;</b> 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 briefing on the identification of a UXB, what actions they should take to keep people and equipment away from such a hazard and to alert Site management. Information concerning the nature of the UXB threat should be held in the Site office and displayed for general information on notice boards, both for reference and as a reminder for ground workers. The safety awareness briefing is an essential part of the <i>Health &amp; Safety Plan</i> for the Site and helps to evidence conformity with the principles laid down in the <i>CDM regulations 2015</i> (this brief can be delivered directly, or in some cases remotely, by <i>6 Alpha</i>).</p> | <p style="text-align: center; color: black; font-weight: bold;">ALARP</p> |
| <p><b>Excavations and Trial Pits into Previously Undisturbed Ground</b></p> | <p><b>3. EOD Banksman Support;</b> an EOD Engineer should be on-site, in the EOD Banksman role, to monitor all 'open' intrusive works into previously undisturbed ground as they progress and identify suspicious items which may or may not be UXO / UXB whilst also acting as the first point of contact for all UXO associated matters (this service can be provided by <i>6 Alpha</i>).</p>  |   |
| <p><b>Piling and Boreholing into Previously Undisturbed Ground</b></p>      | <p><b>4. Intrusive UXO Survey;</b> Where 'blind' intrusive works into previously undisturbed ground are proposed, an intrusive UXO survey (employing down-hole magnetometer or MagCone techniques) is strongly recommended. Such a survey should extend to the <i>assessed average bomb penetration depth</i> or to the maximum depth of the works, whichever is encountered first, or until geology is encountered through which it is assessed a UXB would not penetrate, to identify for signs of sub-surface anomalies which may model as the target UXO in advance of said works. (this service can be provided by <i>6 Alpha</i>).</p>   |   |

This assessment has been conducted based on the information provided by the Client, should the proposed works change then *6 Alpha* should be re-engaged to refine this risk assessment

## Report Figures

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## Figure One - Site Location

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### Site Location



BRITISH NATIONAL GRID



|                      |             |             |               |                         |  |  |  |
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| PROJECT NO.<br>P7115 | FIGURE<br>1 | DRAWN<br>BL | CHECKED<br>CC | DATE<br>09 January 2019 | Contains Ordnance Survey data ©<br>Crown copyright and database right 2017 | Produced by and Copyright to 6 Alpha Associates<br>Ltd. Users noting any errors please notify 6 Alpha. |  |
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## Figure Two - Site Boundary

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