Appendix A
Geotechnical Desk Study
This report takes into account the particular instructions and requirements of our client. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.
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**Issue Document Verification with Document**

- Prepared by
- Checked by
- Approved by

Signature

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Executive Summary

Introduction

Capital & Counties is proposing to develop a site compromising Earls Court Exhibition Centre, Earls Court Two and adjacent land. The site investigated in this desk study occupies approximately 44 acres.

At the instruction of Capital & Counties the scope of this desk study does not currently extend to the assessment of contamination and archaeology. It also excludes council housing to the west of the site that form part of the future development proposal.

The desk study provides early identification of potential site constraints that enables the design of a targeted, cost-effective intrusive investigation.

The Site and its Surrounding Areas

The site is located at Earls Court, London centred on TQ251782 and is on the boundary of the Royal Borough of Kensington & Chelsea and the borough of Hammersmith & Fulham.

The Light Detecting And Ranging (LiDAR) survey indicates that the average site level is between 3mOD and 5mOD with rail cuttings as deep as -3mOD. There is a general slope from east to west, with levels along Warwick Road between 7.2mOD and 7.5mOD dropping to between 5.0mOD and 4.1mOD from northwest to southeast, along North End Lane approx 600m to the west.

The site comprises of Earls Court Exhibition Centre, Earls Court Two, the Lillie Bridge Depot, rail siding and adjacent land as defined in the introduction to this report.

History of the Site’s Development

The site was agricultural in the 1800s with a canal running through the site which was later infilled to build a railway link. This later became part of the West London Line (originally called the West London Extension). There was additional railway development including the Metropolitan District Line and the Piccadilly Line, along with adjacent rail sidings and buildings including the Lillie Bridge Depot. The land was derelict and was used to host a fairground prior to development.

A review of historical mapping indicates the presence of ‘brick fields’ along the western boundary of the site. As a result of this land use, it is possible that some of the locally occurring gravels and clay may have been extracted from the site.

In 1935 work began on the Earls Court Exhibition Centre which opened in 1937. Earls Court Two opened in 1991 and spans the West London Line, now part of the London Overground network. The Exhibition site has not significantly developed since this time.

The A4 Cromwell Road Bridge was constructed during the Second World War and had been completed by 1944. A bridge has been located on Lillie Road since the construction of the canal.

The surrounding area has steadily developed with a mix of housing, retail and industrial units since the arrival of the railways.

Underground Structures and Obstructions

There is significant rail track and associated property owned by Transport for London and London Underground Limited within the site boundary. The District Line, Piccadilly Line and West London Line all intersect the site. West Kensington Station is within the site boundary and both Earls Court Station and West Brompton Station are adjacent to the site boundary. In addition to this, the A4 Cromwell Road A4 Bridge is a trunk road and therefore partially under control by TFL.

Other tunnels (such as MOD secret tunnels and the Thames Water Ring Main) may exist on the site. These parties should be contacted in the future, when we are more free to discuss proposed re-development details with outside parties.
1 Introduction

Ove Arup & Partners Limited (Arup) has been commissioned by Capital & Counties (the Client) to provide a geotechnical desk study for the proposed development at Earls Court, London.

The scope of work carried out as part of the Desk Study compromised:

- A limited walkover survey of the site from areas of public access;
- A review of historical mapping and aerial photographs;
- A review of the local geology, geomorphology, hydrogeology and hydrology;
- A review of available factual ground investigation data for the site;
- A review of third party information relating to the site.

At the instruction of the Client, the scope of the desk study does not include:

- Assessment of local archaeology;
- Potential for contamination.
- Contacting third parties for information including London Underground, Transport for London and local authorities without express approval from The Client. Furthermore, where approval has been granted, information pertaining to potential future development by the client should not be disclosed to third parties.

The proposed development site includes land currently occupied by council housing which is managed by Hammersmith & Fulham Council. This area has been excluded from the scope of the desk study which focuses on the core area where there are significant constraints to development.

The desk study provides early identification of potential site constraints that enables the design of a targeted, cost-effective intrusive investigation. The desk study provides information on the site that would not otherwise be identified by such an investigation.

This report takes into account the particular instruction and requirements of the Client. It is not intended for, and should not be relied upon by any third party. The report does not replace the need to carry out ground investigation works at the site and recommendations for further investigation are included.
2 The Site

2.1 Site Location Description

The site is located in Earls Court, London, SW5 and is approximately centred at TQ251782. The site is situated on the boundary of the Royal Borough of Kensington & Chelsea and the London Borough of Hammersmith & Fulham.

The site covers an approximate area of 44 acres and for the purposes of this desk study has been divided into three zones:

- Zone 1 contains the Earls Court Exhibition Centre and its grounds. It consists of a primary structure which is utilised as a mixed-use indoor hall used for concerts and exhibitions.
- Zone 2 contains Earls Court Two, an extension of the primary Earls Court Exhibition Centre. It also contains the Lillie Bridge Depot, rail sidings, assorted railway sheds and other structures.
- Zone 3 contains West Kensington Station and a parcel of industrial land running adjacent on the south side of West Cromwell Road (A4) between North End Road and Warwick Road.

Further to the above, the site contains three active train lines:

- The West London Line, an above-ground rail line orientated in the southeast – northwest direction;
- The District Line, a collection of buried and above-ground rail lines broadly orientated in the east-west direction;
- The Piccadilly Line, a deep train line orientated in the east-west direction.

The site and respective zones are shown on an Ordnance Survey plan and current Google Earth image as Figures 2.1 and 2.2 respectively. A plan detailing the layout of existing train lines is presenting as Figure 2.3.

2.2 Topography

The LIDAR survey undertaken in 2005 indicates that the average site level is between +3mOD and +5mOD with rail cuttings extending to -3mOD, constructed in the past 160 years. Road levels are between +8mOD and +10mOD. The site rises from the west from North End Road to the east towards Warwick Road Figure 2.4 shows the Digital Terrain Model (DTM) showing surface level, whilst Figure 2.5 shows the Digital Elevation Model (DEM) indicating building heights. Exact site levels should be confirmed by a topographic survey.

2.3 Site Walkover

An initial site walkover was conducted on 03 July 2008. At the request of the Client, this walkover was conducted from areas of public access only.

An additional visit was conducted on 28 July 2008 in order to visit the basement of Earls Court Exhibition Centre and the parcel of disused land between the rear of Philbeach Gardens and the West London Line.

Photographs taken during the site visits are presented as Appendix A.

2.4 Existing Bridge Structures

During the course of the site walkovers, existing bridge structures were observed at Lillie Street, Earls Court Two, Warwick Road, West Cromwell Road, West Kensington Station, and Lillie Bridge Depot.

Photographs of bridges at Warwick Road, Lillie Bridge Depot, and West Kensington Station are presented as Figures 2.6 to 2.8. Additional details relating to Lillie Bridge and Cromwell Road A4 Bridge are provided in the following sections.

2.4.1 Lillie Bridge

The Lillie Street Bridge is present at the southern tip of Zone 2 and was constructed sometime prior to 1827 (the date of the oldest map reviewed in Section 3.0).

Observations made during the site walkover indicate the bridge to be approximately 11m wide, 25m long, and is supported on two brick piers placed either side of the West London Line.

A photograph of Lillie Street Bridge, taken from Earls Court Two, is presented as Figure 2.9.

2.4.2 Cromwell Road A4 Bridge

The Cromwell Road A4 Bridge lies to the north of the site and is understood to be co-owned and managed by TFL and LUL.

The bridge is of concrete construction, contains a three lane carriageway and is supported on two concrete piers located either side of the West London Line. The approaches to the bridge appear to be constructed on earthen embankments. A single line of sheet piles can be seen on the southern face of the western approach embankment, possibly as a means of improving slope stability.

A photograph of the Cromwell Road A4 Bridge is presented as Figure 2.10.
3 Site History

3.1 Introduction

The historical interpretation utilised a combination of historical aerial photographs obtained from English Heritage, historical maps and a series of ten articles appearing in a publication called The Engineer over the period October to December 1937. Other sources were pre-Ordnance Survey (OS) mapping, annotated maps of the Geological Survey and bomb damage mapping.

In addition to the three zones defined in Section 2.3, an additional area covering the railway corridor which intersects Zones 1 and 2 is examined in this section as it is likely to influence any development proposals.

Copies of historical maps and aerial photographs reviewed as part of the desk study are presented as Appendices B and C respectively.

3.2 Aerial Photographs & Historical Maps

3.2.1 Zone 1

1800s

Greenwood’s map of 1827 (see Figure 3.1) shows limited coverage of this zone, but indicates that it is open agricultural land west of the estate called Earls Court on the east bank of a tributary of the River Thames. A lane extending from Brompton Road crossed the tributary at the present location of Lillie Road Bridge. The tributary, although unnamed on this map, was a minor canal with a dock cut in the bank at the site of the present West Brompton Station. The tributary is shown more completely on an undated, ca. 1850, map of the Kensington Canal. This canal was opened in 1828 along and near the line of Counters Creek which is shown on the map running sub-parallel to the canal and canal basin. The canal was tidal up to the locked basin north of the site. The canal was not a financial success and eventually the land occupied by the canal was sold to the London and Birmingham Railway Company which, as the West London Railway Company, infilled the canal and opened the West London Line (originally called the West London Extension) in 1863 along the canal route.

Stanford’s 1862 map (see Figure 3.2) shows the new railway as the West London Junction Railway traversing suburban fringe market gardens on the line of the former canal and tributary. West London (now Brompton) Cemetery had been laid out just south of the site area. Warwick Road had been extended southward to Richmond Road (now Old Brompton Road/Lillie Road) which bridged the new railway.

The first OS plan of 1869 (see Figure 3.3) shows a new railway junction of the Metropolitan District Line with the West London Line. This forms the distinctive triangular site formed by tracks in railway curve cuttings which link with the West London Line. In the south cutting twin tracks joined the West London Line tracks on the east side and in the north cutting twin tracks cross under the rail tracks in a short tunnel and then rise to link with the West London Line on its west side. The triangular area within the junction has no mapped detail. At the midpoint of each curve was a bridge over the cutting into the site. Eardley Crescent had been constructed to the south, but the site to the north was vacant.

The 1896 OS plan (see Figure 3.5) shows the Earls Court exhibition grounds with a circular road layout in the centre and a crescent-plan building on the east side. An article about the German Exhibition of 1891 shows the layout in greater detail and identifies all the structures (see Figure 3.4). The crescent-plan structure is the amphitheatre overlooking the area. The exhibition ground on the 1891 plan included land to the west accessed by a bridge over the West London Line. Two more bridges had been constructed over the south railway curve cutting between 1869 and 1891.

1900 to 1939

The 1916 OS plan (see Figure 3.6) shows a rectangular building in the place of the former amphitheatre, whilst the arena was little changed. In the south east corner of the site there was a feature called the Water Chute with a pond at the north end of the chute. The inset drawing to Figure 3.6 shows two storey exhibition buildings with a large ferris wheel at the north end and the chute at the south end of the site.

The next OS plan was not published until 1950 however, a series of ten articles appeared consecutively in The Engineer from October 1937 to December 1937 detailing the construction of the then new Earls Court Exhibition Building by Robert J Siddall, the consulting engineer to Earls Court Ltd. The architect was C Howard Crane, an American with considerable experience of large exhibition halls. The articles indicate that:

- Two additional tube lines had been constructed in tunnels beneath the site (see Figure 3.7);
- The rail lines in open cuttings were boxed in by concrete retaining walls and slab covers;
- The foundations of the structure of the new exhibition building were generally designed not to rest on the existing tunnels, but in unspecified locations did rest on augmented tunnel walls;
- There were 60 girders of 40 to 97 feet length carrying 150 columns over tunnels (see Figure 3.8);
- The clearance between girders (supporting columns over the tunnels) and the roofs of the tunnels is only 6/15cm;
- Poor ground conditions were encountered necessitating pad footings up to 15 feet below the tunnel floors at the column positions;
- A layer of ballast 6 to 10 feet depth generally carried the columns and pad footings but was often interrupted by old foundations;
- Where the ballast layer was not adequate, the foundation was extended through brown clay to blue clay (unweathered London Clay) and widened, sometimes extending laterally close to adjacent deepened footings;
- Counters Creek had been diverted to run in a sewer beneath Warwick Road;
- A pedestrian tunnel had been constructed from Earls Court Underground station beneath Warwick road and the Counters Creek Sewer into the Earls Court Exhibition Centre (see Figure 3.9);
- In the northwest third of the Earls Court Exhibition Centre the foundations were deepest, going down to 35feet bgl, due to the presence of the deep Ealing line tunnel;
- A large swimming pool in the building centre with its floor lifting mechanisms is in parts constructed to 34 feet (10m) below main floor level.

1940 to 1990

The air survey photo record (see Appendix C) also fills in the gap in the published OS map editions. The 1941 photos show (see Figure 3.10):

- The Earls Court Exhibition Centre with an elaborate camouflage pattern painted on it to break up its outlines and reduce its visibility;
- On the southeast and northeast sides, the access roads occupy decks over the former curved railway cutting rising above the gardens of houses fronting on Eardley Crescent and Philbeach Gardens respectively;
- On the long west side multiple tracks with sidings (6 to 10 tracks) occupy a cutting;
- There was a substantial building on a bridge over the cutting linking the Earls Court Exhibition Centre with most easterly of the depot buildings;
- The 1944 photographs show that the Cromwell Road elevated section was complete.

There was no change to Earls Court Exhibition Centre recorded on maps or air photos to 1990.

1990 to present

The 1997 photos show major change along the north-south rail cutting along the west side of Earls Court Exhibition Centre (see Figure 3.12). The building and bridge over the cutting and linked to Earls Court Exhibition Centre had been removed and replaced by the new Earls Court Two built over the cutting and extending over a large part of the former rail sidings and depot area to the west. The new
building consisted of a large single barrel vault. It is described in Section 3.2.2 below. Within the cutting, the number of tracks had been reduced to two. It appeared that earth had been imported and laid against the original steep cut slopes. Earls Court Exhibition Centre had been re-roofed but with no change to the roof profile or plan. There was no further change visible on the Google image of the site (see Figure 2.2).

3.2.2 Zone 2

1900s

Stanford’s 1862 map (see Figure 3.2) shows the new West London Junction Railway traversing suburban fringe market gardens. Zone 2 lies to the west of the railway and was not yet developed. Cromwell Road did not exist and Lillie Road was called Richmond Road at this time.

The first OS plan of 1869 (see Figure 3.3) shows the east half of the zone developed as the Lillie Bridge Works of the Metropolitan District Railway. It consisted of:

- Sidings entered from the north and occupying a level above the West London Line cutting with a carriage shed and workshops at the south end and along the edge of the cutting.
- The west half of the zone remained undeveloped as orchards and small fields;
- A stream and ditch are shown in the southwest corner, ending at the boundary of the Lillie Bridge Works.
- To the west of the site, there were brick fields west of North End Lane.

The second edition OS plan of 1896 shows (see Figure 3.5):

- Expansion of the exhibition grounds into the area with an access bridge across the West London Line cutting and the Lillie Bridge Works to a new exhibition building, and to the north, open park with a bandstand.
- The sidings area of Lillie Bridge Works expanded between the rail corridor and the extended exhibition grounds with additional small sheds.
- A new access cutting from the new West Kensington Station (Zone 3) extended down the west boundary to sidings of the Midlands Railway to the west side of a new exhibition building.
- New terraced housing adjacent to the west of the site on former large properties with gardens and orchards.
- New housing over the brickfields west of North End Lane.

1900 to 1939

The third edition OS plan of 1916 (see Figure 3.6) shows:

- The elevated section of Cromwell Road over the main West London Line rail track was under construction. It was extended to the west over the curve of the Ealing Line track running westward.
- A new long shed at the Lillie Bridge Depot, of the London Electric Railway, in place of the several small buildings of the former Lillie Bridge Works;
- A realigning of some sidings;
- New exhibition buildings replacing the long rectangular exhibition building of 1896;
- Three bridges over the Midlands Railway sidings access cutting.

There is a gap in the OS map record to 1950. The aerial survey photographs provide a three dimensional view of the site in 1941, 1944, 1945, 1946, 1947 and 1948.

1940 to 1990

The 1941 photos show (see Figure 3.10):

- The exhibition no longer occupied the north end of Zone 2;
- The exhibition buildings of 1916 had been removed and replaced by a long shed similar to the Lillie Bridge Depot;
- Between the sheds there was open storage of materials served by a travelling crane;
- At the south end a new exhibition building, the Empress Hall on a raised level above Lillie Road;
- Over the West London Line corridor the former bridge was replaced by a wider building spanning the corridor and linking with the Lillie Bridge Depot;
- There was a large camouflaged deck area around the Empress building and adjoining the Lillie Bridge Depot. The deck appears to be over sidings;
- The bridges over the Midland Railway sidings access had been removed.

There was no further change to the site to 1947. The 1951 OS map and 1955 air photo show no change.

The 1960 air photos show the Empress State Building under construction to approximately six storeys. The previous elevation of the Empress Hall had been removed so that the site was rising from a concrete surface at street level.

1990 to Present

No further changes are mapped to 1991. However, Earls Court Two was under construction at this time.

The 1997 air photo (see Figure 3.12) shows the completed large barrel vault roof of the newly built Earls Court Two spanning the West London Line corridor, and the east part of the previous decked depot and exhibition building. Earls Court Two was as long as the Earls Court Exhibition Centre and linked to it. There was an access bridge to the south entrance from the access ramp to Earls Court Exhibition Centre. At the north end there was an external road attached to Earls Court Two and bridging the railway corridor. The road turns and continues along the west side of the building with ramps down to car parks onto the roof/deck remaining of Earls Court Exhibition Centre.

There was no further change shown on the 2006 image (see Figure 2.2).
The first OS plan of 1869 (see Figure 3.3) shows:

- A new railway junction of the Metropolitan District Line with the West London Line with twin tracks in a curved south cutting joined the rail tracks on the east side;
- Twin tracks in the deeper north curved cutting, crossed under the West London Line in a short tunnel and then ascended to link with the West London Line on its west side;
- The rail tracks are shown in cutting from Lillie Bridge. The cut slope symbol extended the length of the corridor on the east side;
- On the west side the cut slope symbol extended from Lillie Bridge up to the point opposite where the north curved cutting entered. From this point the cut slope symbol changed to a single line and it appeared that there was a retaining wall for approximately 100m alongside the tunnel under the rail tracks, the tunnel portal and the ramp up to the West London Line track level. The cut slope symbol resumed and continued northward on the west side the rail tracks, well beyond the site boundary.
- Sidings on the west of the West London Line ascend southward from the rail tracks by the retaining wall to the level of the Lillie Bridge Works (later called the Lillie Bridge Depot);
- At the Lillie Bridge end of the corridor the West London Line consisted of twin tracks in a separate cutting from the twin tracks entering from the south curved cutting on the east and twin track sidings in a separate cutting on the west;
- The three narrow cuttings at Lillie Bridge merged into a wide single cutting with between two and seven sidings tracks;
- At the north site boundary, there were two sets of twin running track, the West London Line and the District Line from Earls Court Station and five sidings;
- The westward extension and Cromwell Road did not exist at this stage;
- A sinuous dashed line running west of the line of the retaining wall and then along the west side of the cutting is a boundary symbol following the line of the former Counters Creek.

The 1896 OS plan shows the following changes:

- A bridge from the exhibition grounds (Zone 1) crossing over the cutting and the adjacent Lillie Bridge Works to a new exhibition gallery (Zone 2);
- The reduction of the cut slope or the construction of a retaining wall on the east side of the corridor where the north curved cutting enters a tunnel under the West London Line;
- At Lillie Bridge, the remnant soil ridge was removed from the cutting to make a single wide cutting for the West London Line to accommodate more sidings, seven on the west side and one to the east of twin running tracks;
- At the north end of the cutting a new branch to the west and the new West Kensington Station (Zone 3);
- The tracks emerging from the tunnel under the West London Line (from the north curved cutting) entered a second short tunnel under sidings of the Lillie Bridge Works to enter the cutting to West Kensington Station;
- The earlier retaining wall was removed in association with the construction of the second short tunnel and a probable new retaining wall appeared to the east of the earlier retaining wall position and a cut slope symbol appeared to the west of it.

1900 to 1939

The 1916 OS map (see Figure 3.6) shows little change. The small buildings observed in the north end of the exhibition grounds were in different locations and had different shapes, suggesting that they were temporary exhibition buildings. There was no change to the track layouts. East of the West London Line rail corridor there was no change other than the indication of tennis courts and a nursery in the vacant space south of the houses on Fenelon Road.

There was no change to the tracks in the rail corridor to 1916. There is a gap in the OS map record to 1951. The aerial survey photographs provide a three dimensional view of zone 3 in 1941 and 1944, and partial mono cover in 1947.

1940 to 1990

The 1941 stereopair shows (see Figure 3.10):

- The elevated section of Cromwell Road over the main West London Line rail track was under construction. It was extended to the west over the curve of the track on the north side of West Kensington Station leading into the Lillie Bridge Works;
- The houses on both sides of the former Fenelon Road were demolished as part of the Cromwell Road extension; however, the open space of the tennis courts survived;
- The exhibition grounds had become part of the rail depot;

By 1944 the Cromwell Road A4 Bridge had been completed.

No further change was recorded on the 1960 photographs.

By 1971 the empty strip south of Cromwell Road, east of the West London Line, appeared to be used for material storage. West Kensington station is not covered, but the track layout up to it had not been altered. There was no further change recorded on the 1991 OS plans east of the rail corridor. To the west of the rail corridor and east of West Kensington Station, Ashfield House had been constructed and an adjacent bridge over the District Line cutting.

1990 to Present

There was no further change to 2006.

3.2.4 Railway Corridor

The corridor traverses the site from south to north and separates Zone 1 and Zone 2.

1900s

Greenwood's map of 1827 (see Figure 3.1) shows the corridor as a tributary of the River Thames flowing through open agricultural land west of the estate called Earls Court. It shows only the south end of the corridor bridged by the lane extending from Brompton Road at the present location of Lillie Road Bridge. Further detail of the canal is present in section 3.2.1.

Stanford's 1862 map (see Figure 3.2) shows the new railway as the West London Junction Railway traversing suburban fringe market gardens on the line of the former canal and tributary. The railway is shown as a single track. West London (now Brompton) Cemetery had been laid out just south of the site area. Warwick Road had been extended southward to Richmond Road (now Old Brompton Road/Lillie Road) which bridged the new railway. Cromwell Road did not exist at this time.
An extract of the bomb damage map depicting the site is presented as Figure 3.13. This map indicates that:

- A single V1 rocket landed in a residential area to the south of West Kensington Station. The impact resulted in several buildings being ‘totally destroyed’, with several others being ‘seriously damaged’.
- Two V1 rockets landed to the north of Earls Court Exhibition Centre. The impacts resulted in many buildings being ‘seriously damaged’, although a small number of buildings were ‘totally destroyed’.
- Varying levels of bomb damage are noted to the general east and south of the site. The nearest such incident is recorded at the former Empress Building, located to the immediate southwest of Earls Court Two. This building is noted to have suffered ‘general blast damage’ of a ‘non structural’ nature.
- A small area of bomb damage is noted within the site boundary, to the west of the present day Earls Court Two building. The bomb impact caused ‘serious’ damage to a previous area of car parking.

A review of aerial photographs (refer to Appendix C) confirm details obtained from bomb damage maps. Furthermore, these photos indicate that, in June 1941, several holes were present in the roofs of buildings comprising the Lillie Bridge Depot. It is likely that these holes were the result of aerial bomb strikes.

The Communities & Local Government Department were contacted and they have reported that there are no references to UXO for Earls Court within their database. However they note that London suffered extensive bomb damage during the war and that their search is not exhaustive.

Following a review of historical aerial photographs and published bomb damage mapping, it is apparent that the site and general surrounding area were bombed during the Second World War. Given that the site was associated with railway use during the war, however, it is unlikely that any bomb strikes would have gone unnoticed and that UXO is present at the site. In order to confirm this, however, a UXO desk study may be required.
4 Underground Structures

4.1 London Underground Tunnels

The site is underlain by tunnels of the District and Piccadilly Line.

4.1.1 District Line

In 1869 the junction of the Metropolitan District Line at Earls Court was formed with the West London Extension with two curved cuttings to the north and south. The former was deeper in order to pass under the West London Line.

The District Line tunnel from Earls Court to West Kensington Station was completed in 1874 (The London Underground 2007) and, as indicated on Figure 2.3, is comprised of three distinct sections:

- A covered section;
- A tunnel section;
- An overland section.

A review of historical mapping (refer to Section 3.0) indicates that the covered sections of track were originally constructed in 'open cut' shortly prior to 1869. These sections remained open until 1936, when they were covered over during the construction of Earls Court Exhibition Centre. Photographs of the culverted sections prior to burial are presented as Figures 4.1 and 4.2.

The tunnel sections of track are illustrated on a survey of Earls Court exhibition ground prior to the construction of the exhibition centre. This drawing (refer to Appendix D) indicates that:

- Two tunnels were present below Earls Court Exhibition Centre prior to 1935;
- Both tunnels measure approximately 6.5m in diameter;
- The crown of the northern tunnel (which runs from Ealing Broadway) is located at elevations of between 113.7 and 114.9 feet (+4.2 and +4.5mOD);
- The crown of the eastern tunnel (which runs from Putney) is located at elevations of between 127.9 and 128.8 feet (+8.5 and +8.8mOD).

Photographs of the tunnel section are presented in Appendix A. The overland District Line component extends from Earls Court Exhibition Centre to West Kensington Station. A photograph depicting the interface between the tunnelled and overland sections is presented as Figure 4.3.

4.1.2 Piccadilly Line

Twin tunnels of the Piccadilly Line were constructed during the late 1800s below the alignment of the pre-existing District Line. Information obtained from LUL (refer to Appendix E) indicates that the tunnel crowns are located at elevations of between -6.9 and -11.2mOD (approximately 15.9 to 20.2m below ground level).

4.2 Other Tunnels

4.2.1 Thames Water Main, Sewers & Conduits

Reference has been made to a plan detailing the proposed alignment of the Thames Water Ring Main in 1887. From this plan, the ring main is located approximately 700m northwest of the site, although the approximate as-built location will need to be verified.

4.2.2 MOD Tunnels

The Ministry of Defence (MOD) have been contacted via Groundwise. This enquiry is pending.

4.2.3 CrossRail

The site is not within the CrossRail safeguarding zone.

4.3 Underground Statutory Services

4.3.1 Introduction

A utility search has been carried out in order to locate the existing utilities within the site boundary and around the perimeter of the site, so that any constraints can be taken into account. Groundwise was commissioned by Arup to undertake a "C2" utility search in March 2008.

Out of 36 enquiries, 14 responses indicated plant in the area, of which 10 have equipment within the site boundary, and 4 have equipment adjacent but outside the site boundary. 21 utility companies have no apparatus in the area, and have confirmed this in writing. 1 response is awaited, from MOD Tunnels.

In addition, Kelly Taylor & Associates have been commissioned to continue the utility search for the site.

4.3.2 Findings

The 10 utility companies with equipment in the area are:

1. EDF Energy – The records indicate approximately 6 transformer compounds within the area of interest, with associated cable routes.
2. National Grid Gas – There are approximately 5 supply points at various locations round the site, but no evidence of large mains within the site boundary. The National Grid Gas 36 inch main and gas governor station which serves the Earls Court Exhibition Building is located just inside the site boundary, on the east side of the building coming from Warwick Road.
3. Thames Water – There are three supply connection points around the site perimeter for portable and fire main connections.
4. EDF Powerlink – The records show power cable routes running along the District and Piccadilly Lines.
5. BT – There are approximately 4 cable duct routes within the site boundary.
6. Thus – There is a leased duct running along the West London Line railway corridor.
7. Verizon - There is evidence of a supply to the Earls Court Exhibition Centre from Warwick Road.
8. Mobile Phone base stations – There is evidence of approximately 6 base stations within the site boundary. These will probably be attached to the existing buildings within the site.
10. LUL Tunnels – District and Piccadilly Lines are routed through the site. We have been informed that a disused section of line, formerly a connection from West Kensington Station to West Kensington Midland Railway coal yard, located to the west of Lillie Bridge Depot was removed in the 1960 – 1970 period, and Ashfield House is now on part of the alignment.

The table below provides summarised details of the utility search.
<table>
<thead>
<tr>
<th>No.</th>
<th>Utility</th>
<th>Undertaker</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Electricity</td>
<td>EDF Energy</td>
<td>6 transformer compounds and associated cable routes at: Ashfield House (1) Empress State Bldg (3) West London Line (1) ECEB (1)</td>
</tr>
<tr>
<td>2</td>
<td>Gas</td>
<td>National Grid Gas</td>
<td>150mm LP supply in Beaumont Avenue to Ashfield House 180mm LP supply to north side of Empress State Building LP supply in Empress Place LP supply at Lillie Bridge MP Mains in Lillie Road / Lillie Bridge 36 inch MP supply and gas governor to Earls Court Exhibition Building</td>
</tr>
<tr>
<td>3</td>
<td>Water Mains</td>
<td>Thames Water</td>
<td>6 inch metered supply and 10 inch fire supply to ECEB at Lillie Bridge 250mm and 180mm mains supply to ECEB from Warwick Road Three 125mm fire mains and a 90mm domestic main at Beaumont Avenue</td>
</tr>
<tr>
<td>4</td>
<td>Sewers</td>
<td>Thames Water</td>
<td>No TW sewers within boundary No record of private sewers available</td>
</tr>
<tr>
<td>5</td>
<td>Rail / Electricity</td>
<td>EDF Powerlink</td>
<td>Power cable routes within site boundary for District and Piccadilly Lines</td>
</tr>
<tr>
<td>6</td>
<td>Telecoms</td>
<td>BT</td>
<td>4 routes within site boundary</td>
</tr>
<tr>
<td>7</td>
<td>Colt</td>
<td></td>
<td>No routes within site boundary</td>
</tr>
<tr>
<td>8</td>
<td>Virgin Media</td>
<td>(NTL: Telewest)</td>
<td>No routes within site boundary</td>
</tr>
<tr>
<td>9</td>
<td>Thus</td>
<td></td>
<td>Leased duct in West London Line railway corridor</td>
</tr>
<tr>
<td>10</td>
<td>Verizon (MKI, MCI, Worldcom, MFS)</td>
<td></td>
<td>Supply to ECEB from Warwick Road</td>
</tr>
<tr>
<td>11</td>
<td>OFCOM Mobile Phone Bases</td>
<td></td>
<td>6 base stations within boundary</td>
</tr>
<tr>
<td>12</td>
<td>Cable &amp; Wireless</td>
<td></td>
<td>Routed along Piccadilly and District Lines</td>
</tr>
<tr>
<td>13</td>
<td>Transport</td>
<td>TIL (London Streets)</td>
<td>No routes within site boundary</td>
</tr>
<tr>
<td>14</td>
<td>LUL Tunnels and Open-cut</td>
<td></td>
<td>Piccadilly and District Lines</td>
</tr>
</tbody>
</table>
5 Ground Conditions

5.1 Published Geological Information

5.1.1 Introduction
The 1:10,000 BGS geology maps sheets TQ27NW and TQ27NE cover the site area and typically show the ground conditions to comprise level to very gently sloping Kempton Park river terrace gravels overlaid by London Clay (see Figure 5.1). The site surface however has been extensively disturbed by building and transportation developments since the 1860s, which has resulted in the placement of Made Ground over much of the site.

The site has been occupied by a canal, major exhibition buildings, a railway corridor and extensive railway sidings, for a depot and workshops. A north-south railway corridor traverses the site in shallow cutting with a branch to the west in the northeast corner. Tunnels – cut and cover, and bored – underlie the east part of the site with connections to the surface rail corridor.

5.1.2 Geologic Formations
As described above, the geology maps show that the site area comprises Kempton Park Gravels overlaid by London Clay. The surface of the Kempton Park Gravel is recorded to be either level or gently sloping and Made Ground is only recorded in the centre of the Earls Court Exhibition Centre. London Clay is exposed only in the main railway corridor south of the Empress State Building. The generalised section shows that the Kempton Park Gravels are underlain by London Clay, Lambeth Group, Thanet Sands and Chalk in succession.

The River Terrace Gravels at the site formed after the Anglian glaciation approximately 500,000 years ago, which caused the diversion of previous river courses by ice blockages and formed the Thames Valley. The terrace gravels were deposited in the new river valley and are differentiated by altitude rather than composition as they formed in progressively lower elevations above the modern floodplain as the River Thames down cut into its surroundings (BGS, 2004). The Kempton Park Gravel found at the site was deposited in a braided river system and is the lowest level of river terrace gravels above the current River Thames flood plain (BGS, 2004). The Kempton Park Gravel was deposited between 150,000 and 670,000 years ago.

The Kempton Park Gravel typically consists of 5 to 8m of sandy, clayey flint gravel. The gravel cover is continuous over the site and general vicinity except in the railway cutting to the south of the site.

The London Clay formed under marine conditions in the Palaeogene Period (65 to 24 million years ago) and is a stiff silty clay which contains glauconite, selenite (gypsum) in its upper few metres, carbonate concretions and pyrite. This unit has been eroded over time, removing the younger overlying glacial deposits and resulting in the direct deposition of recent River Terrace Gravels onto the older London Clay.

The London Clay typically consists of grey to blue-grey fissured clay weathering in the top 3 to 6m to brown. Its full thickness ranges between 90 and 130m. It is sandier towards the top of the formation and at its base. The only exposure of London Clay in the vicinity is in the railway cutting immediately south of the site.

5.1.3 Geologic Structure
The structure of London is dominated by the broad north-east-trending syncline with low dip angles which forms the London Basin. This structure formed contemporaneously with mountain building in Europe, which formed the Alps and began during the early Palaeogene Period (approximately 60 million years ago). Compression forced the London Platform to subside as the Wessex Basin and East Midlands Shelf were uplifted.

Although no large-scale faults are known in the area, many small-scale extensional faults occur throughout the basin, typically trending north-west. There is no published information about the regional distribution of small faults (BGS, 2004).

5.1.4 Existing Earthworks and Made Ground
The area has been totally developed since it was open agricultural land in the 1850s. The railway corridor of the West London Line is in shallow cutting along the infilled channel of Counters Creek and the Kensington Canal which followed on and near the creek channel. Counters Creek was culverted and diverted along the line of Warwick Road. The rail corridor cutting is within the river terrace gravels except for a short length just south of the site where the London Clay is exposed along the railway.

Excavated gravel from the cuttings of the Metropolitan District Line would have been used or sold as aggregate. Excavated clay from the deep tunnels may have been spread in the area of sidings to the west of the West London Line corridor where the Made Ground is primarily brown sandy clay. The railway cutting, opened as the West London Extension in the 1850s, had a width accommodating 10 tracks. It was infilled in the 1990s as the sidings had been taken up, leaving two running tracks in a narrower apparent cutting with actual fill side slopes (see Figure 2.2).

5.2 Geomorphology & Hydrology

Original surface drainage was towards the southeast across the site; flowing in Counters Creek approximately along the line of the existing main railway corridor. It is depicted on the 1:10,560 geological map of London without tributaries. The early 1827 Greenwood maps (refer to Figure 3.1) suggests field perimeter ditches for drainage or irrigation.

Counters Creek now runs in a sewer under Warwick Road and all former surface drainage ditches and channels are accommodated in sewers.

The flood risk map shows that the site area is susceptible to flooding from the River Thames, which lies 1.5km from the southern site boundary. However, Thames flood defences are designed to contain a 1 in 100 year event (see Figure 5.2).

5.3 Hydrogeology

Much of the London area is underlain by a ‘shallow’ aquifer contained within locally occurring River Terrace Deposits and a ‘deep’ aquifer flowing through the Thanet Sand and Upper Chalk Formations. These aquifers are typically separated by a significant thickness of clay of the London Clay and Lambeth Group Formations.

5.3.1 Shallow Aquifer

Information presented on the Environment Agency website (EA 2008) suggests that the River Terrace Deposits underlying the site constitute a ‘minor’ aquifer of variable permeability. Records of shallow groundwater levels at the site are presently unavailable, although such groundwater is typically encountered at depths of around 1.5 to 2.0m.

5.3.2 Deep Aquifer

A recent report on groundwater levels in the Chalk aquifer (EA 2007) indicates the piezometric surface of the deep aquifer to be located at an approximate elevation of -10mOD (19m below ground level) and that the direction of groundwater flow is towards the east.
5.4 British Geological Survey (BGS) Records

The site is well covered by existing borehole information held by the BGS, particularly along the north boundary, near West Kensington Station and south of Lillie Road Bridge (refer to Figures 5.3). Summaries of anticipated ground conditions at each of the redevelopment zones are as follows:

### Zone 1

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Elevation of Top of Stratum (mOD)</th>
<th>Observed Stratum Thickness (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Made Ground</td>
<td>+4.1 to +7.9</td>
<td>0.4 to 3.6</td>
</tr>
<tr>
<td>River Terrace Deposits</td>
<td>+1.2 to +5.9</td>
<td>1.4 to 6.6</td>
</tr>
<tr>
<td>London Clay Formation</td>
<td>-1.1 to +2.8</td>
<td>56.4*</td>
</tr>
<tr>
<td>Lambeth Group Formation</td>
<td>-53.6*</td>
<td>22.1*</td>
</tr>
<tr>
<td>Thanet Sand Formation</td>
<td>-75.7*</td>
<td>3.8*</td>
</tr>
<tr>
<td>Upper Chalk Formation</td>
<td>-79.5*</td>
<td>&gt;42.6*</td>
</tr>
</tbody>
</table>

* Values obtained from single deep borehole located at southern tip of Zone 1

### Zone 2

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Elevation of Top of Stratum (mOD)</th>
<th>Observed Stratum Thickness (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Made Ground</td>
<td>+1.5 to +4.2</td>
<td>0.3 to 0.5</td>
</tr>
<tr>
<td>River Terrace Deposits</td>
<td>-2.0 to +2.0</td>
<td>0.3 to 5.9</td>
</tr>
<tr>
<td>London Clay Formation</td>
<td>-4.0 to +1.0</td>
<td>51.2</td>
</tr>
<tr>
<td>Lambeth Group Formation</td>
<td>-53.3</td>
<td>15.4</td>
</tr>
<tr>
<td>Thanet Sand Formation</td>
<td>-69.0</td>
<td>10.5</td>
</tr>
<tr>
<td>Upper Chalk Formation</td>
<td>-78.9</td>
<td>&gt;64.3</td>
</tr>
</tbody>
</table>

* Values obtained from single deep borehole located west of Zone 2

### Zone 3

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Elevation of Top of Stratum (mOD)</th>
<th>Observed Stratum Thickness (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Made Ground</td>
<td>+2.3 to +5.1</td>
<td>0.3 to 3.1</td>
</tr>
<tr>
<td>River Terrace Deposits</td>
<td>+2.0 to +2.7</td>
<td>1.5 to 5.1</td>
</tr>
<tr>
<td>London Clay Formation</td>
<td>-3.1 to -1.1</td>
<td>51.2</td>
</tr>
<tr>
<td>Lambeth Group Formation</td>
<td>-53.3</td>
<td>15.4</td>
</tr>
<tr>
<td>Thanet Sand Formation</td>
<td>-69.0</td>
<td>10.5</td>
</tr>
<tr>
<td>Upper Chalk Formation</td>
<td>-78.9</td>
<td>&gt;64.3</td>
</tr>
</tbody>
</table>

* Values obtained from single deep borehole located south of Zone 3

A plan depicting the elevation of the top of the London Clay Formation across the site is presented as Figure 5.4.

Copies of the BGS borehole logs are presented as Appendix F.

6 Engineering Design Considerations

This section summarises the principal ground related issues and risks identified during the desk study. These ground related issues have the potential to delay or add cost to the overall redevelopment. It should be noted that engineering issues associated with potential ground contamination and archaeology have not been considered.

6.1 Buried Obstructions

Historical foundations and sub-structure remains are likely to exist on site and may lead to construction difficulties for future development. Specific obstructions likely to be encountered across the site are outlined as follows:

#### 6.1.1 Earls Court Exhibition Centre

As indicated on Figure 2.1, the entirety of Zone 1 is occupied by the Earls Court Exhibition Centre, which was constructed in 1936 at the site of a previous exhibition space. It comprises of first and second level assembly halls, a ground floor level with swimming pool, a basement, and a partial lower basement. A plan of the development, which contains first and second levels assembly halls, a ground floor level with swimming pool, a basement, and a partial lower basement, is contained within Appendix D. Design levels are not provided in these drawings, although it is understood from articles published in *The Engineer* that the swimming pool extends approximately 10m below ground level.

The design and construction of Earls Court Exhibition Centre is discussed in a series of ten articles which were published in *The Engineer* during the period of October to December 1937 (*The Engineer* 1937). A review of these articles indicates the following:

- Prior to the construction of Earls Court Exhibition Centre, two railway lines were present below the northern and eastern edges of the building site. As these railways were constructed in ‘open cut’, they were culverted and covered over prior to the construction of Earls Court Exhibition Centre. Photographs of the culverted sections are presented as Figures 4.1 and 4.2.
- Two new tunnels were constructed below the site prior to the construction of Earls Court Exhibition Centre. As illustrated in Appendix D, these tunnels are 6.5m in diameter. The crown of the northern tunnel (which runs from Ealing Broadway to Earls Court) is situated at elevations of between +4.2 and +4.5mOD and the crown of the eastern tunnel (which runs from Putney to Earls Court) is situated at elevations of between +8.5 and +8.8mOD.
- In order to limit vibration loads on the underlying rail lines, it was determined the most of Earls Court Exhibition Centre would be founded on a combination of ‘shallow’ spread and piled foundations. These foundations were designed to bear on sand and gravel River Terrace Deposits at an approximate elevation of +3.0mOD (6m below ground level) and would have been constructed within narrow, braced hand excavations. Where unsuitable bearing materials were encountered at design founding elevation, the depth of the excavation would have been increased or, alternatively, the base of the excavation would have been ‘undercut’ in order to accommodate an increased foundation width.
- The locations of the shallow pad and strip foundations, together with typical foundation cross sections are presented in Appendix D. The width of these foundations is noted to vary from between 4ft (1.2m) and 31.5ft (9.6m).
- The existing track layouts below the southern and eastern tips of the exhibition site required the construction of some piled foundations (referred to as ‘stanchions’ in *The Engineer*). These piles were required to extend 15ft (4.5m) below track level, which corresponds to an approximate toe elevation of -2mOD.

Records obtained from London Underground Limited (LUL) indicate that the exhibition centre basement was reconstructed during the late 1940s. As part of the reconstruction process, additional walls, columns, and ground beams were constructed. In order to carry the revised loading, the redevelopment also required the construction of additional piles and column pads. Design drawings...
relating to the basement reconstruction are presented as Appendix G. Drawing number C182 / 54 is of particular interest as it indicates several column pads sitting directly on top of an existing rail tunnel. It is thought that this rail tunnel forms part of the District Line to Ealing Broadway.

Records obtained from TFL also indicate that in the early 1960s design drawings were issued for the construction of a new access ramp. Although the location of this ramp cannot be determined, it is clear that the ramp was intended to be supported by a series of 36 new piles. Plans depicting the proposed pile locations are presented as Appendix H.

6.1.2 Earls Court Two

Earls Court Two is located within the southern half of Zone 2, to the immediate west of Earls Court Exhibition Centre. The development was opened to the public in 1991 and was constructed at the site of a former car park associated with the adjoining Earls Court Exhibition Centre. A review of historical OS maps (refer to Section 3.0) indicates that, prior to being used for car parking, the site contained a small number of railway buildings.

A drawing has been obtained from LUL depicting two cross sections through the Earls Court Two structure. This drawing (refer to Appendix I) indicates the building to be comprised of two main levels:

- An upper exhibition level at 111.7m (11.7mOD);
- A lower level at elevations of between 102.550m (2.6mOD) and 104.02m (4.0mOD).

In order to provide a column-free exhibition space, the building has been covered with an arched roof. In a leaflet published by British Steel (British Steel 1991), it is stated that the development is constructed on piles of unspecified depth, diameter, and construction. Shallow foundations were not considered feasible due to the relatively long spans and high impact loads resulting from potential railway accidents.

The central portion of the lower level has been sub-divided to form two levels of parking at 103.975m (4.0mOD) and 107.675m (7.7mOD).

6.1.3 Lillie Bridge Depot

Much of Zone 2 is presently occupied by the Lillie Bridge Depot, which was observed to contain:

- A brick train shed;
- Between eight and ten metal clad industrial shed and/or warehouses;
- Three two storey office buildings;
- An undetermined number of temporary storage containers and sheds;
- Areas of hard standing and associated rail track.

A review of historical OS maps (refer to Section 3.0) indicates this area to be associated with railway use from as early as 1869. Much of this area has undergone successive phases of redevelopment, which has likely resulted in the presence of numerous buried obstructions. These obstructions will most likely relate to ‘shallow’ strip, raft, or pad foundations, although tanks, rail sidings, etc may also be present.

The depot is accessed from the western edge of Earls Court Two (see above).

6.1.4 Ashfield House

Ashfield House is located at the eastern edge of Zone 3. Although detailed foundation plans have not been obtained from Transport For London (the building’s occupant), this structure is likely to be founded on piles extending into the London Clay Formation. This assumption is based upon the observed height of building, which is around 10 stories.

Further to the above, limited above ground parking facilities were observed during the site walkover. Additional basement parking facilities are therefore inferred.

6.1.5 West Kensington Station

The West Kensington Underground Station is located at the western tip of Zone 3. The station is located on the District Line (Upminster to Richmond and Upminster to Ealing Broadway) and contains two above ground platforms, together with a private LUL bridge with is used by LUL and TFL for access to Ashfield House and Lillie Bridge Depot.

Drawings obtained from LUL (refer to Appendix J) indicate the station to be founded on shallow strip and pad foundations extending approximately 0.9m below platform level. These depths cannot be referenced to Ordnance Datum, as elevations are not provided.

A review of historical mapping (refer to Section 3.0) indicates that West Kensington Station was constructed during the period of 1874 to 1896. Prior to being developed as railway land, the site contained a number of small houses and an orchard.

6.1.6 Beaumont Road Industrial Estate

An industrial estate presently occupies the southern half of Zone 3. This estate is dominated by two brick, two storey buildings. Recent OS mapping (refer to Figure 2.1) indicates the western building to be a ‘laundry’.

Based upon the building’s outward appearance and height, it is likely that the trading estate structures are founded on ‘shallow’ strip, pad, or spread foundations. The foundations were likely constructed within locally occurring River Terrace Deposits, which are located approximately 2.5m below ground level.

A review of historical mapping (refer to Section 3.0) indicates that the industrial estate site previously contained terraced housing and a ‘laundry’. These structures were likely constructed on shallow foundations which may not have been fully removed during the construction of the present day buildings.

6.1.7 Empress Place

Two and three storey terraced apartments are present at the southern tip of Zone 2, off Empress Place. A review of historical OS mapping (refer to Section 3) indicates that most of these buildings were constructed sometime during the period of 1862 and 1869 may possess basements and would be founded on strip foundations.

6.2 Services and Underground Utilities

Redevelopment of the site may cause ground movements both within and around the site boundary. When designing any substructure, potential ground movements need to be evaluated and, where required, controlled in order to avoid damaging existing services and underground utilities.

6.3 Tunnels

As outlined in Section 4, the proposed redevelopment site is known to be underlain by tunnels of the Piccadilly and District Line.

The effects of any future redevelopment at the site will need to be considered and evaluated, with a view towards limiting the magnitude of any additional vertical stresses being applied to the tunnel crowns.

6.4 Unexploded Ordnance

As outlined in Section 3, the proposed redevelopment site and surrounding area is known to have been bombed during the Second World War. A risk assessment for German air dropped unexploded ordnance (UXO) therefore, may need to be undertaken.

Further to the above, it should be recognised that the probability of encountering any UXO at the site during ground investigation is considered very low due to small volume of soil disturbed during advancement of boreholes and trial pits. Nevertheless, the ground investigation contractor should make their own assessment and take appropriate precautions.

6.5 Groundwater

As outlined in Section 5, the proposed redevelopment area is underlain by 2.3 to 8.3m of Made Ground and River Terrace Deposits, overlying approximately 50m of London Clay Formation.
Although groundwater levels are presently unknown, it is likely that some ‘shallow’ groundwater will be present within the Made Ground and River Terrace Deposits.

Given the high permeability of the River Terrace Deposits, any excavation penetrating these deposits will likely be subject to high rates of groundwater ingress. Groundwater control measures will therefore be required at the site prior to initiating any excavation deeper than around 2.0m without a cut-off wall. Any basement constructed as part of the redevelopment should be designed to act as a vertical cut-off wall.

6.6 Earth Retaining Structures

During the site walkover, earth retaining structures were noted:

- Below Earl's Court Two;
- At the interface between tunnelled and overland components of the District Line;
- Along the southern edge of District Line track, between Ashfield House and West Kensington Station.

The locations of observed earth retaining structures are illustrated on Figure 2.1, with photographs being presented as Figures 4.1, 6.1, and 6.2.

If these walls are to be retained as part of the proposed redevelopment, then as-built details will need to be obtained or intrusive investigation will need to be undertaken. It is possible that some of the walls have been stabilised using metal ‘tie backs’, which would form an obstruction to excavation and/or piling.

6.7 Earthen Slopes

Earthen slopes are present along the southern edge of the District Line railway, in the vicinity of West Kensington Station, and at the approaches to the A4 Cromwell Road Bridge. The stability of these features will need to be considered during the design of any proposed redevelopment.
7 Foundation Options, Earthworks Issues, and Recommendations

7.1 Foundation Options

The following Section considers foundation options for the proposed development. Although these options are generally applicable to all areas of the site, it must be remembered that the overall redevelopment strategy has not yet been determined.

7.1.1 Shallow Foundations

Traditional strip, spread, or pad foundations could be used across the site for founding components of the proposed redevelopment. Given the variable nature of the Made Ground, it is recommended that all shallow foundations be designed to extend beyond this stratum, which has been observed at a maximum thickness of around 5.6m.

7.1.2 Piled Foundations

Piled foundations could either comprise a single large diameter pile per column or groups of smaller diameter piles in a pile cap. Each of these options has associated advantages and disadvantages and these will need to be considered in deciding upon the most appropriate foundation scheme. The choice of piling option will also be governed by the choice of piling method as discussed below.

Rotary Bored Piles

Rotary bored piles are a common method of pile construction in London, pile diameters can range from 0.6m to 2.7m with very long piles possible if required.

Construction of all rotary bored piles would require temporary casing of the bore through the unstable Made Ground and Terrace Gravel. In addition, probing and removal of obstructions will be required prior to commencement of piling.

Continuous Flight Augur (CFA) Piles

Construction of CFA piles have the advantage that neither casing nor drilling mud is required for pile construction. Pile construction times are usually less than for rotary bored piles as long as a thorough pile probing operation has been carried out beforehand to remove all ground obstructions.

Conventional pile diameters from 0.6m up to 1.2m and lengths up to 25m can be achieved using conventional CFA methods but this is highly dependent upon the torque capacity of the piling rig and the presence of obstructions and hard band layers (e.g. Limestone and Claybands) in the London Clay. Pile design for this pile type would be based primarily on generating friction along the pile sides, with piles extending into the London Clay. This method of piling lends itself to the piling option where groups of smaller diameter piles are positioned under a pile cap.

CFA piles are also unable to progress through old foundations and obstructions in the fill and claystone in the London Clay. If the site is situated in an area with scour hollows then the London Clay strength will be reduced and piles will have lower capacity, this may preclude the use of CFA piles.

Driven Piles

On account of the noise and vibrations experienced during piling, driven piles are unlikely to be suitable for use at the site.

7.2 Earthwork Issues

Borehole data obtained from the BGS (refer to Section 6) indicates that between 1.3 to 2.5m of Made Ground is likely to be present at the site. With the exception of areas beneath any proposed basement, all earthworks are therefore likely to encounter this material.

As the nature of Made Ground is inherently variable it is not possible at this stage, and in the absence on site specific ground investigation data, to define the exact nature of future earthworks on the site. The following issues should be considered as part of the development of an enabling works / earthworks programme:

- Safe and documented management of excavations through potentially contaminated Made Ground including control of dust and appropriate protection for workers.
- Safe and documented management of stockpiled material for reuse on site or offsite disposal.
- Enabling works program to remove known obstructions (associated with historical development of the site) along alignments of new services and for new building substructure / foundations.
- Measures to control groundwater in exactions that are progressed below 2.0m below ground level.

7.3 Recommendations

The following section discusses recommendations for future work to assist in the design of any redevelopment of the site.

7.3.1 Further Desk Study Research

At the request of the Client, the desk study did not consider potential issues relating to archaeology and contamination. In order to inform any forthcoming redevelopment proposals, it is recommended that the desk study be updated to include these items.

The proposed development site includes land currently occupied by council housing which is managed by Hammersmith & Fulham Council. This area has been excluded from the scope of the desk study which focuses on the core area where there are significant constraints to development. It is recommended that the coverage of the desk study be extended to incorporate this area prior to the master planning stage.

7.3.2 Ground Investigation

In order to inform future development proposals for the site, it is recommended that additional ground investigation be carried out. The scope of the proposed ground investigation will be largely determined by the scale of the proposed redevelopment, but will generally be required to confirm:

- Soil stratigraphy;
- Soil parameters for geotechnical design;
- Depth to shallow groundwater below the site;
- Potential for sulphate attack on buried concrete.

Further to the above, it is often economical to combine geotechnical and geoenvironmental ground investigation work into a single ground investigation. If this model is adopted for the site, then the recommended ground investigation should also confirm:

- Environmental quality of site soils and groundwater;
- Potential for generation and flow of soil gasses below the site.
8 References

(The Engineer 1937) Earls Court Exhibition Building (10 articles), October – December 1937
(Envirocheck 2007) Landmark Envirocheck Report (December 2007)
Legend

- Earls Court Exhibition Centre
- Earls Court Two
- Lillie Bridge Depot
- West Kensington Station
- Industrial Park
- Terrace Housing
- West Cornwall Road Bridge
- Lillie Bridge
- LUL private footbridge
- Bridge at Lillie Bridge Depot
- Retaining walls at Entrance to District Line
- Retaining walls to North of Ashfield House
- Ashfield House
- Retaining walls below Earls Court Two

Tracks under LUL Ownership

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SCALE 1:4000

PROJECT ECO
ZONE LOCATIONS
125066  FIGURE 2.1
Processed using ArcGIS from Infoterra LIDAR (flown 2005)