University of London

Ground Investigation, Geotechnical and Geoenvironmental Assessment

Garden Halls, University of London

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Cundall Johnston and Partners LLP Horsley House Regent Centre Gosforth Newcastle-upon-Tyne NE3 3LU Tel +44 (0)191 213 1515
www.cundall.com

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EXECUTIVE SUMMARY

Scheme

University Partnerships Programme Limited (UPP) proposes to redevelop the site of existing University Halls of Residence at Cartwright Gardens, Camden, London on behalf of the University of London. The existing Hughes Parry tower is to be retained but the remaining existing halls of residence (Hughes Parry Hall, Canterbury (including York) and Commonwealth Halls) will be demolished and replaced by a series of new 5 to 8 storey residential student accommodation blocks.

The development area is currently occupied by the university buildings which include a basement covering the majority of the site, except the car park area. Brick faced retaining structures, up to 4.3m high, are present along the perimeter of the site retaining the adjoining roads.

Scope

A preliminary Phase 1 Geotechnical and Geoenvironmental Desk Study Report for the subject site was undertaken by Cundall Geotechnical in September 2011 on behalf of UK Structure Finance Holdings Ltd (UKSF) to provide an assessment of the development constrains that may be present at the site based upon a review of published historical geological environmental and hydrogeological information pertaining to the site. A preliminary conceptual site model (CSM) was developed for the site, based on the available information reviewed.

Subsequent to preparation of the Desk Study report, Cundall was commissioned by UPP to scope an intrusive ground investigation for the proposed development and procure and manage the site investigation company to undertake the ground investigation. A scheme specific ground investigation was scoped by Cundall taking into account the general scheme details and site access conditions. Due to the presence of existing buildings covering the majority of the proposed development footprint, some of the exploratory holes were positioned outside the development area (e.g. Cartwright Gardens).

Prior to undertaking the intrusive investigation Cundall procured a Detailed Unexploded Ordnance (UXO) Risk Assessment Report (prepared by an UXO specialist) for the subject site, including the area of Cartwright Gardens, in accordance with the recommendations of the Preliminary UXO report contained in the Desk Study Report. This report was made available to Dunelm to comply with its requirements with respect to intrusive investigations to be undertaken at the site.

Dunelm Geotechnical and Geoenvironmental Services Ltd (Dunelm) was appointed by the client through competitive tendering to undertake the scoped ground investigation and prepare a factual and an interpretative ground investigation (geotechnical and geoenvironmental assessment) report for the proposed development based upon the findings of the investigation. Dunelm commissioned Cundall Geotechnical (who prepared the Desk Study Report) to prepare the ground investigation (geotechnical and geoenvironmental assessment) report on their behalf, based on the findings of the ground investigation. Cundall Geotechnical has also prepared the laboratory schedules for the testing to be undertaken by Dunelm.

This report summarises the findings of the current ground investigation and presents a geotechnical and geoenvironmental assessment of ground conditions revealed by the investigation, including a Tier 1/2 semi-quantitative risk assessment and conceptual site model for the assessment of site contamination and an outline remediation strategy, based on the results of the investigation.

Site Investigation

The fieldwork was carried out by Dunelm between 24 and 28 September 2012. The ground investigation comprised five cable percussion boreholes (two located in Cartwright Gardens) to a maximum depth of 25m and two hand dug trial pits with associated sampling and in situ testing and installation of gas/groundwater standpipes. Due to the Cartwright Gardens being classified as a medium to high risk zone in the Detailed Unexploded Ordnance (UXO) Risk Assessment Report procured for the site, a downhole UXO survey of each exploratory hole location was undertaken as the hole progressed during the drilling of boreholes in this area.

Six rounds of gas and groundwater monitoring visits were undertaken between 5 October 2012 and 21 January 2013.

The investigation and laboratory testing was carried out in general accordance with BS 5930, BS 1377, BS EN 1997 and BS 10175, BS EN ISO 14688 and BS EN ISO 22475-1.

Ground Conditions

Exploratory holes drilled during the current investigation indicated a made ground thickness, up to 3.6m deep, in the car park area in the northeast of the site. A thin unit of Taplow Gravel (also including a lower clay unit) was also locally present in the car park area. Made Ground/Taplow Gravel (where not removed by basement excavation) is underlain by the London Clay at a depth of approximately 2.7m to 4.8m bgl (about 19m to 19.8m AOD). The base of London Clay was proven to 0.8m and 3.2m AOD, underlain by the Lambeth Group strata. The Chalk strata is anticipated to be at a depth of approximately 45m bgl in the site area.

Based on the monitoring records and site observations during the fieldwork, it is considered that shallow groundwater is present within the made ground/Taplow Gravel, perched above the London Clay.

Obstructions

Two shallow trial pits located to investigate the presence (roof) of a historical rifle range indicated no evidence of a relict structure/foundations in the car park area. A GPR survey undertaken in the car park area was inconclusive. It is recommended that further investigation by deep trial pits is undertaken during the demolition of the structures to confirm the presence/absence of the underground obstructions in this area.

Geotechnical Assessment and Engineering Considerations

Only preliminary guidance is provided in this report on foundation solutions for the proposed scheme, based on the preliminary foundation design information provided by Cundall structural design team and the ground conditions revealed by the intrusive investigation. As the detailed scheme design has not yet been completed, only the preliminary loads and general scheme layout provided by the design teams have been used in this assessment. The recommendations may need to be revised in accordance with the final design details for the proposed scheme. Further assessments will be required if the structural details, layout of the proposed buildings or structural loadings are revised.

Gas Protection Measures

No radon protective measures are required for proposed development. Based on the gas monitoring undertaken and the revealed ground conditions, the gas regime at the site classifies as Characteristic Gas Situation 1 (very low hazard potential in accordance with Table 1, BS 8485:2007) and no specific gas protection measures are likely to be required.

Ground Aggressivity

A ground aggressivity analysis for sulphate attack to concrete has been carried out in accordance with BRE Special Digest 1, using the results of ground aggressivity tests undertaken on site soils.

The calculated oxidisable sulphide contents determined from ground aggressivity tests undertaken on a number of samples indicated the potential presence of some pyrite in the London Clay. The London Clay would therefore be classified as ACEC class AC-3s and design sulphate class DS-4, mainly based on the high total potential sulphate content of 0.93 to 1.95%, with the majority of results being in excess of 1.2%, in accordance with BRE (2005).

Proposed basement slab/pad foundations are all anticipated to be founded on or within the London Clay. Therefore, a design sulphate class of DS-4 is recommended for concrete in contact with London Clay. The Aggressive Chemical Environment for Concrete (ACEC) within the site is classified as AC-3s in accordance with BRE Special Digest 1:2005.

Foundation Design Considerations

As part of the proposed scheme, the existing structures (except Hughes Parry Tower in the north of the site) will be demolished prior to the construction of the new buildings. However, the existing ground slab within the basement is generally to be retained.

Preliminary calculations undertaken by the structural design team indicate that the existing building loads in the southern part of the site vary from about 19 kPa to 121 kPa, whereas the proposed loads could be between 79 kPa to 129 kPa, except for the currently unoccupied courtyard area. In some areas, the loads will increase from about 5 kPa to 94 kPa, elsewhere the loads could reduce between 42 kPa and 111 kPa.

Ground Heave. The demolition of existing buildings may result in ground heave at the surface of the slab, which will be retained. As the existing building loads vary throughout the site, the heave at different parts of the development area is likely to be variable following demolition. At this stage, limited heave calculations have been undertaken for the areas with existing highest calculated load and the car park area which will be excavated down to the proposed FFL level. Detailed heave calculations should be undertaken once the proposed building loads are confirmed and the construction programme is agreed.

Foundation Design. The existing buildings are not supported on piled foundations and the new development is also not likely to be supported on piled foundations based on the assumption that the proposed building loads will not be significantly different (more) than the existing loads. It is anticipated that traditional raft or shallow pad footings will be adopted for the proposed development. Either option would involve constructing the new foundations on top of the retained existing ground floor raft slab in the Commonwealth Hall area. For the Hughes Parry and York/Canterbury Hall areas, it will be necessary to construct new pad/raft foundations below the proposed FFL of 20.4m AOD.

In designing the foundations, differential settlement that could occur between the southern parts of the site (where new pads will be placed on the existing raft) and the central/northern sections of the development area where new shallow footings will be constructed onto London Clay, should be taken into account. Similarly, the effects of the new foundations on the existing foundations of the Hughes Parry Tower that will be retained should be accounted for in determining the foundation depths for the new footings.

It is recommended that detailed geotechnical calculations should be undertaken when proposed structure details/loads are determined.

Effects of Development on London Underground Tunnels

The existing London Underground tunnels (Piccadilly line) run at about 26m below the existing/proposed development across the southeast corner of the development site, running NNE to SSW. Numerical calculations based on the preliminarily determined existing and proposed loads applied at basement level, indicated that the vertical and lateral heave/settlement and load effects on the tunnel from the proposed development will be negligible.

Reuse of Site Won Soils

At this stage, no cut and fill figures are available. However, it is not anticipated that any significant volumes of site won materials will be reused at the site due to the nature of the proposed development. Some off site disposal of site won soils may be necessary, especially from the current car park area. Therefore, no compaction tests were undertaken on made ground and natural soils at the site.

Excavations, Temporary Support and Groundwater Control

If groundwater is encountered in basement excavations during construction works, it is considered likely that any groundwater flows will be of limited volume and be able to be managed by traditional sump pumping methods. Temporary support may be required in the new basement areas if the basement levels are taken deeper than existing.

In order to prevent damage to adjacent structures/services, the design of the retaining wall and basement excavation must address the risk of excessive displacement of the wall and bracing, both in the temporary and permanent conditions, will be required to ensure that the soil deformation (vertical and horizontal) around and below the excavation remain within acceptable levels.

Car Park/Road Pavement Design

As the whole site will be covered by the proposed building footprints no CBR tests were undertaken for pavement/road design purposes.

Site Contamination and Risk Assessment

Limited made ground is present only in the car park area. Elsewhere, any historical made ground, if present, would have been removed by the basement construction which covers the remaining areas of the development site. No significant elevated determinand concentrations have been identified within the made ground samples analysed. Consequently, no plausible risk to human health has been identified at the site.

Although soil leachate test results have indicated marginally elevated benzo(a)pyrene and PAH (total), concentrations, the potential risk to controlled waters arising from these PAHs are assessed as negligible. A single made ground sample has recorded elevated TPH concentration above the UKWIR threshold value for PE pipe material only. However, as part of proposed development, the made ground in the car park area is likely to be excavated and disposed off site, removing any potential risk to controlled waters and future water supply pipes.

Disposal of Soil Waste

No WAC testing was undertaken as part of this investigation. However, preliminary assessment (based on the recorded soil concentrations) has indicated that the made ground materials analysed are likely to classify as 'inert' waste for offsite disposal purposes. This preliminary assessment will require confirmation/approval prior to any disposal of soil materials from site. Therefore, it is recommended that should any off site disposals be required, the materials should be carefully segregated, stockpiled and subjected to WAC analysis to determine their actual waste classification under the Landfill Directive Waste Acceptance Criteria.

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Contents

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TABLES

FIGURES

APPENDICES

1. INTRODUCTION

1.1 The Scheme

University Partnerships Programme Limited (UPP) proposes to redevelop the site of existing University Halls of Residence at Cartwright Gardens, Camden, London on behalf of the University of London. The existing Hughes Parry tower is to be retained but the remaining existing halls of residence (Hughes Parry Hall, Canterbury (including York) and Commonwealth Halls) will be demolished and replaced by a series of new 5 to 9 storey residential student accommodation blocks.

A site location plan is presented as Figure 1 and the proposed development layout plan is presented as Figure 2.

1.2 The Brief

A preliminary Phase 1 Geotechnical and Geoenvironmental Desk Study Report for the subject site was undertaken by Cundall Geotechnical (dated 22 February 2013, Rev. B) to provide an assessment of the development constrains that may be present at the site based upon a review of published historical geological environmental, hydrogeological information pertaining to the site. A preliminary conceptual site model (CSM) was developed for the site, based on the available information reviewed.

Subsequent to preparation of the Desk Study report, Cundall was commissioned by UPP to scope an intrusive ground investigation for the proposed development and procure and manage the site investigation company to undertake the ground investigation. A scheme specific ground investigation was scoped by Cundall taking into account the general scheme details and site access conditions. Due to the presence of existing buildings covering the majority of the proposed development footprint, some of the exploratory holes were positioned outside the development area (e.g. Cartwright gardens area).

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The fieldwork was carried out by Dunelm between 24 and 28 September 2012.

This report summarises the findings of the current ground investigation and presents a geotechnical and geoenvironmental assessment of ground conditions revealed by the investigation, including a Tier 1/2 semi-quantitative risk assessment and conceptual site model for the assessment of site contamination and an outline remediation strategy, based on the results of the investigation.

Guidance is provided in this report on foundation solutions for the proposed scheme, based on the preliminary foundation design information provided by Cundall structural design team and the ground conditions revealed by the intrusive investigation. As the detailed scheme design has not yet been completed, only the preliminary loads and general scheme layout provided by the design teams have been used in this assessment. If significant changes are proposed to the scheme currently being considered, a re-assessment of the ground conditions will be required and the recommendations made, especially with regard to foundation and retaining solutions and ground treatment, will need to be reviewed.

1.3 Limitations

The investigation of the site has been carried out to provide sufficient information on the geotechnical and geoenvironmental characteristics of the ground and groundwater at the development site and to provide a reasonable assessment of the geoenvironmental risks together with engineering and development implications.

The opinions provided and recommendations given in this report are based on a visual site inspection, reference to accessible referenced historical records, the information provided by the third parties, the results of ground investigations as detailed in the text and the factual data provided by the specialist ground investigation contractor. Whilst every effort has been made to interpret the conditions between the investigation locations, such information is only indicative and liability cannot be accepted for its accuracy. There may be exceptional ground conditions elsewhere on the site which have not been disclosed by the investigation and which have therefore not been taken into account in this report. The test results obtained can only be regarded as a limited but likely representative sample range, assessed against current guidelines. The possibility of the presence of contaminants, possibly in higher concentrations elsewhere on the site or the presence of encountering ground conditions at variance with the logs elsewhere on the site cannot be discounted.

The scope of the investigation was selected based on the development proposals provided by the Client and may be inappropriate to another form of development. The assessments carried out and recommendations made in this report with regard to foundation and infrastructure design are based on the preliminary details provided by the Client and the results of ground investigation at discrete locations. If the ground conditions are found to vary from those revealed by the investigation, or the structural details and layout of the proposed buildings, structures and infrastructure are revised, Cundall reserves the right to carry out further assessments and revise their recommendations in line with the revised scheme details.

The ground investigation was conducted and this report has been prepared for the private and confidential use of Dunelm and University Partnerships Programme Limited (acting on behalf of the University of London) only and cannot be reproduced in whole or in part or relied upon by any third party for any use whatsoever without the express written authorisation of Cundall. If any third party whatsoever comes into possession of this report, they rely on it at their own risk and Cundall accepts no duty or responsibility (including in negligence) to any such third party.

2. SITE DESCRIPTION AND PROPOSED DEVELOPMENT

2.1 Site Description and Topography

Site Location

The site is located at Cartwright Gardens, London WC1H 9EF. The approximate centre of the site is at National Grid Reference 530080 E, 182560 N. The development site is bounded by Cartwright Gardens to the west, Hastings Street to the north, Sandwich Street to the east and Leigh Street to the south. A site location plan is presented as Figure 1.

Site Inspection/ Walkover Survey

A site inspection was carried out by Cundall Geotechnical on 24 September 2012. The site visit was undertaken to provide a general overview of site features and conditions. The key features of the site noted during the inspection visit are described overleaf.

Site Area and Shape	The development site occupies an area of approximately 0.5ha (150m long x 35m wide).
Site Boundaries and Adjacent Land Use	• North – Hastings Street, beyond which are residential/office blocks. • East – Sandwich Street, beyond which are predominately residential blocks with a food shop in the northeast, a church in the central east and a pub in the southeast. • South – Leigh Street, beyond which are residential blocks, food shops and a dry & iron shop. • West – Cartwright Gardens (street), beyond which is Cartwright Gardens (garden), with hotel and residential blocks in the west.
Site Topography	• The surround streets is generally flat between about 23m AOD in the north and 23.8m in the south. • A grass/shrubs covered mound/underground tank storage (up to 1.5m high) is present in the northeast corner of the site. • A tarmac car park is present in the northeast of the site, the ground level of which is about 2.2m to 2.5m below Sandwich Street. • Two court yards, underlain by basement, are present in the central of the site. • A tarmac (partially concrete) service yard, underlain by basement, is present in the southeast of the site. • Several small service yards/ hardstanding (about 2 to 4.5m below footpath levels) are present between the buildings and the surrounding footpath/access roads.
Existing Land Uses	• The existing buildings on the subject site are predominately 8 to 15 storey student accommodations plus basements owned

	by University of London including Hughes Parry Hall, Canterbury Hall and Commonwealth Hall. • A car park is present in the northeast of the subject site. • Several service/court yards and hardstandings are present within the subject site.
Surface Cover	• The footpaths present surrounding the subject site are surfaced with concrete paving slabs. • The car park in the northeast is surfaced with tarmac. • The court/service yards and hardstanding areas within the subject site are surfaced with concrete paving slabs.
Underground	• Piccadilly underground railway lines are present just outside the south eastern corner of the site. The data provided by London Underground indicates that the tunnel crown level for the nearest Piccadilly Line is at approximately 5.7m below Ordnance Datum (approximately 29.6m depth below ground level).
UXO	• Detailed UXO report prepared by 6 Alpha
Trees	• Several semi-mature trees, about 5m – 15m high, are present along the footpath in the east and south of the site.
Contamination	• No visual evidence of contamination was observed within the site during the walkover survey. • Oil storage rooms are presents within the northwest of Hughes Parry Hall. • Possible underground oil tank is present in the northeast of the site. • Several substations are present on the footpath in southwest, northwest of the site. • Electronic service rooms within the buildings are present in central northwest, southwest and central northwest of the site.

2.2 Proposed Development

The existing Hughes Parry tower is to be retained but the remaining existing halls of residence (Hughes Parry Hall, Canterbury (including York) and Commonwealth Halls) will be demolished and replaced by a series of new 5-9 storey residential student accommodation blocks.

The proposed development layout plan (lower ground floor and ground floor only) is presented as Figure 2.

3. GEOLOGICAL AND ENVIRONMENTAL SETTING OF THE SITE

3.1 Sources of Information

The following reference sources, providing background information, were reviewed, with relevant information utilised during the preparation of this report:

1. Cundall (September 2011). Phase 1 Geoenvironmental Desk Study Report, Cartwright Gardens Development, University of London, (prepared for UK Structured Finance Holdings Ltd). (This report includes a copy of the Envirocheck Report for the site).

2. 6 Alpha Associates Ltd (September 2012). Detailed Unexploded Ordnance (UXO) Risk Assessment for the site at University of London, Cartwright Gardens, London (Landmark Order Number 41107341_1).

3. Dunelm (November 2012). Factual Report on Site Investigation of Land at Cartwright Gardens Development, University of London. (Report No. D4325).

4. Correspondence from London Underground on Piccadilly Line Alignment

The above documents (References 1 to 3) should be read in conjunction with the report in order to understand its context.

3.2 Summary of the Previous Phase 1 Desk Study Report

In September 2011, Cundall produced a Phase 1 Desk Study Report for the site (Ref. 1, Section 3.1). A summary of the key findings of the desk study report are presented below. Reference should be made to the Desk Study Report for full details of the site's historical development and environmental setting.

Land Use History

The Site. Historically, the site had been developed with residential housing by 1874. A number of buildings located within a small area in the southern part of the site had been demolished by 1911, however this area was redeveloped further with houses by 1916. The majority of the buildings at the site were demolished prior to 1953, allowing the construction of the Canterbury Hall (University of London) in the central part of the site by 1953. Additional buildings were constructed in the southern part of the site by 1965. A number of buildings in the northern part of the site had been demolished by 1972, although new university buildings were constructed in this area by 1974.

Surrounding Land. Key features recorded within the surrounding land include residential and light commercial properties, railway stations, a goods shed, demolished buildings recorded as 'ruins', confectionery works, printing works, disused cemetery, hospital, gas works, depots, telephone exchange, electricity substations, a works building and the Institute of Ophthalmology.

Site Geology

According to the Envirocheck Report included in the Desk Study Report (Ref. 1, Section 3.1), the site is underlain by Lynch Hill Gravel Member (Sand and Gravel) overlying the London Clay Formation. However, the published BGS map (Sheet 256) covering the site indicates that the strata belonging to the Taplow Gravel Formation occupies a very small area in the southern part, with the remainder of the site being directly underlain by the London Clay Formation. (**Note:** In this report, Taplow Gravel Formation will be used for ease of reference in place of the Lynch Hill Gravel Member).

The London Clay is underlain by the Lambeth Group strata and Thanet Sand overlying the Chalk strata at a depth of about 45m bgl in this area.

Hydrogeology and Hydrology

The superficial strata (Taplow Gravel/Lynch Hill Gravel Member) is classified as a 'Secondary A' aquifer, which indicate permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. However, the underlying solid geology (London Clay Formation) is classified as 'Unproductive Strata', which indicate strata with low permeability that have negligible significance for water supply or river base flow.

Three groundwater abstraction points (used for 'heat pump' schemes) were recorded within 1km of the site. The nearest is indicated 73m north of the site, while another two are located 667m south of the site. The nearest groundwater abstraction point for portable public water supply is recorded at about 1.2km east of the site. No groundwater source protection zones (SPZs) are recorded within 1km of the site.

The nearest recorded surface water feature (the Grand Union Canal - Regent's Canal) is located approximately 760m north of the site. The canal has River Quality GQA Grade C at about 780m north of the site, with a flow rate greater than 80 cumecs. No surface water abstraction points are located within 500m of the site. The site is not located in an area at risk of flooding.

Ground Stability

The site is not located in an area underlain by coal mining.

A low hazard potential for shrinking or swelling clay is also recorded at the site. A natural cavity is recorded 470m east of the site. The cavity type and depth are unknown.

Radon Status

The site is located in a lower probability radon area, as less than 1% of homes are above the action level. Therefore, no radon protective measures are considered necessary in the construction of new dwellings or extensions at the site.

Landfilling & Waste

No landfills are located within 1km of the site. The nearest licensed waste management facility (for metal recycling) is recorded 753m north of the site. The nearest registered waste transfer site (now obsolete) is recorded 582m north of the site with no known restriction on source of waste (authorised waste comprised 'Construction and Demolition Wastes', while the prohibited waste comprised 'Biodegradable/Putrescible Waste', Clinical Wastes, Notifiable Wastes and Special Wastes').

Statutory Registers & Environmental Status

Discharge Consents: No discharge consents are recorded within the subject site. However, a discharge consent is located 66m northwest of the site, and refers to 'trade discharges – cooling water' into land. The receiving water is indicated as 'Gw via Re-Inject Borehole'.

Local Authority Pollution Prevention and Control: The nearest Local Authority Pollution Prevention and Control (PPC) referring to CYMA (a petrol filling station business) is recorded some 184m west of the site. The status is recorded as 'application not yet authorised'. In addition fifteen other Local Authority PPCs are recorded within between 282m and 895m radius of the site.

Pollution Incidents to Controlled Waters: No pollution incidents to controlled waters are recorded within the subject site. The nearest pollution incident to controlled waters is recorded 462m southwest of the site (a Category 3 – Minor Incident involving 'oils-unknown' pollutant).

Contemporary Trade Directory Entries: Twenty six Contemporary Trade Directory Entries are recorded between 18m and 234m radius of the site. Active Contemporary Trade Directory Entries recorded within 100m radius of the site include a hardware business (18m southeast), a dry cleaners business (19m southeast) and 'electrolysis' business (35m north). Two inactive Contemporary Trade Directory Entries are also recorded within 100m radius of the site, namely; a medical waste disposal business (35m north) and photographic processors business (62m south east).

Fuel Station Entries: The nearest fuel station entry (obsolete) is recorded 139m west of the site.

Preliminary Conceptual Site Model and Risk Assessment

No significant potential sources of contamination were identified at the site. However, it was considered that made ground may be present at the site (associated with the historical development of the site), which could provide a source of limited and localised contamination. An area of worked ground located 180m east of the site was also identified as a potential source of contamination.

The preliminary Conceptual Site Model (CSM) identified that the risk to human health was negligible to low (site users) and low to moderate (construction workers). The risk to subsurface concrete was considered moderate, while a negligible to low risk was determined for new water supply pipes. The risk to controlled waters was assessed as negligible to low.

An intrusive investigating was recommended to confirm/refine the preliminary CSM and risk assessment. A revised CSM and risk assessment has been completed for the site based on the findings of the current intrusive investigation and is presented in Section 7.

3.3 Detailed UXO Risk Assessment

Detailed Unexploded Ordnance (UXO) Risk Assessment for the subject site (including the Cartwright Gardens area) was undertaken by an UXO specialist, 6 Alpha Associates Ltd in September 2012.

The WWII Luftwaffe bombing targets including stations, gas work and depots in the surrounding lands were identified in the UXO report. In addition, a number of WWII high explosive bomb strikes were recorded within 200m radius to the subject site.

The London County Council Bomb Damage Map enclosed in the UXO report indicate the site and the surrounding land may have been damaged by bombs (seriously damaged to blast damage at the site) during the Second World War.

6 Alpha considered the UXO risk for the subject site (Site A – University of London Accommodations) to be low/medium risk whereas the gardens immediately west (Site B – Cartwright Gardens) to be medium/high risk.

A down hole UXO survey of each exploratory hole location was undertaken as the hole progressed during the drilling of the boreholes within the Cartwright Gardens in accordance with the recommendations given in the UXO report.

3.4 London Underground

A plan enclosed in the letter received from London Underground Ltd (05 July 2011, Ref No 20878-ND-P052) indicates London underground tunnels crossing the southeast corner of the site, running approximate NNE to SSW direction. The tunnel crown level is recorded at about 5.7 – 5.8m AOD.

4. GROUND INVESTIGATION

4.1 Fieldwork

A ground investigation was scoped by Cundall based on a review of available information and taking into consideration the preliminary layout and general details of the proposed scheme and site access conditions. As the development area was largely occupied by the existing buildings, which included a basement, the exploratory holes were located in areas where no buildings/basement existed. Two of the proposed boreholes were located in the Cartwright Gardens area to the west of the existing buildings.

There was anectodal evidence of a historical underground rifle range crossing the western part of the car park within the existing development. A couple of shallow trial pits were located to investigate the presence (roof) of this rifle range.

Prior to the intrusive work, a GPR (Ground penetration radar) survey was undertaken for identification of previous foundations at the car park area and the underground services at each exploratory hole location.

The intrusive ground investigation was carried out by Dunelm Geotechnical and Environmental Ltd. The investigation and laboratory testing was carried out in general accordance with BS 5930:1999 +A2:2010, BS 1377, BS EN 1997 and BS 10175, BS EN ISO 14688, BS EN ISO 14689 and BS EN IOS 22475-1. The fieldwork was carried out by Dunelm from 24 September to 03 October 2012. The exploratory hole location plan is presented as Figure 3.

Due to the garden area (Cartwright Gardens) being classified as a medium to high risk zone in the Detailed Unexploded Ordnance (UXO) Risk Assessment Report procured for the site, a downhole UXO survey of each exploratory hole location was undertaken as the hole progressed during drilling of three boreholes (including the abandoned borehole) in this area.

The ground investigation comprised the following:

- 5 No cable percussive boreholes (CBH1 to CBH5) up to 20m depth were scheduled to confirm the thickness and nature of superficial deposits/made ground, obtain data for preliminary foundation design, and acquire soil samples for geotechnical testing. However, borehole CBH5 was cancelled as a number of services were identified by the GPR survey at the proposed borehole location (pavement area) and surrounding area. Borehole CBH3 was abandoned at a depth of 2.5m bgl due to encountering a strong magnetic anomaly and a new borehole CBH3A was undertaken about 3m west of the original location. Boreholes CBH2 and CBH3a were extended to 20m depth, whereas CBH1 and CBH4 were terminated at 25m depth within the Lambeth Group strata.

- 2 No hand dug trial pits (CHTP1 to CHTP2) were excavated to 1.2m depth in the existing car park area to inspect the possible relict wall/roof of historical rifle range structure.

- Standard Penetration Tests (SPTs) were carried out in the cable percussion boreholes.

- 50mm combined gas/groundwater monitoring standpipes were installed in 2 No exploratory holes (CBH1 and CBH4) to allow the measurement of groundwater levels, ground gas concentrations (oxygen, carbon dioxide, methane, hydrogen sulphide) and gas flow rates. 6 No gas and groundwater monitoring visits have been undertaken to date between 5 October and 21 January 2013.

Detailed engineering logs for the exploratory holes, as well as the gas and groundwater monitoring results are contained in the Factual Report produced for the site by Dunelm.

4.2 Laboratory Testing

The following laboratory tests were undertaken on selected soil and rock samples in order to assess the engineering properties of the underlying soils and to assess the contamination status of the site soils and groundwater.

Geotechnical Testing:

- Atterberg limits, natural moisture content determination tests for the general classification of soils.

- Undrained shear strength tests on U100 samples in triaxial compression without the measurement of pore pressure.

- One dimensional consolidation (oedometer) tests.

- Geochemical tests on soil and groundwater samples in accordance with BRE Special Digest 1 in order to determine ground aggressivity potential for concrete.

Chemical (Contamination) Testing

Four soil samples (all made ground) were subjected to laboratory analysis for all of the following determinands:

- Metals [arsenic, cadmium, chromium (total and VI), copper, lead, mercury, nickel, selenium, zinc], cyanide (free and total), pH, soil organic matter (SOM), phenol, sulphate (total and water soluble), sulphide, Polycyclic Aromatic Hydrocarbons (speciated USEPA 16), Total Petroleum Hydrocarbon (TPHCWG aliphatic/aromatic split), benzene, ethylbenzene, toluene, xylenes (BTEX), methyl tert-butyl ether (MTBE) and asbestos.

In addition, two selected soil samples were subjected to leachability testing for the following determinants:

- Metals [arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, zinc], pH, cyanide, phenol, sulphate, PAH (USEPA 16 speciated) and TPH (C5 – C40, PRO/DRO/MRO split).

Geotechnical laboratory testing was carried out by Solmek, a UKAS accredited laboratory, Dunelm in accordance with BS 1377:1990 +A1:1994 and BS EN 1997 Part 2. The geochemical testing and testing for aggressivity to concrete in accordance with BRE Special Digest 1:2005 was subcontracted to Derwentside Environmental Testing Services (DETS), a UKAS and MCERTS accredited laboratory. Environmental testing was also subcontracted to DETS. Copies of the test results sheets are included in the Dunelm Factual Report.

5. GROUND CONDITIONS AND PROPERTIES

5.1 Findings of the Current Ground Investigation

A summary of the ground conditions encountered during the current ground investigation and also the previous investigations, where relevant, is given below.

Stratum	From m bgl (m AOD)	To m bgl (m AOD)	Thickness (m)
Made Ground (including topsoil and tarmac)	GL (22.3 – 23.8)	0.0 – 3.6 (18.7 – 23.1)	0.0 – 3.6
Taplow Gravel (Sand and gravel over clay)	0.5 – 1.9 (20.6 - 23.1)	2.5 – 4.8 (19.0 – 20.8)	0.8 – 4.1
London Clay	2.7 – 4.8 (18.7 – 19.8)	21.4 – 21.7 (0.8 – 2.4)	16.6 – 19.0
Lambeth Group (Base not proven)	21.4 – 21.7 (0.8 – 2.4)	Below 25 – 25.6 Below (-)1.2 – (-)3.1	Greater than 3.6 – 3.9

Ground Conditions

The following descriptions of strata identified at the site are based on the exploratory hole records contained in the Dunelm factual report. Four representative geological cross sections through the site are presented as Figure 4. The location of the cross sections are indicated on Figure 3.

Topsoil

Topsoil, ranging in thickness from 0.5m to 0.7m, was only encountered in the Cartwright Gardens area.

Tarmac

A thin layer of tarmac (0.1m) was encountered in CBH1, CBH2, HTP1 and HTP2 at the existing car park area.

Made Ground

Made ground was proven to 1.6m to 3.9m depth in the exploratory holes located in the existing car park area.

The made ground generally comprised sandy gravel to gravelly sand with localised pockets of clay. The gravel portion predominately comprised brick, concrete and flint, and occasional flint, tile and metal fragments. Cobbles of brick and concrete were also encountered within this unit.

Taplow Gravel

Taplow Gravel stratum was encountered at approximately between 0.5m and 1.9m bgl (approximately 20.6m to 23.1m AOD) in all cable percussion holes except CBH1. Taplow Gravel generally comprised medium dense to dense sandy gravel and gravelly sand over a layer of clay band. Gravels predominately comprised flint.

The localised clay bands, generally described as soft to firm, between 0.4m and 0.9m thick were encountered generally near the base of this stratum in exploratory holes CBH2, CBH3A and CBH4.

London Clay

London Clay was encountered at between 2.7m and 4.8m bgl (approximately between 18.7m and 19.8m AOD). This stratum was generally described as stiff, locally firm, becoming stiff to very stiff, fissured slightly silty clay. London Clay becomes very stiff generally below 6.5m AOD in the north and below 9m AOD in the south of the site (Figure 4).

The base of the London Clay was proven at 21.4 and 21.7m bgl (approximately +2.4 and +0.8m AOD) in the deeper holes of CBH2 and CBH4.

Lambeth Group

Underlying the London Clay, Lambeth Group strata, generally described as very stiff slightly silty clay, was encountered. All SPTs were refusal in this unit. The base of this unit was only proven to 25m and 25.6m bgl (approximately -1.2m to -3.1m AOD).

5.2 Engineering Properties and Behaviour

Laboratory and in-situ test results from the ground investigation have been used to determine the geotechnical properties of the soils encountered within the site and at nearby gardens area.

Table 1 summarises the laboratory and in situ results carried out on soils during the current ground investigation. The characteristic geotechnical parameters recommended for the design of foundations and infrastructure of the proposed development are summarised in Table 2.

All test results record sheets are included in the Dunelm Factual Report.

Standard Penetration Tests (SPT) were undertaken in all cable percussion holes generally in accordance with British Standard BS EN ISO 22476-3:2005 +A1:2011. The standard indicates that energy losses are induced by the hammer assembly due to frictional and other parasitic effects, which cause the hammer velocity at impact to be less than the free fall velocity. Further losses of energy are originated by the impact on the anvil, depending on its mass and other characteristics. The type of machine, skill of the operator and other factors can also influence the energy delivered to the drive rods. Therefore, the value of the blow count N is inversely proportional to the energy ratio Er (i.e. $N_{60} = (Er/60) \times N$).

Based on information provided by Dunelm (07 November 2012), an Er value of 54 was derived for the rig used for boreholes CBH1 and CBH4 whereas an Er value of 88 was derived for the rig used for boreholes CBH2 and CBH3, 3A. Therefore, the N values shown on the logs have been corrected, using N_{60} = 0.9 x N for CBH1 and CBH4 and N_{60} = 1.47 x N for CBH2 and CBH3,3A, for the purposes of this report.

Made Ground

The made ground (excluding topsoil and tarmac) generally comprises sandy gravel to gravelly sand with occasional cobbles of concrete and brick.

In Situ Testing

Four SPTs undertaken in the made ground at between 1.2m and 3.0m depth recorded N values between 17 and 34 (corrected N_{60} between 13 and 50).

Classification Tests

No classification tests were undertaken on made ground.

It is considered that a representative bulk density of 18 kN/m^3 may be adopted for the made ground, based on the recommended values for 'well graded sand and gravel to coarse or medium sand' and/or 'firm clay' in accordance with Table 1 of BS 8002.

Taplow Gravel

The Taplow Gravel at the site generally comprises medium dense to dense sand and gravel over a layer of soft to firm clay.

In Situ Testing

Six SPTs undertaken in the sand and gravel unit of the Taplow Gravel between 1.2m and 2.2m depth recorded N values from 25 to 44 (corrected N_{60} from 23 to over 50)., whereas two SPTs undertaken in the clay unit of the Taplow Gravel at 2.9 m and 4.2m depth recorded N values of 7 and 21 (corrected N_{60} between10 and 19)..

Classification Tests

No classification tests were undertaken for Taplow Gravel units.

It is considered that a representative bulk density of 21 kN/m^3 may be adopted for the sand and gravel units based on the recommended values for 'dense well graded sand and gravel' in accordance with Table 1 of BS 8002.

It is considered that a representative bulk density of 18 kN/m^3 may be adopted for the clay units based on the recommended values for 'soft' and 'firm' clay in accordance with Table 1 of BS 8002.

Effective Shear Strength

Although no laboratory tests were undertaken to determine the angle of shearing resistance in the sand and gravel strata, values ranging from Phi' = 34^o to 40.5^o were derived from the relationship between N values and angle of shearing resistance after Peck et al (1967), based on corrected N_{60} values of generally between 23 and over 50.

A characteristic angle of shearing resistance Phi' = 36^o has been recommended for the sand and gravel unit, based on a characteristic N value of 30.

Undrained Shear Strength

No triaxial tests were undertaken to determine the undrained shear strength of the clay unit present within the Taplow Gravel. An undrained shear strength (Cu) between 42 kPa and 80 kPa has been derived for the clay unit, based on corrected N_{60} values of 10 and 19 recorded in the cable percussion boreholes in this unit, using a correlation coefficient of 4.2 after Stroud (1975).

A characteristic undrained shear strength of 45 kPa is considered appropriate for soft to firm clay within the Taplow Gravel stratum.

Compressibility

No one-dimensional consolidation (oedometer) tests were undertaken on the clays present within the Taplow Gravel.

Approximate m_v values can be derived from SPT N values using the approximate relationship suggested by Stroud (1974). Derived m_v values ranged from 0.13 m^2/MN to 0.23 m^2/MN, based on corrected N_{60} values of 10 to 19, using a correlation coefficient of 0.42.

Based on derived m_v values and log description, a characteristic m_v value of 0.2 m^2/MN is considered appropriate for the clay unit within the Taplow Gravel for a pressure range of 100 to 200 kPa.

London Clay

London Clay encountered at the site was generally described as stiff (locally firm) becoming stiff to very stiff with depth, slightly silty clay with occasional thin sand bands.

In Situ Testing

Forty seven SPTs undertaken in the London Clay at between 2.7m and 20.5m depth (approximately 2m to 19.8m AOD) recorded N values between 9 and 45, excluding one refusal value (>50). The two low SPT N values of 9 were recorded in the 'firm clay' unit between 2.7m and 4.7m depth bgl in CBH2 (car park area). The corrected N_{60} generally ranged between 13 and 50, excluding 5No refusal or N_{60} over 50.

A plot of corrected SPT N_{60} values versus depth for London Clay is presented as Figure 5. The N values generally increase with depth.

Classification Tests

The moisture content of twenty five samples of London Clay obtained from between 3.2m and 18m depth ranged from 22% to 30%. Atterberg limit tests scheduled on fifteen samples obtained from 3.2m to 12m depth recorded plasticity indices (PI) between 30% and 49%, with an average PI of 44%. Based on these results the London Clay can generally be classified as being of high to very high plasticity.

The bulk density values determined on twenty three samples were between 21 kN/m^3 and 22 kN/m^3, whereas the dry density determined on the same samples ranged from 16 kN/m^3 to 18 kN/m^3.

A bulk density of 21 kN/m^3 may be considered as appropriate for the London Clay comprising stiff slightly silty clay.

Undrained Shear Strength

Twenty two U100 samples of London Clay (from 3.7m to 18m bgl) were subjected to laboratory undrained triaxial test. The undrained shear strength (Cu) values ranged from 48 kPa to 140 kPa.

Relatively low Cu values of 52 kPa and 66 kPa were determined in the two samples taken from the uppermost 2m of the London Clay in CBH2. Similarly, low values were also determined on the samples taken from CBH1 (3.9m depth) and CBH3A (4.0m depth).

Back derived undrained shear strength values (Cu) ranged between 57 and 214, based on corrected SPT N_{60} values ranging from 13 to 50 (Excluding values >50), using a correlation coefficient of 4.3 based on a characteristic plasticity index of 49%, after Stroud (1975).

A plot of undrained shear strength versus depth in London Clay is given in Figure 6, based on the results of current investigation. A characteristic depth dependent Cu value can be determined from the following approximate relationship (based on approximate hand drawn curve in Figure 6):

Cu (kPa) = 174 +(-) 6.0 x Depth (m AOD)

Compressibility

Ten one-dimensional consolidation tests have been carried out on samples recovered at between 3.2m and 12m bgl (about 12m to 19.3m AOD), giving a coefficient of volume compressibility, m_v = 0.04 to 0.14 m^2/MN for a pressure range of 50 to 100 kPa and m_v = 0.05 to 0.09 m^2/MN for a pressure range of 100 to 200 kPa.

The m_v values were also derived from correlation with SPT N values after Butler (1975) for London Clay. Using a characteristic N value of 20, m_v = 0.08 m^2/MN is obtained using the correlation of m_v (= 1/E') = 1/(0.6xN) for firm to stiff London Clay above about 6m AOD in the north and 9m AOD in the south of the site. A higher m_v value of 0.05 m^2/MN may be applicable for very stiff London Clay (below about 6m AOD in the north and 9m AOD in the south) based on a characteristic N value of 35.

Lambeth Group Strata

Lambeth Group strata encountered at the site was generally described as very stiff slightly silty clay.

In Situ Testing

Six SPTs undertaken in the Lambeth Group strata at between 21.9m and 25.9m depth (approximately 0.6m to (-) 3.1m AOD) recorded all refusal values.

Classification Tests

No soil classification tests were scheduled on samples of very stiff clay in this unit.

A bulk density of 21 kN/m^3 may be considered as appropriate for Lambeth Group comprising very stiff, slightly silty clay.

Undrained Shear Strength

No laboratory triaxial tests were undertaken to determine the undrained shear strength of clay in this unit.

A back derived undrained shear strength value (Cu) of 215 kPa can be calculated based on a conservative SPT N value of 50 and using a correlation coefficient of 4.3 for a characteristic PI over 40% after Stroud (1975).

Compressibility

No laboratory tests were carried out to determine the compressibility of very stiff clay in this unit. However, the m_v value was derived from correlation with SPT N values after Butler (1975) for Lambeth Group. Using a N value of 50, m_v = 0.03 m^2/MN is obtained based on the following formulae of m_v (= 1/E') = 1/(0.6xN).

5.3 Ground Aggressivity

BRE Special Digest 1:2005 indicates that London Clay is one of the sedimentary clays most likely to contain sulphides (e.g. pyrite). In the current investigation, eight London Clay samples were tested in accordance with procedure outlined in Figure C5 of BRE Special Digest (recommended for pyrite bearing natural ground). In addition, two made ground samples and two natural granular soil samples were tested for water soluble sulphate and pH. The test results are summarised in Table 3b.

Water soluble sulphate concentration in the made ground samples ranged from 200 mg/l to 850 mg/l, with pH ranging from 9.8 to 10.7.

Water soluble sulphate concentration in the natural granular soil samples ranged from 37 mg/l to 850 mg/l, with pH ranging from 8.7 to 10.1.

Water soluble sulphate concentration in the London Clay samples ranged from 240 mg/l to 650 mg/l, with pH ranging from 8.2 to 8.8. Tests on the same samples indicated acid soluble sulphate (total) concentration between 0.15% and 0.33% and a total potential sulphate concentration between 0.93% and 1.95% except to a high value of 5.7% (subject to retest). The calculated oxidisable sulphide contents were between 0.78% and 1.7% except a single value of 5.37% from BH3A (3.5m depth). A higher value of 8.4% was obtained when the sample with the highest value was retested. BRE Special Digest states that if the amount of oxidisable sulphides is greater 0.3% SO4 in a significant number of samples, pyrite is probably present.

5.4 Gas Monitoring

During the current investigation, two combined gas and groundwater standpipes were installed at the site in CBH1 and CBH4. The response zone of CBH1 were within the made ground and the London clay strata, whereas the response zone of CBH2 was within the Taplow Gravel/London Clay strata. Monitoring was carried out in the two current wells on six occasions between 05 October 2012 and 21 January 2013. The results are summarised in Table 4.

Recorded methane concentrations during the monitoring period were negligible (below or equal the detection level of 0.1%v/v). Steady state carbon dioxide concentrations were all well less than 5%.

The recorded gas flow rates were negligible (either below or equal the detection level of 0.1l/hr). The recorded oxygen concentrations generally varied between 18.9% and 21.0%v/v. The recorded atmospheric pressure ranged between 982 and 1017 mbars during the monitoring period.

A detailed gas risk assessment is presented in Section 8 of this report.

5.5 Groundwater

Groundwater was recorded in two exploratory holes during the intrusive works. A groundwater strike was recorded at 15.7m bgl (7.0m AOD) in CBH3 and 'slight' seepage was recorded at 15.5m bgl (7.5mAOD) in CBH2 within the London clay. A summary of the groundwater strikes recorded during the fieldwork is presented in Table 6a.

Groundwater monitoring has been undertaken in two installed gas / groundwater monitoring wells (CBH1 and CBH4) on six occasions between 05 October 2012 and 21 January 2013. The monitoring results are presented in Table 6b.

A detailed assessment of the groundwater regime at the site is presented in Section 7.

6. GEOENVIRONMENTAL ASSESSMENT

6.1 Environmental Sampling and Testing Strategy

Due to the presence of the existing buildings at the site, only two exploratory holes (CBH1 and CBH2) were located within the proposed development site (at the existing car park located in the northern part of the site). Consequently, on-site soil sampling for environmental testing was only undertaken within the existing made ground materials in the northern part of the site. Environmental sampling and testing of the natural soils was deemed unnecessary, unless visual and/or olfactory evidence of contamination was observed/noted.

Based on the geological and environmental setting of the site (as discussed in Section 3), the site is underlain by the Taplow Gravel Formation (a 'Secondary A' aquifer). However, due to the existing 8 to 15 storey buildings (plus basements) at the site, it is anticipated that the majority of the shallow sand and gravel materials belonging to the Taplow Gravel Formation would have been excavated/removed during the site development, resulting in limited thicknesses (if any) of the 'Secondary A' aquifer deposits at the site. In addition, the main/deeper groundwater is anticipated to be present at a significant depth below the site (within the Lambeth Group and/or within the underlying Thanet Sand/Chalk – a confined major aquifer). Therefore, groundwater sampling and testing was not deemed necessary. However, two soil samples were subjected to leachate testing to assess the potential leachable determinant concentrations from the underlying made ground materials.

Volatile Organic Hydrocarbons (VOCs) Screening

Environmental soil samples recovered during the fieldwork were screened for Volatile Organic Compounds (VOCs) on site using a hand-held Photo Ionising Detector (PID). No detectable VOC concentrations were recorded in all the soil samples, which indicate the negligible concentrations of VOCs at the site. In addition, laboratory test results for four soil samples from CBH (0.5 and 1.0m) and CBH2 (0.5m and 1.5m) recorded negligible/low concentrations of PAHs, TPHs and BTEX compounds, indicating insignificant concentrations of volatile hydrocarbons at these locations.

The PID readings are presented in Dunelm's factual report.

Visual and/or Olfactory Evidence of Potential Contamination

During the current investigation, no significant visual and/or olfactory evidence of contamination was identified within the shallow soil materials at the site.

During the site walkover survey, a possible underground oil tank was identified in the north-eastern part of the site. Oil storage rooms were identified within the northwest of Hughes Parry Hall. No evidence contamination was observed at these locations. These features will be retained together with the Hughes Parry Tower.

6.2 Risk Assessment Framework and Methodology

Reference should be made to the detailed information pertaining to the geoenvironmental risk assessment framework and methodology, presented in Appendix A. The risk assessment undertaken is based on the current UK legislative framework.

In order to put the laboratory measured chemical analysis results for the development site into context, the chemical data obtained during this site investigation has been assessed in relation to guideline values and other criteria commonly used for the assessment of land contamination, as summarised below.

Land (Soil) Quality

Given the proposed 'residential' end use of the site, the laboratory test results for soil samples have been compared with the following threshold values for the purpose of generic quantitative risk assessment:

- CLEA SGVs for 'residential' land use; LQM/CIEH GACs for 'residential' land use; and ATRISKsoil SSVs for 'residential without homegrown produce' land use.

In undertaking the Tier 1/2 assessment for 'residential' land use, reference was initially made to the published CLEA SGVs by the Environment Agency. In the absence of published SGVs, the LQM/CIEH GACs were used. The ATRISK^{soil} SSVs were only utilised for contaminants that do not currently have either a CLEA SGV or LQM/CIEH GAC published.

Controlled Waters

In order to assess the recorded soil leachate concentrations, the following Level 1 assessment criteria have been used:

- The Water Supply (Water Quality) (Amendment) Regulations 2000, amended 2007 and 2010 (the UK Drinking Water Standards, DWS).

- Environment Agency (2002) 'Technical advice to third parties on pollution of controlled waters for part IIA of the EPA 1990', Freshwater Environmental Quality Standards (EQS).

The Taplow Gravel strata partially underlying the site is classified as a 'Secondary A' aquifer. No surface water receptors are recorded within 500m of the site, the nearest surface water feature (the Grand Union Canal (Regent's Canal)) is located some 756m north of the site.

Based on the above, the Level 1 controlled waters risk assessment has been undertaken using the DWS threshold values in the first instance. The EQS (freshwater) threshold values have only been used where no DWS threshold values exist.

6.3 Discussion of Analytical Test Results

During the current investigation, four made ground soil samples recovered from the two exploratory holes within the site were subjected to a range of analytical suites as detailed in Section 4.2.

The soil test results are summarised in Table 6, which also include a comparison of the test results against the adopted 'residential' land use Tier 1 threshold values.

Two soil samples were subjected to leachate testing during the current investigation, to determine the potential mobility of contaminants within the soil. The leachate test results and the corresponding Tier 1 assessment criteria values are presented in Table 7.

Soil Test Results

<u>Tier 1/2 Assessment for 'Residential' Land Use</u>

The majority of the soil test results returned determinant concentrations below either the laboratory limit of detection or their respective Tier 1 assessment criteria for 'residential' land use. However, a single soil sample (CBH2 at 1.5m) recorded arsenic concentration of 34 mg/kg, which is marginally above the arsenic CLEA SGV of 32mg/kg.

Further discussion of the potential risk from this marginally elevated arsenic concentration is presented in Section 6.4 of this report.

Soil Leachate Test Results

The majority of the determinants tested recorded results that are below either the laboratory detection limits or the relevant assessment criteria (Table 7). However, marginally elevated concentrations of benzo(a)pyrene and PAH (total) were recorded, as summarised below.

Determinant	Elevated Concentration (µg/l)	Threshold value (DWS) (µg/l)	Location (source)	Remarks
Benzo(a)pyrene	0.02	0.01	CBH2 (1.5m)	These concentrations are only marginally elevated above their DWS threshold values
PAH (total)[1]	<0.18 *(0.17µg/l detected)*	0.1		
Notes: ***1** – based on the sum of the 4 PAHs [benzo(b) fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(1,2,3-cd)pyrene].*				

The marginally elevated leachable concentrations of benzo(a)pyrene and PAH (total) are discussed further in following section (Section 6.4).

Asbestos Screening (Current Investigation)

All four soil samples were subjected to laboratory screening for asbestos fibres. No asbestos fibres were detected in any of the samples analysed. The results of the asbestos screening are summarised in Table 6.

6.4 Risk Assessment Discussion and Summary

Land (Soil) Quality

A marginally elevated arsenic concentration has been recorded at the site. To further evaluate the potential risk presented by the marginally elevated arsenic concentration, consideration for the need to undertake a statistical analysis of the arsenic test results was made. However, the four test results (4 No datasets) were deemed insufficient to allow for a robust statistical analysis.

Therefore, the risk to human health from the recorded arsenic concentration is considered **negligible.** This assessment takes into account the following:

- It is anticipated that the made ground in the car park area is likely to be excavated and removed off site as part of proposed development, thereby removing the potential source of contamination. In addition, any historical made ground (if present) in other areas of the site would have been removed by the basement construction of the existing buildings at the site.
- The recorded arsenic concentration of 34mg/kg is marginally elevated above the *'residential'* SGV of 32mg/kg.
- The CLEA SGV for *'residential'* land use assumes (by default) human exposure to soil contamination through eating 'homegrown produce'. However, no fruit/vegetable gardens are proposed as part of the scheme. The *'residential'* CLEA SGV is therefore considered very stringent for this risk assessment.
- The recorded arsenic concentration of 34mg/kg is below the ATRISK^{soil} SSV for *'residential without homegrown produce'* land use of 35mg/kg.
- Following development, the site will be covered mainly by the building footprints and hardstanding areas, which will eliminate any potential human exposure to the underlying made ground materials (if present).

However, it is advised that construction workers should use appropriate personal protection equipment (PPE) during the works, to avoid exposure to any unidentified contamination that may be present at the site.

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Controlled Waters

Marginally elevated leachable concentrations of benzo(a)pyrene and PAH (total) have been recorded at the site. However, these concentrations are not considered to present a significant risk to controlled waters due to the following:

- Upon completion of the proposed development, a large percentage of the site will be covered by building footprints or impermeable hardstanding areas. The presence of building footprints / hardstanding will minimise the potential infiltration at the site, consequently reducing the potential for leachate generation.

- The site is not located within 1km of a groundwater Source Protection Zone (SPZ). Additionally, no groundwater abstraction points (for portable public water supply) are recorded within 1km of the site. The groundwater abstraction points recorded 73m north, 667m south and 668m south of the site are used for 'heat pump', extracting the groundwater from the deeper aquifer. No surface water abstractions are recorded within 500m of the site.

- It is anticipated that the majority of the shallow sand and gravel materials would have been excavated/removed during the existing basement construction, occupying a great majority of the site. Therefore, no significant thicknesses of the 'Secondary A' aquifer deposits are anticipated at the site.

- As part of proposed development, the made ground currently present in the car park area is likely to be excavated and disposed off site, removing any potential risk to controlled waters.

- The DWS threshold values used in the risk assessment are considered extremely conservative as they represent acceptable concentrations at consumer's taps, and not acceptable concentrations within the groundwater prior to treatment.

- No surface water receptors are recorded within 500m of the site. The nearest surface water feature is the Grand Union Canal (Regent's Canal)) located some 756m north of the site. This is not considered a sensitive receptor.

- Finally, as part of proposed development, the made ground currently present in the car park area is likely to be excavated and disposed off site, removing any potential risk to controlled waters.

Based on the above, it is considered that the risk to controlled waters due to the recorded leachate and dissolved phase concentrations is **negligible**. Therefore, the leachate test results are not discussed further.

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Assessment of Risk through New Water Supply Pipes

The risk to human health resulting from the attack and permeation of new water supply pipes has been undertaken using the threshold concentrations given in the recently published *UKWIR Report Ref. No. 10/WM/03/21*. The soil chemical test results indicate a detectable TPH (aliphatic/aromatic C10 to C21) concentration of 256.2mg/kg (CBH2 at 1.5m), which exceeds the threshold value for PE pipe material of 10 mg/kg (mineral oil C11-C20).

Some of the parameters recommended by UKWIR (i.e., VOCs, SVOCs, BTEX, MTBE) have not been tested for. However, it should be noted that no detectable VOC concentrations have been identified at the site (all PID readings were below detection). In addition, no significant visual and/or olfactory evidence of hydrocarbon contamination was observed at the site. Furthermore, laboratory test results have recorded negligible/low concentrations of TPHs and BTEX compounds, indicating insignificant concentrations of volatile hydrocarbons at the site.

However, given that it is likely that the made ground in the car park area will be excavated and removed off site as part of proposed development, it would appear that new water supply pipes at the site would not require barrier protection. It is therefore considered that the risk to human health resulting from the attack and permeation of new water supply pipes is **negligible.**

Assessment of Risk from Ground/Soil Gas

The risk posed to human health (site users) from ground gases, due to the accumulation of toxic/asphyxiant and explosive gases in confined spaces is assessed as **negligible**, as discussed in Section 7 of this report.

Built Environment

It is considered that the risk to the built environment / structures arising from compounds aggressive to buried concrete is **high** based upon the ground aggressivity test results as discussed in Section 7 of this report.

6.5 Conceptual Site Model

A semi-quantitative risk assessment (Tier 1/2) approach has been undertaken for the site, based on the available site information. This is based upon the *"source – pathway – receptor"* conceptual risk model in accordance with current UK guidelines and establishes the likelihood and severity of potentially active pollutant linkages at the subject site.

The conceptual site model presented below is based on the site's proposed 'residential' end use. A diagrammatic representation of the Conceptual Site Model (CSM) is presented as Figure 7. The risks identified at the site as a result of the proposed development (assuming no remedial action is implemented) are summarised as follows:

Conceptual Site Model ('Residential' End Use)

Contaminant Source	Pathway	Receptor	Consequence of Pollutant Linkage	Likelihood of Pollutant Linkage	Overall Risk
Marginally elevated arsenic concentration	1 Dermal contact	Construction workers / Site users	M / H	N	N
	2 Accidental ingestion	Construction workers / Site users	M / H	N	N
	3 Inhalation of fugitive dust	Construction workers / Site users / Adjacent site users	M / H	N	N
Recorded TPH concentration above the UKWIR threshold value (PE pipe material only)	4 Permeation of new water supply pipes	Site users	M / H	N	N
Marginally elevated leachable concentrations of benzo(a)pyrene and PAH (total) above their DWS threshold values	5 Leaching of mobile contaminants	The underlying 'Secondary A' aquifer	M	N	N
	6 Leaching of mobile contaminants	The Grand Union Canal (Regent's Canal) located 756m north	L	N	N
Compounds aggressive to buried concrete	7 Direct attack of buried structures	Built environment / Structures	M	H	H
Recorded concentrations of ground gas	8 Accumulation in confined spaces and/or explosion	Construction workers / Site users / Built environment	H	N	N

Notes: H (High), M (Moderate) L (Low), N (Negligible)

Based on this risk assessment and CSM, it is considered that no site specific remedial measures will be required for the proposed development.

6.6 Waste Acceptance Criteria and Soil Disposal

No Waste Acceptance Criteria (WAC) testing was undertaken during the current investigation. However, a preliminary assessment of the likely classification of the underlying soil materials have been undertaken using the laboratory soil test results, as presented in Appendix B of this report. The preliminary soil waste classification assessment indicates that the shallow soil materials at the site do not have hazardous properties.

Furthermore, the soil test results have been compared to the inert waste threshold values. The soil test results have recorded soil organic matter (SOM) values ranging between 0.6 and 1.6%, which correlate to total organic carbon (TOC) values ranging between about 0.4 and 0.9%, below the inert waste threshold value for TOC of 3%. In addition, the recorded maximum concentrations of total TPH (360mg/kg) and total PAH (9.0mg/kg) are below their corresponding inert waste threshold values of 500 mg/kg (Mineral Oil) and 100mg/kg, respectively.

Therefore, based on the negligible/low soil determinant concentrations recorded during this investigation and the preliminary WAC assessment, it is considered that the made ground materials tested are likely to classify as 'inert' waste for off-site disposal purposes. This preliminary assessment will require confirmation/disapproval prior to any disposal of soil materials from site. It is therefore recommended that should any off site disposals be required, the materials should be carefully segregated, stockpiled separately and subjected to WAC analysis to determine their actual waste classification.

7. GEOTECHNICAL ASSESSMENT AND ENGINEERING CONSIDERATIONS

7.1 Introduction

Based on the findings of the current ground investigation, the following section provides a geotechnical assessment of the ground conditions at the site, in relation to the proposed buildings at Cartwright Gardens, University of London.

General guidance is provided in this report on foundation solutions for the proposed scheme based on the proven ground conditions, the proposed building layout and anticipated maximum structure loadings. In addition, the effect of proposed development on the existing London Underground Tunnel (with the tunnel crown at 5.8m AOD) has been assessed.

7.2 Ground Model

The area surrounding the development site is generally flat between about 23m AOD in the north and 23.8m in the south. The majority of the development area is currently occupied by the university buildings which include a basement covering the majority of the site, except the car park area in the north east. The basement has a variable existing finished floor level between about 19.7m and 21.3m AOD. A tarmac car park is present in the northeast of the site at levels between about 22.0m and 22.5m AOD.

Brick faced retaining structures, up to 4.3m high, are present along the perimeter of the site retaining the adjoining roads.

Exploratory holes drilled during the current investigation (two drilled outside the development area) indicated a made ground thickness, up to 3.6m deep, in the car park area. Although CBH2 drilled in the car park area indicated a thin unit (1.9m) of sandy gravel overlying a thin unit (0.8m) of firm silty clay (possibly belonging to the Taplow Gravel) underneath the made ground, these thin gravel and clay units were not recorded in the nearby borehole CBH1. The sandy gravel to gravelly sand unit underlain by a thin 0.4m to 0.9m thick soft/firm slightly sandy clay unit was recorded from about 0.5m – 1.9m to 2.5m – 4.8m bgl in both boreholes drilled in the Cartwright Gardens. Based on these borehole records, the base of Taplow Gravel/top of London Clay is at about 2.5m to 4.8m depth (about 19.0m to 20.8m AOD).

Stiff, localised firm, becoming very stiff London Clay of medium to high strength is present underneath the Taplow Gravel stratum, and the base of London Clay was proven to 0.8m and 3.2m AOD. The London Clay is underlain by Lambeth Group of very stiff clay, proven to approximately 25m - 25.6m depth (bgl) in BH2 and BH4 (about -1.2m to -3.1m AOD). Based on the above information, it is anticipated that the granular and cohesive units of the Taplow Gravel has been removed by the basement construction, except perhaps in the car park area in the northeast where a thin (approximately up to 1m thick) layer is present underneath the made ground.

The representative ground conditions underlying the development area are illustrated by a number of cross sections through the site in Figure 4. These cross sections indicate that the existing basements are generally sitting on the London Clay stratum.

The characteristic Cu value of London Clay can be determined from the following approximate relationship: Cu (kPa) = 174 - 6 x Depth (m AOD), whereas the Cu value of Lambeth Group is generally over 200kPa.

7.3 Groundwater

Groundwater strikes/seepages were only recorded in CBH2 and CBH3 at 15.5m bgl (7.0m AOD) to 15.7m bgl (7.5m AOD) within the London Clay. Groundwater monitoring undertaken in the two monitoring wells to date recorded a groundwater level of 2.7m bgl (19.6m AOD) in CBH1 and 7.6m bgl (16.2m AOD) in CBH4. As the response zone of both wells also include the relatively impermeable London Clay, the water level measured in CBH4 is not considered to reflect the true groundwater level at this location.

It is considered that a perched groundwater (perched above the London Clay) is present underlying the site. Deeper groundwater levels are anticipated to be at a significant depth within the Lambeth Group and/or within the underlying Thanet Sand/Chalk (confined major aquifer).

7.4 Existing Perimeter Retaining Structures

A brick faced retaining structure, with a retained height up to 4.3m, is present along the majority of the site perimeter, retaining the existing infrastructure. No investigation was undertaken to determine the wall shape and foundation details during the current investigation. It is recommended that the stability of the wall should be assessed if any development is to take place in close vicinity of the wall. The recommended design parameters in Table 2 may be adopted for retaining wall design purposes.

7.5 Possible Historical Underground Rifle Range/Obstructions

Anectodal evidence indicated the presence of a historical underground rifle range crossing the western part of the car park within the existing development. Two shallow trial pits located to investigate the presence (roof) of this rifle range indicated no evidence of a structure within the depths investigated. In addition, a GPR survey undertaken in the car park area was inconclusive.

It is recommended that further investigation by deep trial pits is undertaken during the demolition of the structures to confirm the presence/absence of the underground obstructions in this area.

7.6 Foundations

Introduction

At this stage, only preliminary design data is available indicating the proposed applied pressures in for the southern part of the site. Neither individual column loadings nor proposed foundation types have yet been determined.

Only preliminary guidance is provided in this report for foundation solutions based on the results of the ground investigation and preliminary geotechnical analysis. The recommendations may need to be revised in accordance with the final design details for the proposed scheme. Further assessments will be required if the structural details, layout of the proposed buildings or structural loadings are revised.

As part of the proposed scheme, the existing structures (except Hughes Parry Tower in the north of the site) will be demolished prior to the construction of the new buildings. However, the existing ground slab within the basement is generally to be retained.

The existing structure finished floor levels (FFL) in the basement vary from about 19.8m to 20.6m AOD, whereas the proposed FFL for new structures will be approximately 20.4m AOD. In addition, the existing ground floor levels in the existing car park and courtyard areas vary from about 22.0m to 23.8m AOD, which is about 1.6m to 3.4m higher than the proposed basement level.

Preliminary calculations undertaken by the structural design team indicate that the existing building loads in the southern part of the site vary from about 19 kPa to 121 kPa, whereas the proposed loads could be between 79 kPa to 129 kPa, except for the currently unoccupied courtyard area. In some areas, the loads will increase from about 5 kPa to 94 kPa, elsewhere the loads could reduce between 42 kPa and 111 kPa.

Ground Heave

The demolition of existing buildings may result in ground heave at the surface of the slab, which will be retained.

As the existing building loads vary from 19 kPa to 121 kPa for different existing structures, the heave at different parts of the development area is likely to be different following demolition. Depending on the demolition/construction programme, the heave may also vary significantly from location to location at the site. Therefore, at this stage, the anticipated ground heave due to demolition and/or excavation has not been calculated for each structure/overall site. However, a preliminary calculation of anticipated heave has been undertaken for the area currently indicated to have the highest building load (121 kPa), as well as for the car park/courtyard areas which will be excavated down to the proposed basement level of 20.4m AOD.

The anticipated heave at the centre of the area with the highest existing load (121 kPa), and measuring about 9.5 X 9.6m, will be approximately 15mm, assuming it is demolished as a single unit and considering that the new building will be constructed, say, within one year of demolition of the existing structure.

In the car park/courtyard areas up to about 4m deep soil will be excavated for basement construction. The heave (short term) in these areas is also anticipated to be within 15mm.

Detailed heave calculations should be undertaken once the proposed building loads are confirmed and the construction programme is agreed.

Foundation Design

The existing buildings are not supported on piled foundations and the new development is also not likely to be supported on piled foundations based on the assumption that the proposed building loads will not be significantly different (more) than the existing loads. It is anticipated that traditional raft or shallow pad footings will be adopted for the proposed development. Either option would involve constructing the new foundations on top of the retained existing ground floor raft slab in the Commonwealth Hall area. For the Hughes Parry and York/Canterbury Hall areas, it will be necessary to construct new pad/raft foundations below the proposed FFL of 20.4m AOD.

At this stage, no structural Eurocode loadings/column loads are available, therefore a detailed foundation assessment has not been undertaken. Based on the results of the ground investigation shallow footings taken into the London Clay at around 19m AOD would be feasible for the northern development area.

In designing the foundations, differential settlement that could occur between the southern parts of the site (where new pads will be placed on the existing raft) and the central/northern sections of the development area where new shallow footings will be constructed onto London Clay, should be taken into account. Similarly, the effects of the new foundations on the existing foundations of the Hughes Parry Tower that will be retained should be accounted for in determining the foundation depths for the new footings.

It is recommended that detailed geotechnical calculations should be undertaken when proposed structure details/loads are determined. The recommended characteristic geotechnical parameters for the design of foundations are given in Table 2.

7.7 Effects of Development on London Underground Tunnel

The existing London Underground tunnels (Piccadilly line) run at about 26m below the existing/proposed development across the southeast corner of the development site, running NNE to SSW.

The cross sections A-A' and C-C' in Figure 4 indicate that immediately below the proposed basement (FFL of 20.4m AOD) an approximate 16m thick, stiff to very stiff London Clay of high to very high strength, overlies a band of Lambeth Group Clay. This layer is approximately 9m thick comprising very stiff, high strength, and overlies the existing London Underground Tunnels (crown at about (-) 5.7m AOD, based on drawings received from London Underground, LCS code P052, 05/07/11).

In the area of the development directly above the tunnel preliminary structural calculations indicate the proposed loads to be approximately 92 kPa, whereas the existing building loads were approximately 87 kPa. In other areas of the development the loadings vary as summarised in the previous section. The relevant area of concern is the southeast corner of the site closest to the tunnel alignment.

In the southeast corner of the site, directly above the existing underground tunnel, the heave due to the proposed demolition has been assessed based on about 85 kPa load reduction (= about 87kPa – 0.25m thick concrete slab).

The undrained Young's modulus of 36 MPa adopted for the heave calculation is based on the correlation of Eu = 400 x Cu for London Clay (Tomlinson, 1995), using an average (characteristic) Cu of 90 kPa (stiff London Clay). The calculations indicate that the total heave on the surface could be around 10mm at the southeast corner of the site immediately overlying the tunnel and the heave on the top of the Lambeth Group is around 2mm. Therefore, the heave within the soil immediately above the tunnel crown is likely to be much less than 2mm and therefore negligible. The lateral displacement of soil along the existing tunnel is anticipated to be less than 1mm and is also therefore considered to be negligible.

Based on a 2 in 1 method stress distribution in depth, the increase in stress at the crown of existing tunnel (26m below FFL) is about 9 kPa; approximately 1.5% of the overburden pressure (say 550 kPa based on 25m thick London Clay).

In the central area away from the southeast corner of the site, preliminary settlement calculations indicate a total consolidation settlement of about 10mm, occurring at proposed basement level (20.4m AOD), as the result of 80 kPa load increase in this area. The proportion of the calculated total vertical deformation within the Lambeth Group is about 3mm. The lateral deformation is anticipated to be again less than 1mm in the soil (Lambeth Group strata) near the tunnels.

In summary, numerical calculations based on the preliminarily determined existing and proposed loads applied at basement level, indicated that the vertical and lateral heave/settlement and load effects on the tunnel from the proposed development will be negligible. Detailed calculations are included in the letter report forwarded to London Underground and not repeated here.

7.8 Soil Volume Change Potential

The combination of shrinkable soils and trees represents a hazard due to volume changes resulting in ground moment. In order to minimise the potential risk, the design depth of foundations has been assessed in accordance with NHBC Standards – Chapter 4.2: Building Near Trees.

The plasticity index values of London Clay at the site ranged between 30% and 49% resulting in modified plasticity index values generally over 30%. These results indicate the London Clay unit to have a medium to high volume change potential.

Chapter 4.2, Table 3 and Table 5 of the NHBC Standards indicate that for cohesive soils of high volume change potential foundation depths should not be less than 1.5m allowing for restricted new planting. In areas outside the zone of influence of trees, foundation depths should not be less than 1.0m for high potential volume change soil.

Although the London Clay has a medium to high volume change potential, the development will also include deep basements, and therefore, the proposed foundations are unlikely to be affected by existing or proposed trees.

7.9 Ground Gas Risk Assessment

No radon protection measures are required for development at the site.

The ground gas risk assessment for the site has been undertaken using the monitoring data obtained from the current investigation. Monitoring was carried out in the two current wells on six occasions between 05 October 2012 and 21 January 2013. The results are summarised in Table 4.

Recorded methane concentrations during the monitoring period were negligible (below or equal the detection level of 0.1%v/v). Steady state carbon dioxide concentrations were all well less than 5%. The steady state gas flow rates were negligible.

Based on the monitoring data, the characteristic gas screening value (GSV) for both CO_2 and/or CH_4 calculated in accordance with BS 8045 is negligible (less than 0.003 l/hr). Based on the monitoring results, the gas regime at the site classifies as Characteristic Gas Situation 1 (CS1 – very low hazard potential) in accordance with Table 1, BS 8485:2007.

It is therefore considered that the risk from ground gases is negligible and no special protection measures will be required for the proposed structures at the site.

CUNDALL

7.10 Ground Aggressivity

In the current investigation, eight London Clay samples were tested in accordance with procedure outlined in Figure C5 of BRE Special Digest (recommended for pyrite bearing natural ground). In addition, two made ground samples and two Taplow Gravel samples were tested for water soluble sulphate and pH. The test results are summarised in Table 3.

A ground aggressivity analysis for sulphate attack to concrete has been carried out in accordance with BRE Special Digest 1, using the results of chemical tests as detailed below.

Water soluble sulphate concentration in the made ground samples ranged from 200 mg/l to 850 mg/l, with pH ranging from 7.8 to 10.7. The characteristic sulphate concentration in the made ground is 525 mg/l (based on a mean of two highest test results in accordance with BRE guidance). Therefore, the made ground would be classified as ACEC class AC-1s, requiring DS-2 for buried concrete, assuming brownfield conditions and static groundwater. In any case, the made ground present in the car park area is likely to be removed by the basement extension in this area.

It is considered that the adoption of 'static groundwater conditions' is more appropriate for the site, due to the presence of the perimeter wall and the existing/proposed basement being founded on London Clay.

Two tests undertaken on the granular samples of the Taplow Gravel recorded water soluble sulphate concentration values of 37 mg/l and 850 mg/l, with pH ranging from 8.7 to 10.1. Similarly, any Taplow Gravel locally present in the car park area is likely to be removed by basement extension.

Water soluble sulphate concentration in the London Clay samples ranged from 240 mg/l to 650 mg/l, with pH ranging from 8.2 to 8.8. Tests on the same samples indicated an acid soluble sulphate (total) concentration between 0.15% and 0.33% and a calculated total potential sulphate concentration between 0.93% and 1.95%. A significantly high total potential sulphate value of 5.7 to 8.4 was determined on a sample from CBH3A drilled in Cartwright Gardens. The calculated oxidisable sulphide contents were between 0.9% and 1.6% in all samples tested, except in the sample from CBH3A, which recorded a calculated oxidisable sulphide content of 5.37 to 8.08%.

Magnesium and chloride contents of the soil / groundwater samples were not determined during the ground investigation as the soluble sulphate contents were measured well below the trigger level of 3000 mg/l on the samples tested.

BRE Special Digest states that if the amount of oxidisable sulphides is greater 0.3% SO4 in a significant number of samples, pyrite is probably present. It is therefore considered that some pyrite is potentially present in the London Clay. Based on these test results, the London Clay would be classified as AC-3s (static groundwater conditions) and design sulphate class DS-4, mainly based on the high total potential sulphate content of 0.93 to 1.95%, with the majority of results being in excess of 1.2%, in accordance with BRE (2005). Very high value obtained from the borehole drilled in Cartwright Gardens has not been used in the assessment, as it may reflect local condition within London Clay.

BRE (2005) states that total potential sulphate test results are only appropriate if the natural ground is to be substantially disturbed, for example, by cutting and filling to terrace a site, or by excavation and backfilling, so that air can enter and oxidise any pyrite contained therein. Cutting through ground without opening up the ground beyond the cut face (e.g. piling operations or excavation without backfill) does not generally result in disturbed ground.

The proposed basement slab/pad foundations are all anticipated to be founded on/within the London Clay. Therefore, based on the test results, as discussed above, it is recommended that the foundation soils are classified as ACEC class AC-3s and the design sulphate class for buried concrete in contact with the ground as DS-4.

7.11 Excavations, Groundwater Control and Temporary Support

It is expected that basement excavations in the made ground and the underlying sand/gravel unit and London Clay will be achievable by means of normal hydraulic excavating plant.

It is possible that some groundwater will be encountered in basement excavations based on the monitoring records. Groundwater levels may rise during wet periods or following heavy prolonged rainfall as indicated by the monitoring records.

If groundwater is encountered in basement excavations during construction works, it is considered likely that any groundwater flows will be of limited volume and be able to be managed by traditional sump pumping methods. Excavations into the natural clay should not be left open for long periods, as clays are prone to softening particularly during inclement weather.

Temporary support may be required in the new basement areas or the basement levels are taken deeper than existing.

In order to prevent damage to adjacent structures, the design of the retaining wall and basement excavation must address the risk of excessive displacement of the wall and bracing, both in the temporary and permanent conditions, to ensure that the soil deformation (vertical and horizontal) around and below the excavation remain within acceptable levels.

7.12 Reuse of Materials

At this stage, no cut and fill figures are available. However, it is not anticipated that any significant volumes of site won materials will be reused at the site due to the nature of the proposed development. If any some off site disposal of site won soils may be necessary, especially from the current car park area. Therefore, no compaction tests were undertaken on made ground and natural soils at the site.

CUNDALL

8. CONCLUSIONS AND RECOMMENDATIONS

Ground Conditions

Exploratory holes drilled during the current investigation indicated a made ground thickness, up to 3.6m deep, in the car park area in the northeast of the site. A thin unit of Taplow Gravel (also including a lower clay unit) was also locally present in the car park area. Made ground/Taplow Gravel (where not removed by basement excavation) is underlain by the London Clay at a depth of approximately 2.7m to 4.8m bgl (about 19.2m to 20.0m AOD). The base of the London Clay was proven to 0.8m and 2.6m AOD, underlain by the Lambeth Group strata.

Based on the monitoring records and site observations during the fieldwork, it is considered that shallow groundwater is present within the made ground/Taplow Gravel, perched above the London Clay.

Obstructions

Two shallow trial pits located to investigate the presence (roof) of a historical rifle range indicated no evidence of a relict structure/foundations in the car park area. A GPR survey undertaken in the car park area was also inconclusive. It is recommended that further investigation by deep trial pits is undertaken during the demolition of the existing buildings to confirm the presence/absence of the underground obstructions in this area.

Gas Protection Measures

No radon protective measures are required for development at the site. Based on the gas monitoring undertaken and the revealed ground conditions, the gas regime at the site classifies as Characteristic Gas Situation 1 (very low hazard potential in accordance with Table 1, BS 8485:2007) and no specific gas protection measures are likely to be required.

Soil Volume Change Potential

The plasticity index values of the London Clay at the site ranged between 30% and 49% resulting in modified plasticity index values generally over 30%. These results indicate the London Clay to have a medium to high volume change potential.

As the development will also include a deep basement, the proposed foundations are unlikely to be affected by existing or proposed trees.

Ground Aggressivity

A ground aggressivity analysis for sulphate attack to concrete has been carried out in accordance with BRE Special Digest 1, using the results of ground aggressivity tests undertaken on site soils.

The calculated oxidisable sulphide contents determined from ground aggressivity tests undertaken on a number of samples indicated the potential presence of some pyrite in London Clay. The London Clay would therefore be classified as ACEC class AC-3s and design sulphate class DS-4, mainly based on the high total potential sulphate content of 0.93 to 1.95%, with the majority of results being in excess of 1.2%, in accordance with BRE (2005).

Proposed basement slab/pad foundations are all anticipated to be founded on or within the London Clay. Therefore, a design sulphate class of DS-4 is recommended for concrete in contact with London Clay. The Aggressive Chemical Environment for Concrete (ACEC) within the site is classified as AC-3s in accordance with BRE Special Digest 1:2005.

Foundation Design Considerations

Only preliminary guidance is provided in this report for foundation solutions based on the results of the ground investigation and preliminary geotechnical analysis. The recommendations may need to be revised in accordance with the final design details for the proposed scheme. Further assessments will be required if the structural details, layout of the proposed buildings or structural loadings are revised.

As part of the proposed scheme, the existing structures (except Hughes Parry Tower in the north of the site) will be demolished prior to the construction of the new buildings. However, the existing ground slab within the basement is generally to be retained.

Preliminary calculations undertaken by the structural design team indicate that the existing building loads in the southern part of the site vary from about 19 kPa to 121 kPa, whereas the proposed loads could be between 79 kPa to 129 kPa, except for the currently unoccupied courtyard area. In some areas, the loads will increase from about 5 kPa to 94 kPa, elsewhere the loads could reduce between 42 kPa and 111 kPa.

Ground Heave. The demolition of existing buildings may result in ground heave at the surface of the slab, which will be retained. As the existing building loads vary throughout the site, the heave at different parts of the development area is likely to be variable following demolition. At this stage, limited heave calculations have been undertaken for the areas with existing highest calculated load and the car park area which will be excavated down to the proposed FFL level. Detailed heave calculations should be undertaken once the proposed building loads are confirmed and the construction programme is agreed.

Foundation Design. The existing buildings are not supported on piled foundations and the new development is also not likely to be supported on piled foundations based on the assumption that the proposed building loads will not be significantly different (more) than the existing loads. It is anticipated that traditional raft or shallow pad footings will be adopted for the proposed development. Either option would involve constructing the new foundations on top of the retained existing ground floor raft slab in the Commonwealth Hall area. For the Hughes Parry and York/Canterbury Hall areas, it will be necessary to construct new pad/raft foundations below the proposed FFL of 20.4m AOD.

At this stage, no structural Eurocode loadings/column loads are available, therefore a detailed foundation assessment has not been undertaken. Based on the results of the ground investigation shallow footings taken into the London Clay at around 19m AOD would be feasible for the central and northern development area.

In designing the foundations, differential settlement that could occur between the southern parts of the site (where new pads will be placed on the existing raft) and the central/northern sections of the development area where new shallow footings will be constructed onto London Clay, should be taken into account. Similarly, the effects of the new foundations on the existing foundations of the Hughes Parry Tower that will be retained should be accounted for in determining the foundation depths for the new footings.

It is recommended that detailed geotechnical calculations should be undertaken when proposed structure details/loads are determined.

Effect of Development on London Underground Tunnels

The existing London Underground tunnels (Piccadilly line) run at about 26m below the existing/proposed development across the southeast corner of the development site, running NNE to SSW. Numerical calculations based on the preliminarily determined existing and proposed loads applied at basement level, indicated that the vertical and lateral heave/settlement and load effects on the tunnel from the proposed development will be negligible.

Retaining Walls

Brick faced retaining structure, with a retained height up to 4.3m, is present along the majority of the site perimeter, retaining the existing infrastructure. No investigation was undertaken to determine the wall shape and foundation details during the current investigation. It is recommended that the stability of the wall should be assessed if any development is to take place in close vicinity of the wall. The recommended design parameters in this report may be adopted for retaining wall design purposes.

Reuse of Site Won Soils

At this stage, no cut and fill figures are available. However, it is not anticipated that any significant volumes of site won materials will be reused at the site due to the nature of the proposed development. If any some off site disposal of site won soils may be necessary, especially from the current car park area. Therefore, no compaction tests were undertaken on made ground and natural soils at the site.

Excavations, Temporary Support and Groundwater Control

If groundwater is encountered in basement excavations during construction works, it is considered likely that any groundwater flows will be of limited volume and be able to be managed by traditional sump pumping methods. Temporary support may be required in the new basement areas or the basement levels are taken deeper than existing.

In order to prevent damage to adjacent structures, the design of the retaining wall and basement excavation must address the risk of excessive displacement of the wall and bracing, both in the temporary and permanent conditions, to ensure that the soil deformation (vertical and horizontal) around and below the excavation remain within acceptable levels.

Car Park/Road Pavement Design

As the whole site will be covered by the building footprints no CBR tests were undertaken for pavement/road design purposes.

Site Contamination and Risk Assessment

Limited made ground is present only in the car park area, elsewhere, any historical made ground, if present, would have been removed by the basement construction which covers the remaining areas of the development site. No significant elevated determinant concentrations have been identified within the made ground samples analysed. Consequently, no plausible risk to human health has been identified at the site.

Although soil leachate test results have indicated marginally elevated benzo(a)pyrene and PAH (total), concentrations, the potential risk to controlled waters arising from these PAHs are assessed as negligible. A single made ground sample has recorded elevated TPH concentration above the UKWIR threshold value for PE pipe material only. However, as part of proposed development, the made ground in the car park area is likely to be excavated and disposed off site, removing any potential risk to controlled waters and future water supply pipes.

Disposal of Soil Waste

No WAC testing was carried out during this investigation. A preliminary assessment undertaken using the recorded geochemical test results has indicated that the made ground materials analysed are likely to classify as ‘inert’ for offsite disposal purposes. However, this preliminary assessment will require confirmation/disapproval prior to any disposal of soil materials from site. It is therefore recommended that should any off site disposals be required, the materials should be carefully segregated, stockpiled and subjected to WAC analysis to determine their actual waste classification under the Landfill Directive Waste Acceptance Criteria.

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TABLES

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Table 1: Summary of Engineering Properties of Soils

Stratum	Typical Range From(m AOD) to (m AOD)	Index Properties		Density	Corrected SPT N_{60} values	Angle of shearing resistance	Undrained Shear Strength*	Undrained Shear Strength**	Coefficient of Volume Compressibility
		w (%)	PI (%)	γ (kN/m^3)	'N_{60}'	ϕ' (deg)	C_u (kPa)	C_u (kPa)	m_v (m^2/MN)
Made Ground	From 22.5 – 24.0 To 18.9 – 23.3	-	-	-	13 – 50 (4)		-	-	-
Taplow Gravel (sand and gravel) (clay bands)	From 20.6 – 23.3 To 19.2 – 21.0	-	-	-	23- 50 (6) plus 10 -19 (2) in clay bands	34 – 40.5 (granular)	42 -80 (clay bands)	-	-
London Clay	Form 19 – 20.6 To 0.8 – 2.6	22 – 30 (22)	30 – 49 (44)	21 – 22 (23)	13 – 50 (42) plus 5No refusal	-	48 – 140 (22)	48 – 215 (64)	100 – 200kPa 0.04 – 0.14 (10) 200 – 400kPa 0.05 – 0.09 (10)
Lambeth Group	From 0.8 – 2.6 Base not proven	-	-	-	All refusal	-	-	-	-

Notes: 12-16: range of values; (7): total number of results.
* Based on results of laboratory undrained triaxial tests.
** Based on results of laboratory undrained triaxial tests and values derived from SPT tests; Cu derived from SPT N values (Stroud & Butler method). **A factor of 4.3 for London Clay**

Table 2: Summary of Characteristic Geotechnical Parameters

Foundations

Stratum	Depth From - To (m AOD)	Strength Description	Weight Density γ (kN/m³)	Undrained Shear Strength C_u (kPa)	Angle of Shearing Resistance Φ' (degrees)	Coefficient of Volume Compressibility m_v (m^2/MN)
Made Ground	From 22.5 – 24.0 To 18.9 – 23.3	-	18	-	$\varnothing' = 26^o$ (C' = 0)	-
Taplow Gravel (sand and gravel) (clay bands)	From 20.6 – 23.3 To 19.2 – 21.0	Medium dense to dense	18		$\varnothing' = 36^o$ (C' = 0)	-
London Clay	From 19 – 20.6 To 0.8 – 2.6	Stiff, locally firm, becoming stiff to very stiff	21	Cu (kPa) = 174 - 6.0 x Depth (m AOD)		0.08 (above about 9m AOD) 0.05 (below 9m AOD
Lambeth Group	From 0.8 – 2.6 Base not proven	Very stiff	21	>200kPa	$\varnothing' = 25^o$ (C' = 3kPa)	0.03

Table 3: Ground Aggressivity Test Results

Soil Type	Exploratory Hole	Depth (m bgl)	Water Soluble Sulphate 2:1 soil/water extract (mg/l)	Acid Soluble Sulphate (%)	Total Potential Sulphate (%)	pH	Oxidisable Sulfides (%)
Made Ground							
Granular	CBH1	2.2	850	-	-	10.7	-
Granular	CBH2	1.3	200	-	-	9.8	-
		Range	**200 - 850**	**-**	**-**	**9.8-10.7**	
Natural Soil							
Gravel	CBH3A	2.0	850	-	-	10.1	-
Gravel	CBH4	3.2	37	-	-	8.7	-
		Range	**37 - 850**	**-**	**-**	**8.7 – 10.1**	
London Clay	CBH1	4.2	650	0.24	1.95	8.8	1.71
London Clay	CBH1	5.2	440	0.18	1.47	8.6	1.29
London Clay	CBH2	3.7	360	0.17	1.08	8.3	0.91
London Clay	CBH2	4.7	450	0.19	1.47	8.3	1.28
London Clay	CBH3A	3.5	390/410*	0.33/0.32*	**5.7/8.4***	8.2/ 8,.7*	**5.37/8.08***
London Clay	CBH3A	4.5	240	0.15	1.14	8.3	0.99
London Clay	CBH4	6.2	280	0.15	0.93	8.3	0.78
London Clay	CBH4	5.2	290	0.2	1.32	8.6	1.12
		Range	**240 - 650**	**0.15 – 0.33**	**0.93 – 1.95 except 5.7/8.4**	**8.2 – 8.8**	**0.78 – 1.71 except 5.37/8.08**

Note: * retest result.

Table 4: Gas Monitoring Results

BH No	CBH1 (Cundall)								
Date	Atmospheric pressure (mbars)	CO_2 (%v/v)	O_2 (%v/v)	CH_4 (%v/v)	H_2S (ppm)	CO (ppm)	Gas Flow Rate (l/hr)	Gas screening value (l/hr)	
								CO_2	CH_4
05/10/2012	1004	<0.1	20.3	<0.1	ND	ND	<0.1	<0.0001	<0.0001
13/10/2012	1001	<0.1	21.0	<0.1	ND	ND	<0.1	<0.0001	<0.0001
25/10/2012	1013	0.1	20.9	<0.1	ND	ND	<0.1	<0.0001	<0.0001
15/11/2012	1017	0.1	20.8	<0.1	ND	ND	<0.1	<0.0001	<0.0001
14/12/2012	982	0.1	20.8	<0.1	ND	ND	<0.1	<0.0001	<0.0001
21/01/2012	988	<0.1	20.8	<0.1	ND	ND	<0.1	<0.0001	<0.0001
BH No	CBH4 (Cundall)								
Date	Atmospheric pressure (mbars)	CO_2 (%v/v)	O_2 (%v/v)	CH_4 (%v/v)	H_2S (ppm)	CO (ppm)	Gas Flow Rate (l/hr)	Gas screening value (l/hr)	
								CO_2	CH_4
05/10/2012	1004	0.9	19.0	<0.1	ND	ND	<0.1	<0.0009	<0.0001
13/10/2012	1001	2.5	19.0	<0.1	ND	ND	<0.1	<0.0025	<0.0001
25/10/2012	1013	2.6	18.9	<0.1	ND	ND	<0.1	<0.0026	<0.0001
15/11/2012	1017	2.4	19.0	<0.1	ND	ND	<0.1	<0.0024	<0.0001
14/12/2012	982	1.7	19.6	<0.1	ND	ND	<0.1	<0.0017	<0.0001
21/01/2012	988	1.5	19.3	<0.1	ND	ND	<0.1	<0.0015	<0.0001

Notes: Calculated in accordance with current guidance (CIRIA C665: 2007 and BS 8450:2007).
ND: None detected.

Table 5a: Groundwater Observations during Fieldwork

Exploratory Hole	Water Strike Level*			After 20 mins	Remarks
	Stratum	**Depth (m bgl)**	**Depth (m AOD)**	**Depth (m bgl)**	
CBH2	London Clay	15.5	7.0		'Slight' Seepage
CBH3	London Clay	15.7	7.5	-	'Water Strike'

Table 5b: Groundwater Monitoring Results

Date	**BH No**		CBH1 (Cundall)	CBH4 (Cundall)
	Installation type*		Groundwater (19mm)	Groundwater (19mm)
	Response Zone		Made Ground London Clay	Taplow Gravel London Clay
	Pipe Depth	(m bgl)	**8.0**	**8.0**
05.10.2012	GW Depth	m bgl (m AOD)	6.0 (16.3)	*DRY*
13.10.2012	GW Depth	m bgl (m AOD)	3.9 (18.4)	*DRY*
25.10.2012	GW Depth	m bgl (m AOD)	2.7 (19.6)	7.6 (16.2)
15.11.2012	GW Depth	m bgl (m AOD)	2.7 (19.6)	7.6 (16.2)
14.12.2012	GW Depth	m bgl (m AOD)	3.2 (19.1)	6.7 (17.1)
21.01.2012	GW Depth	m bgl (m AOD)	2.7 (19.6)	3.8 (20.0)

Table 6: Summary of Soil Chemical Test Results and Tier 1 Assessment (‘Residential’ Land Use)

Contaminant	Units	Test Results Range	Mean Value Test (US_{95})	No. of Tests	Threshold Value for ‘Residential’ Land Use	Locations of values above Threshold	Does US_{95} Exceed Threshold?
Metals, semi-metals, pH							
pH	pH units	9.9 – 10.6	N/A	4	N/A	N/A	N/A
Arsenic	mg/kg	9.5 – 34	N/A	4	32[1]	CHB2 (1.5m)	Not Calculated
Boron (water soluble)	mg/kg	1.4 – 1.9	--	4	291[2]	--	--
Cadmium	mg/kg	1.6 – 6.5	--	4	10[1]	--	--
Chromium (III)	mg/kg	<14 – <54	--	4	627[2]	--	--
Chromium (VI)	mg/kg	<1.0	--	4	4.3[2]	--	--
Copper	mg/kg	20 – 71	--	4	2330[2]	--	--
Mercury	mg/kg	0.11 – 2.1	--	4	1[1]	--	--
Nickel	mg/kg	9 – 25	--	4	130[1]	--	--
Lead	mg/kg	23 – 210	--	4	383[3]	--	--
Selenium	mg/kg	<5.0	--	4	350[1]	--	--
Zinc	mg/kg	65 – 390	--	4	3750[2]	--	--
Cyanide (free)	mg/kg	<0.1 – 0.1	--	4	34[3]	--	--
Cyanide (total)	mg/kg	0.1 – 4.1	--	4	34[3]	--	--
PAHs							
Acenaphthylene	mg/kg	<0.1 – 0.1	--	4	850[2]	--	--
Acenaphthene	mg/kg	<0.1 – 0.6	--	4	1000[2]	--	--
Anthracene	mg/kg	<0.1	--	4	9200[2]	--	--
Benzo(a)anthracene	mg/kg	<0.1 – 0.5	--	4	5.9[2]	--	--
Benzo(a)pyrene	mg/kg	0.2 – 1.0	--	4	1.0[2]	--	--
Benzo(b)fluoranthene	mg/kg	0.1 – 0.7	--	4	7.0[2]	--	--
Benzo(ghi)perylene	mg/kg	0.2 – 1.2	--	4	47[2]	--	--
Benzo(k)fluoranthene	mg/kg	<0.1 – 0.4	--	4	10[2]	--	--
Chrysene	mg/kg	0.3 – 1.3	--	4	9.3[2]	--	--
Dibenzo(ah)anthracene	mg/kg	<0.1 – 0.2	--	4	0.9[2]	--	--
Fluorene	mg/kg	<0.1 – 0.7	--	4	780[2]	--	--
Fluoranthene	mg/kg	0.3 – 1.3	--	4	670[2]	--	--
Indeno(123cd)pyrene	mg/kg	0.3 – 1.2	--	4	4.2[2]	--	--
Naphthalene	mg/kg	<0.1 – 0.4	--	4	8.7[2]	--	--
Phenanthrene	mg/kg	<0.1 – 0.2	--	4	380[2]	--	--
Pyrene	mg/kg	0.3 – 0.8	--	4	1600[2]	--	--
TPHs							
TPH Aliphatic C5-C6	mg/kg	<0.01	--	4	110[2]	--	--
TPH Aliphatic C6-C8	mg/kg	<0.01	--	4	370[2]	--	--
TPH Aliphatic C8-C10	mg/kg	<0.01	--	4	110[2]	--	--
TPH Aliphatic C10-C12	mg/kg	<1.5 – 3.6	--	4	540[2]	--	--
TPH Aliphatic C12-C16	mg/kg	<1.2 – 77	--	4	3000[2]	--	--
TPH Aliphatic C16-C35	mg/kg	<14.5 – 180	--	4	76000[2]	--	--
TPH Aromatic C5-C7	mg/kg	<0.01	--	4	280[2]	--	--
TPH Aromatic C7-C8	mg/kg	<0.01	--	4	611[2]	--	--
TPH Aromatic C8-C10	mg/kg	<0.01	--	4	151[2]	--	--
TPH Aromatic C10-C12	mg/kg	<0.9	--	4	346[2]	--	--
TPH Aromatic C12-C16	mg/kg	<0.5 – 8.6	--	4	593[2]	--	--
TPH Aromatic C16-C21	mg/kg	<0.6 – 47	--	4	770[2]	--	--
TPH Aromatic C21-C35	mg/kg	14 – 51	--	4	1230[2]	--	--
Others							
Phenol	mg/kg	<0.3 – 0.4	--	4	420[1]	--	--
Soil Organic Matter	%	0.6 – 1.6	--	4	N/A	N/A	N/A
Asbestos Screen	--	None	--	4	Presence	--	--
Sulphate (total, SO4)	%	0.19 – 0.42	--	4	N/A	N/A	N/A
Sulphate (2:1 water sol.)	mg/l	99 – 440	--	4	N/A	N/A	N/A
Benzene	mg/kg	<0.01	--	4	0.33[1]	--	--
Toluene	mg/kg	<0.01	--	4	610[1]	--	--
Ethylbenzene	mg/kg	<0.01	--	4	350[1]	--	--
Xylenes	mg/kg	<0.01	--	4	230[1]	--	--
MTBE	mg/kg	<0.01	--	4	N/A	N/A	N/A

Notes: N/A – Not applicable / No threshold value exists; **1** – Refers to CLEA Sol Guideline Values (SGVs) for ‘Residential’ land use; **2** – Refers to the LQM/CIEH Generic Assessment Criteria (GACs) for ‘Residential’ land use; **3** – Refers to ATRISK Soil Screening Values (SSVs) for ‘Residential without homegrown produce’ land use; Mercury concentrations have been assessed based on the CLEA SGV for elemental mercury (conservative).

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Table 7: Summary of Soil Leachate Test Results and Tier 1 Assessment

Contaminant	Units	Test Results		Threshold Value	Source of Threshold Value	Locations of Threshold Value Exceedances
		CBH1 (1.0m)	CBH2 (1.5m)			
Metals, pH, Cyanide						
pH	units	8.0	8.4	6 – 9	EQS (Freshwater)	--
Arsenic	ug/l	1.1	5.1	10	DWS	--
Chromium	ug/l	0.45	0.39	50	DWS	--
Cadmium	ug/l	<0.03	<0.03	5	DWS	--
Copper	ug/l	2.1	0.83	2000	DWS	--
Lead	ug/l	0.4	8.6	25	DWS	--
Nickel	ug/l	<0.5	0.57	50	DWS	--
Zinc	ug/l	3.4	3.8	5000	DWS	--
Mercury	ug/l	<0.01	<0.01	1	DWS	--
Selenium	ug/l	<0.25	0.33	10	DWS	--
Boron	ug/l	200	<100	1000	DWS	--
Cyanide	ug/l	<40	<40	50	DWS	--
Phenol, Sulphate, Sulphide						
Phenol	ug/l	<0.5	<0.5	0.5	DWS	--
Sulphate	mg/l	6.8	18	250	DWS	--
Polycyclic Aromatic Hydrocarbons (PAHs)						
PAH (total)	ug/l	<0.04[1]	<0.18[1]	0.1[1]	DWS	CBH2
Naphthalene	ug/l	<0.01	<0.01	10	EQS (Freshwater)	--
Benzo(a)pyrene	ug/l	0.01	0.02	0.01	DWS	CBH2
Total Petroleum Hydrocarbons (TPHs)						
GRO (C5-C10)	ug/l	<1.0	<1.0	10	DWS	--
DRO (C10-C24)	ug/l	<10	<10	10	DWS	--
MRO (C24-C40)	ug/l	<10	<10	10	DWS	--

Notes:
N/A – Not applicable / No threshold value exists.
DWS – UK Drinking Water Standards.
EQS (Freshwater) – Environmental Quality Standards (Freshwater).
1 – The PAH (total) concentrations and the DWS for PAH are based on the sum of the 4 PAHs [benzo(b) fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(1,2,3-cd)pyrene].

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FIGURES

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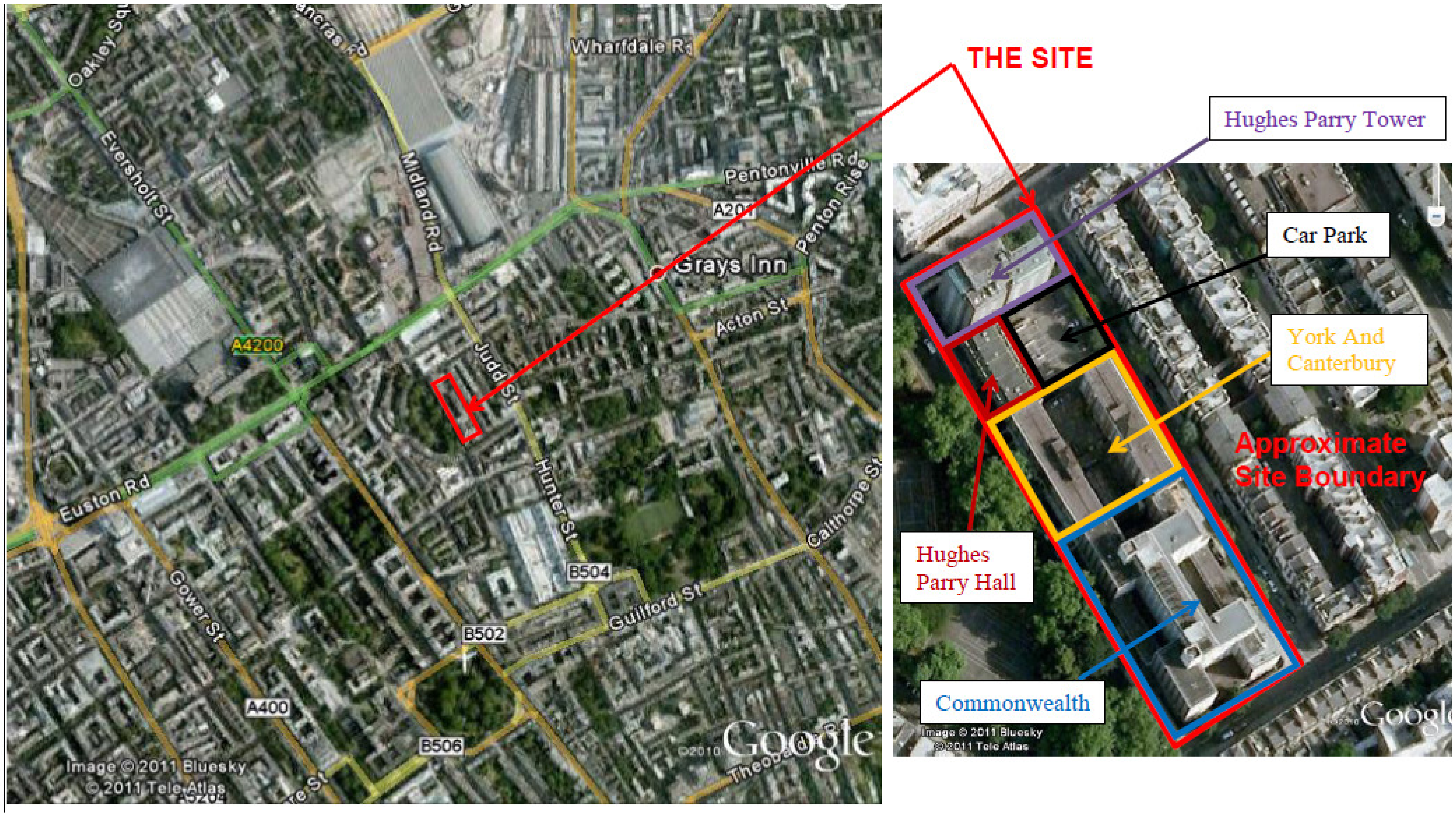

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Approximate centre of the site at NGR 530080E, 182560N

Project	Garden Halls, University of London
Client	University of London
Architect	
Title	Site Location Plan
Stage	-
Drawing No.	Figure 1
Rev.	A
Scale	NTS
Date	22-02-13
Drawn	ED
Checked	JA
Verified	JA

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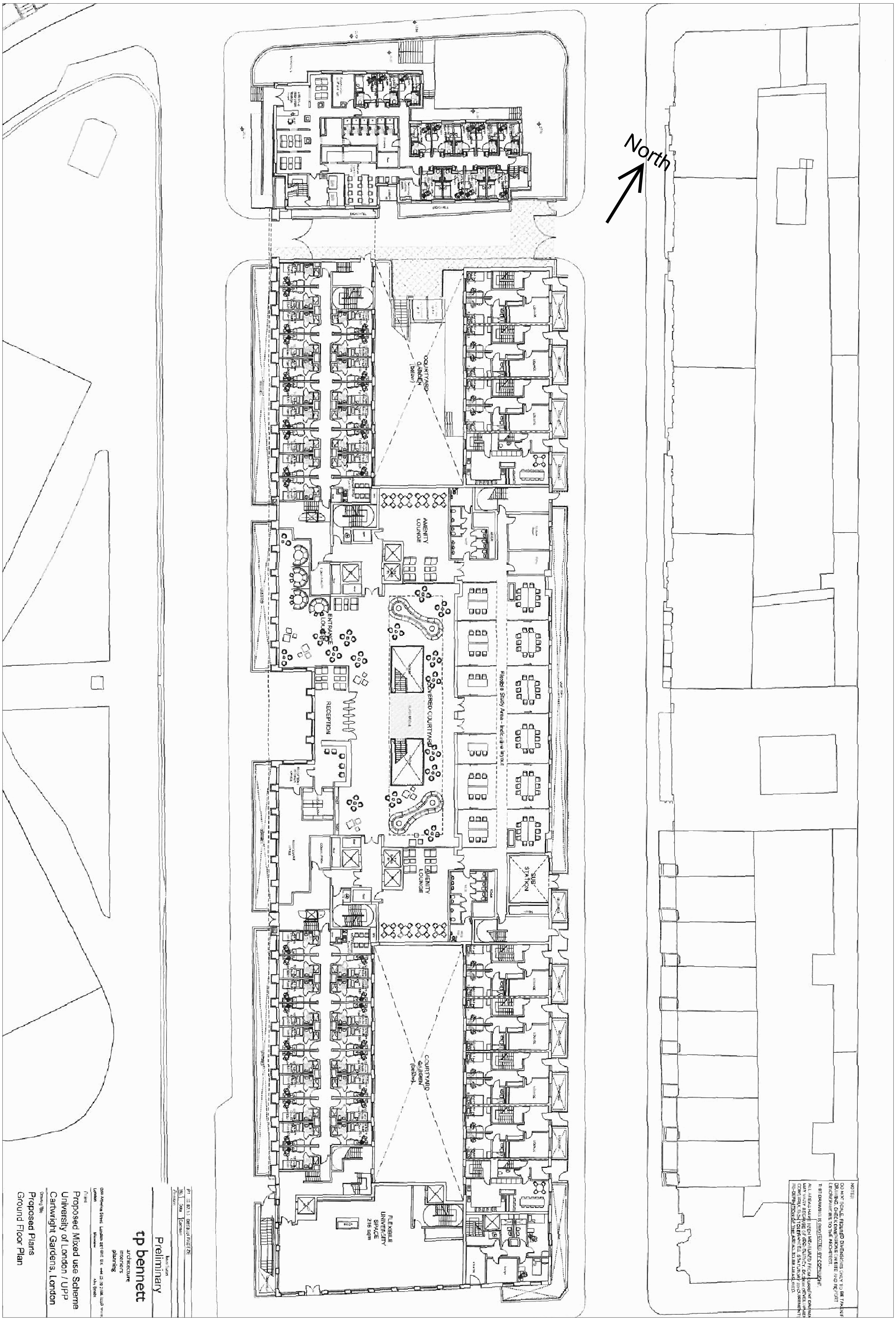
Facsimile: (0191) 213 1701

1004327	A3



Source:
Based on the Proposed Ground Floor Plan prepared by tp bennett, Drawing No. C08 100, Rev P1, dated Nov 2012.

Issue	Date	Description	By	Chkd	Verfd
B	13/03/13	Information only	ED	JA	JA
A	22/02/13	Information only	ED	JA	JA
0	09/11/12	Information only	MS	EP	YI

Project: **Garden Halls, University of London**

Client: **University of London**

Architect:

Title: **Proposed Development Plan**

Drawing Number: **Figure 2**

Job No **1004327**

Scale –

Status –

Issue –

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Gosforth,
Newcastle NE3 3LU
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Fax: (0191) 213 1701
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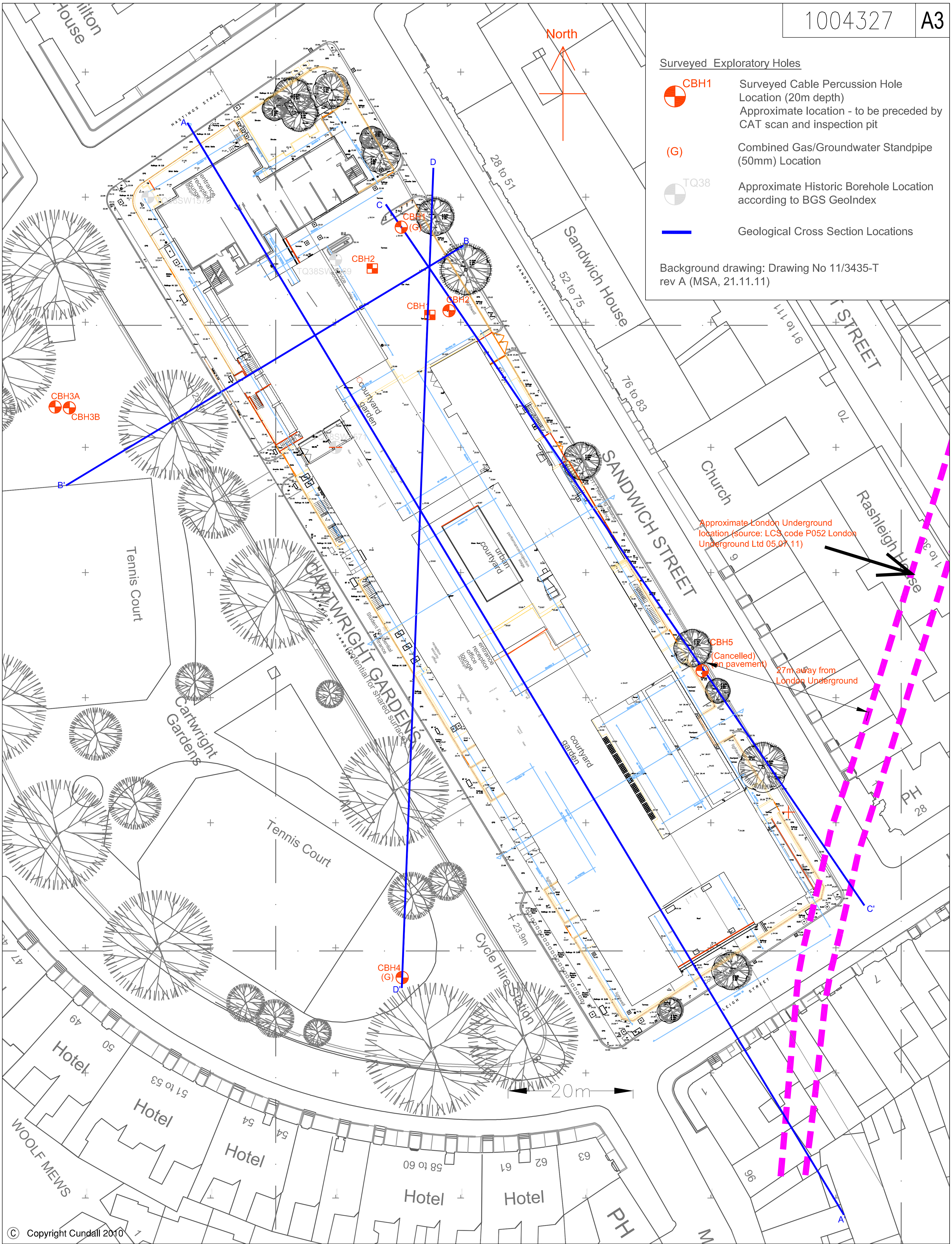

1004327 | A3

Surveyed Exploratory Holes

- CBH1 — Surveyed Cable Percussion Hole Location (20m depth). Approximate location - to be preceded by CAT scan and inspection pit
- (G) — Combined Gas/Groundwater Standpipe (50mm) Location
- TQ38 — Approximate Historic Borehole Location according to BGS GeoIndex
- Geological Cross Section Locations

Background drawing: Drawing No 11/3435-T rev A (MSA, 21.11.11)

Issue	Date	Description	By	Chkd	Verfd
A	22/02/13	Information only	ED	JA	JA
0	09/11/12	Information only	MS	EP	YI

Project: Garden Halls, University of London

Client: University of London

Architect:

Title: Exploratory Hole Location Plan and Cross Section Locations

Drawing Number: Figure 3

Job No: 1004327

Scale: –

Status: –

Issue: –

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Fax: (0191) 213 1701
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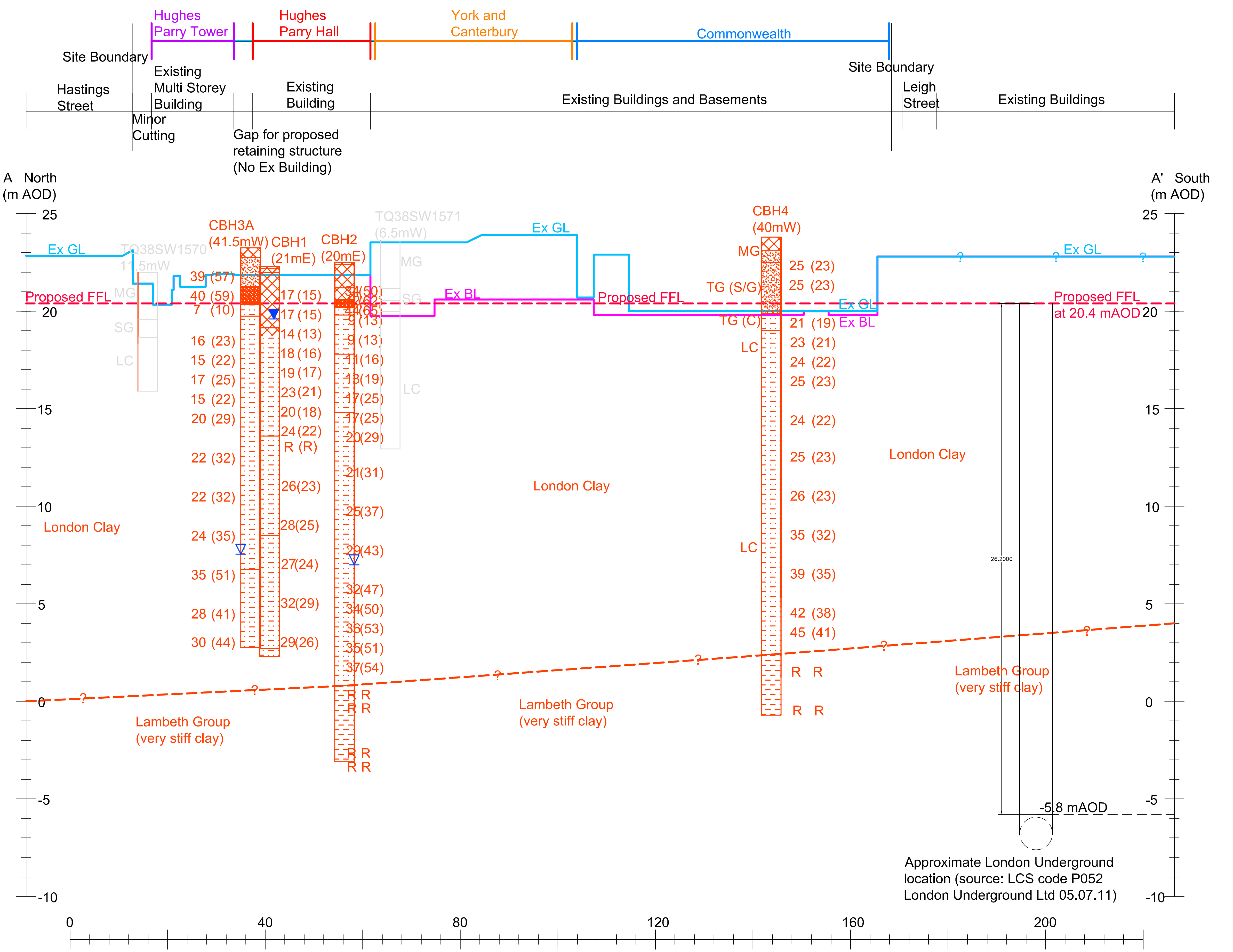

1004327 | A3

NOTES

- Made ground
- Taplow Gravel (Sand/Gravel)
- Taplow Gravel (Gravel)
- Taplow Gravel (Clay)
- London Clay
- Lambeth Group (Clay)
- Water strike
- Monitored groundwater level (25/10/12)
- 30 SPT N Value
- (39) SPT N(60) Value

Indicative Only

Issue	Date	Description	By	Chkd	Verfd
A	22/02/13	Information Only	ED	JA	JA
0	27/11/12	Information Only	MS	EP	YI

Project: Garden Halls, University of London

Client: University of London

Architect

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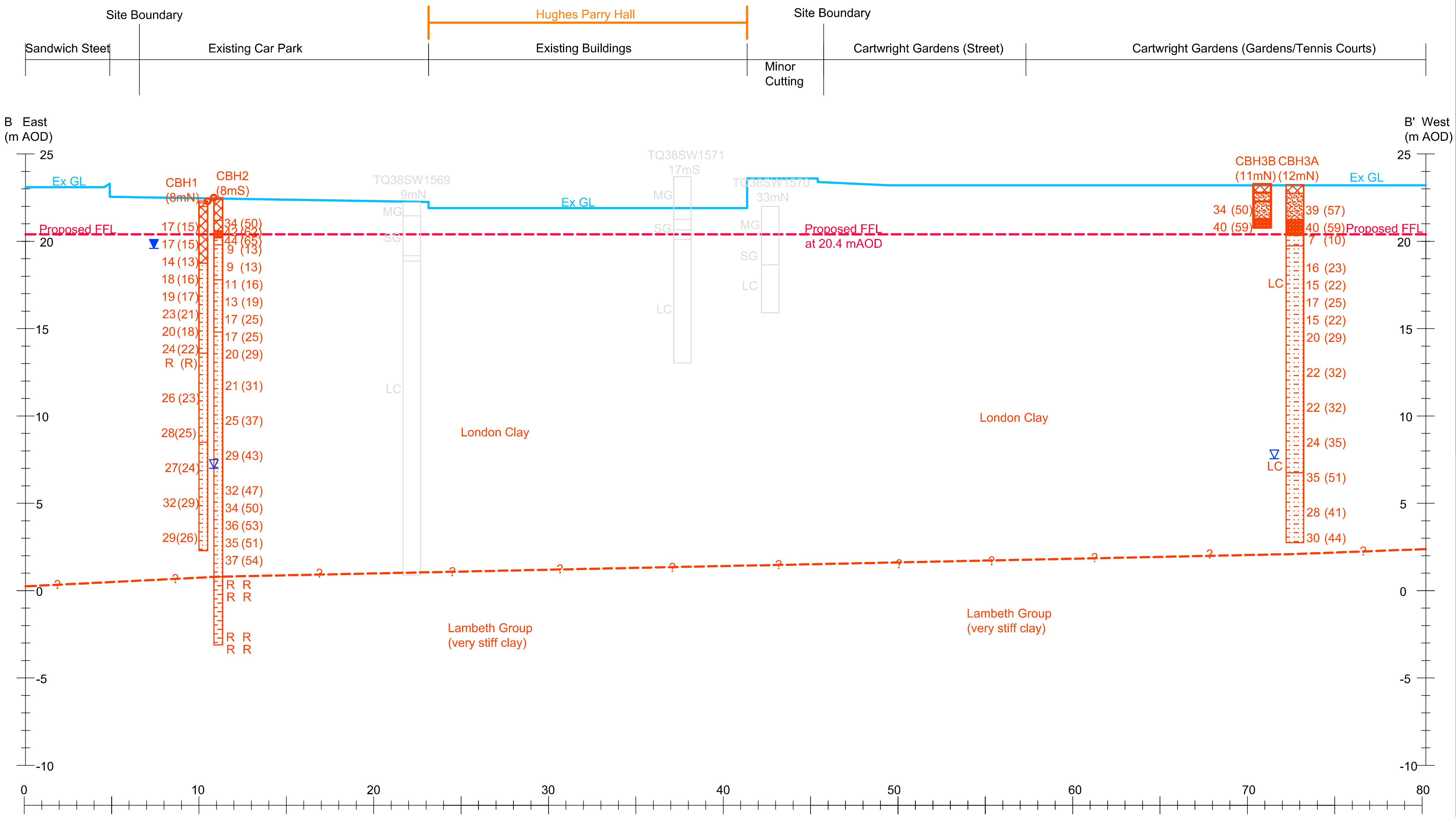
Title: Representative Geological Cross Section A - A'

Drawing Number: Figure 4a

Iss.



1004327 A3

NOTES

- Made ground
- Taplow Gravel (Sand/Gravel)
- Taplow Gravel (Gravel)
- Taplow Gravel (Clay)
- London Clay
- Lambeth Group (Clay)
- Water strike
- Monitored groundwater level (25/10/12)
- 30 SPT N Value
- (39) SPT N(60) Value

Indicative Only

Issue	Date	Description	By	Chkd	Verfd
A	22/02/13	Information Only	ED	JA	JA
0	27/11/12	Information Only	MS	EP	YI

Project: Garden Halls, University of London

Client: University of London

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Scale 1H : 4V

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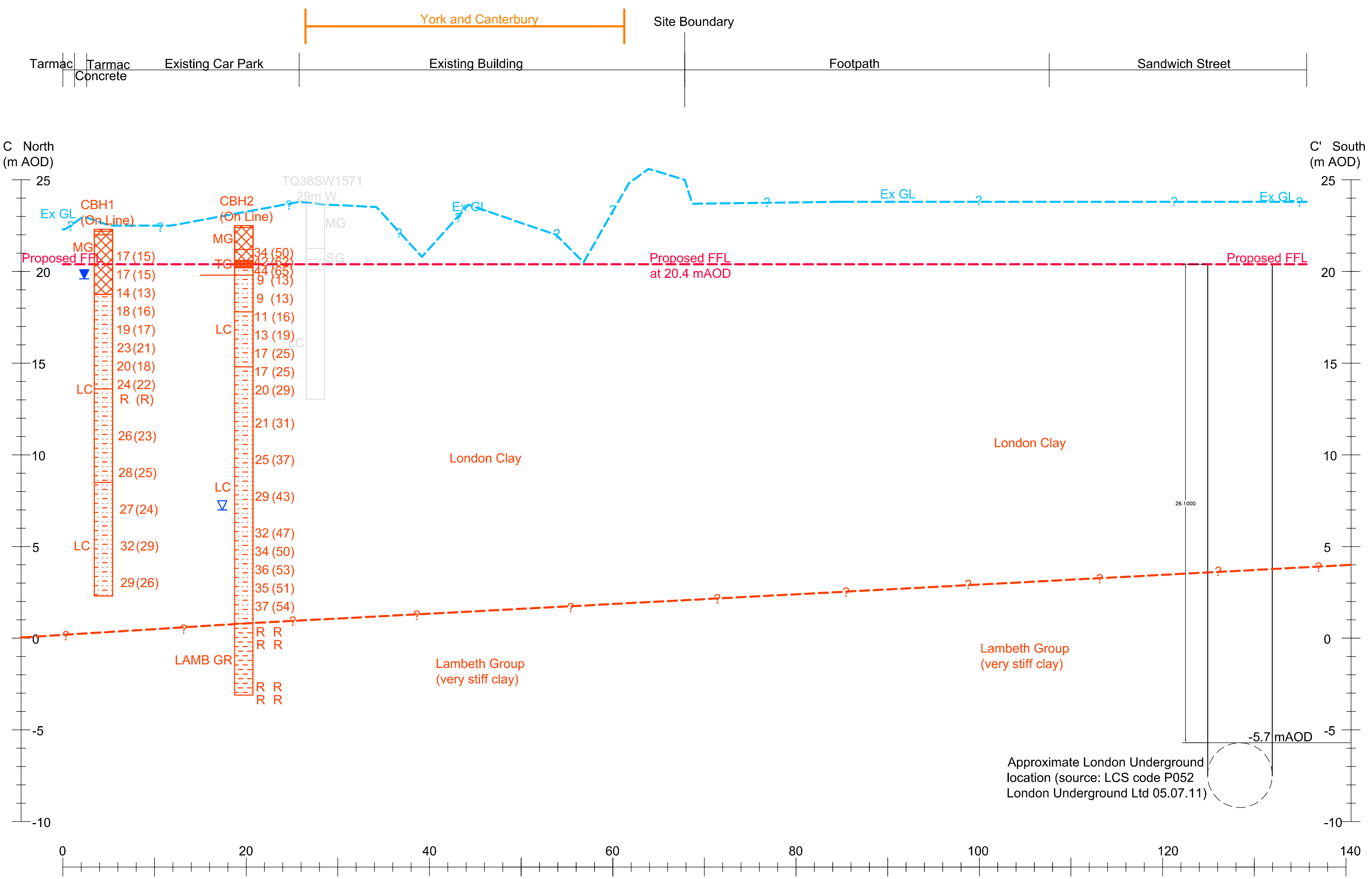
Title: Representative Geological Cross Section B - B'

Drawing Number: Figure 4b

Iss.



1004327 | A3

NOTES

- Made ground
- Taplow Gravel (Sand/Gravel)
- Taplow Gravel (Gravel)
- Taplow Gravel (Clay)
- London Clay
- Lambeth Group (Clay)
- Water strike
- Monitored groundwater level (25/10/12)
- 30 SPT N Value
- (39) SPT N(60) Value

Indicative Only

Issue	Date	Description	By	Chkd	Verfd
A	22/02/13	Information Only	ED	JA	JA
0	27/11/12	Information Only	MS	EP	YI

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Fax: (0191) 213 1701
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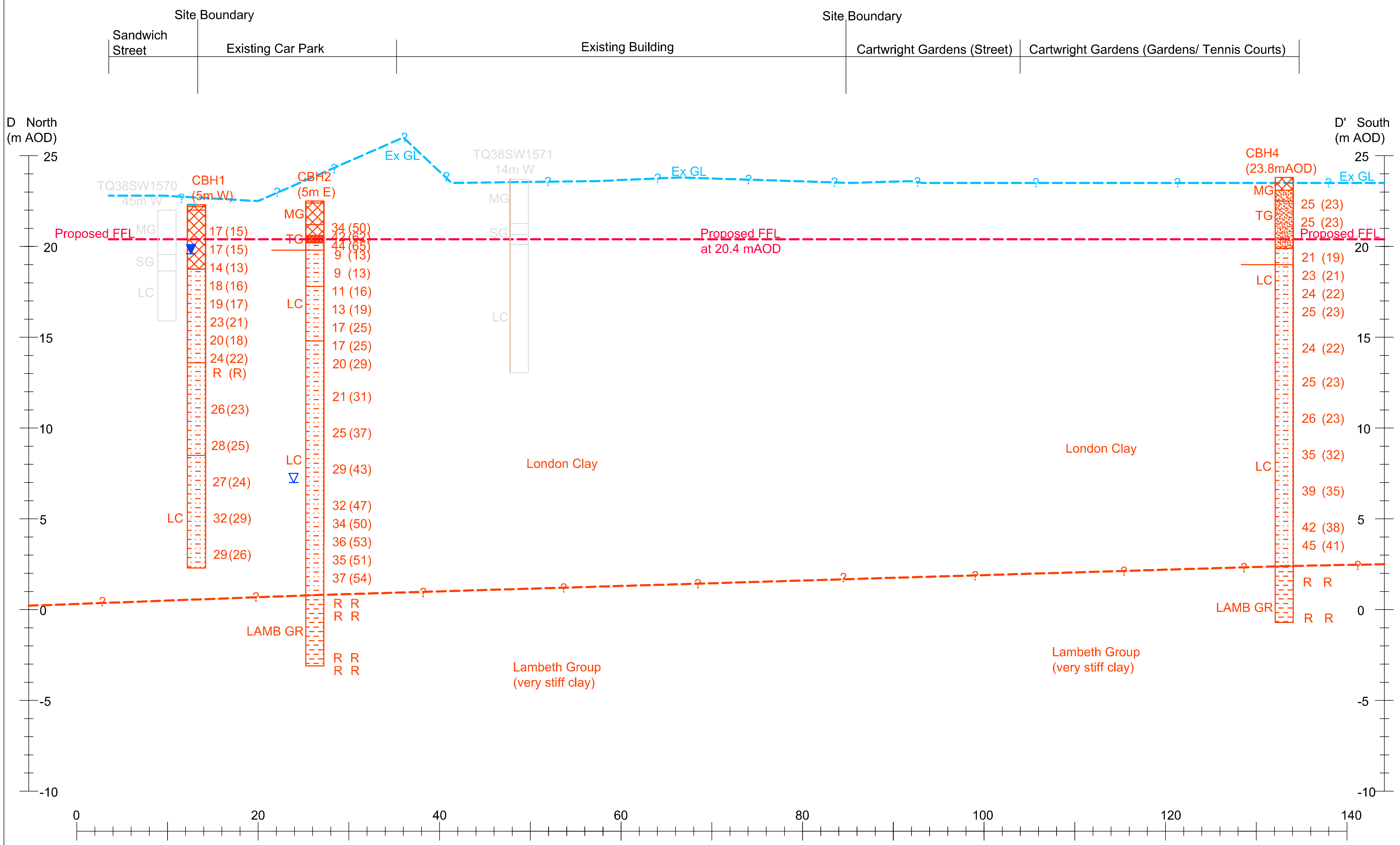
Title
Representative Geological Cross Section C - C'

Drawing Number
Figure 4c

Iss.



1004327 | A3

NOTES

- Made ground
- Taplow Gravel (Sand/Gravel)
- Taplow Gravel (Gravel)
- Taplow Gravel (Clay)
- London Clay
- Lambeth Group (Clay)
- Water strike
- Monitored groundwater level (25/10/12)
- 30 SPT N Value
- (39) SPT N(60) Value

Indicative Only

Issue	Date	Description	By	Chkd	Verfd
A	22/02/13	Information Only	ED	JA	JA
0	27/11/12	Information Only	MS	EP	YI

Project: Garden Halls, University of London

Client: University of London

Architect

Job No.1004327

Scale 1H : 2V

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Fax: (0191) 213 1701
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Title: Representative Geological Cross Section D - D'

Drawing Number: Figure 4d

Iss.

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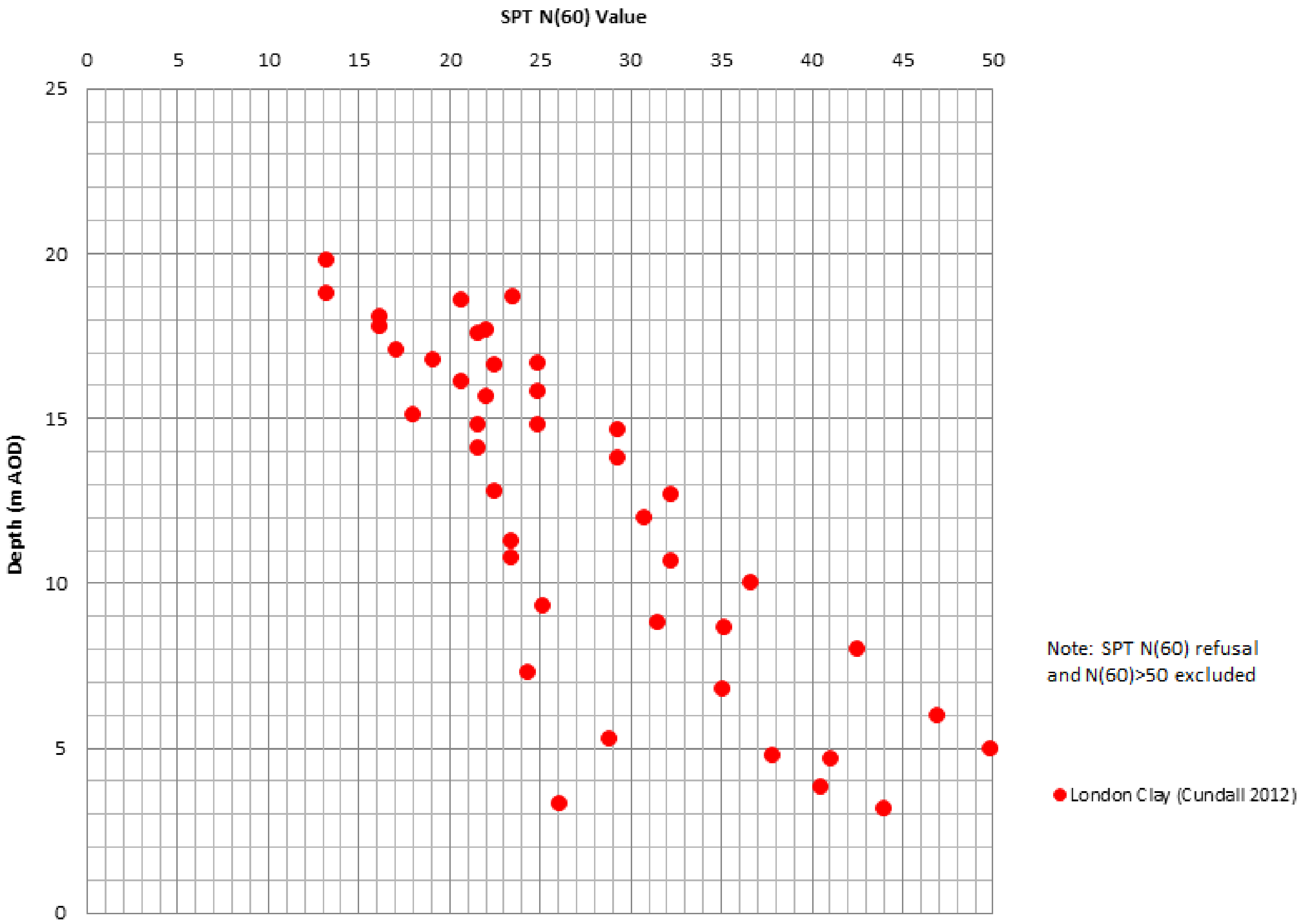

Project	Garden Halls, University of London	Title	SPT $N_{(60)}$ Value versus Depth Plot, London Clay	Scale	NTS
Client	University of London			Date	22-02-13
				Drawn	ED
		Stage	Drawing No.	Rev.	
		-	Figure 5	A	
				Checked	JA
				Verified	JA

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Gosforth, Newcastle NE3 3LU
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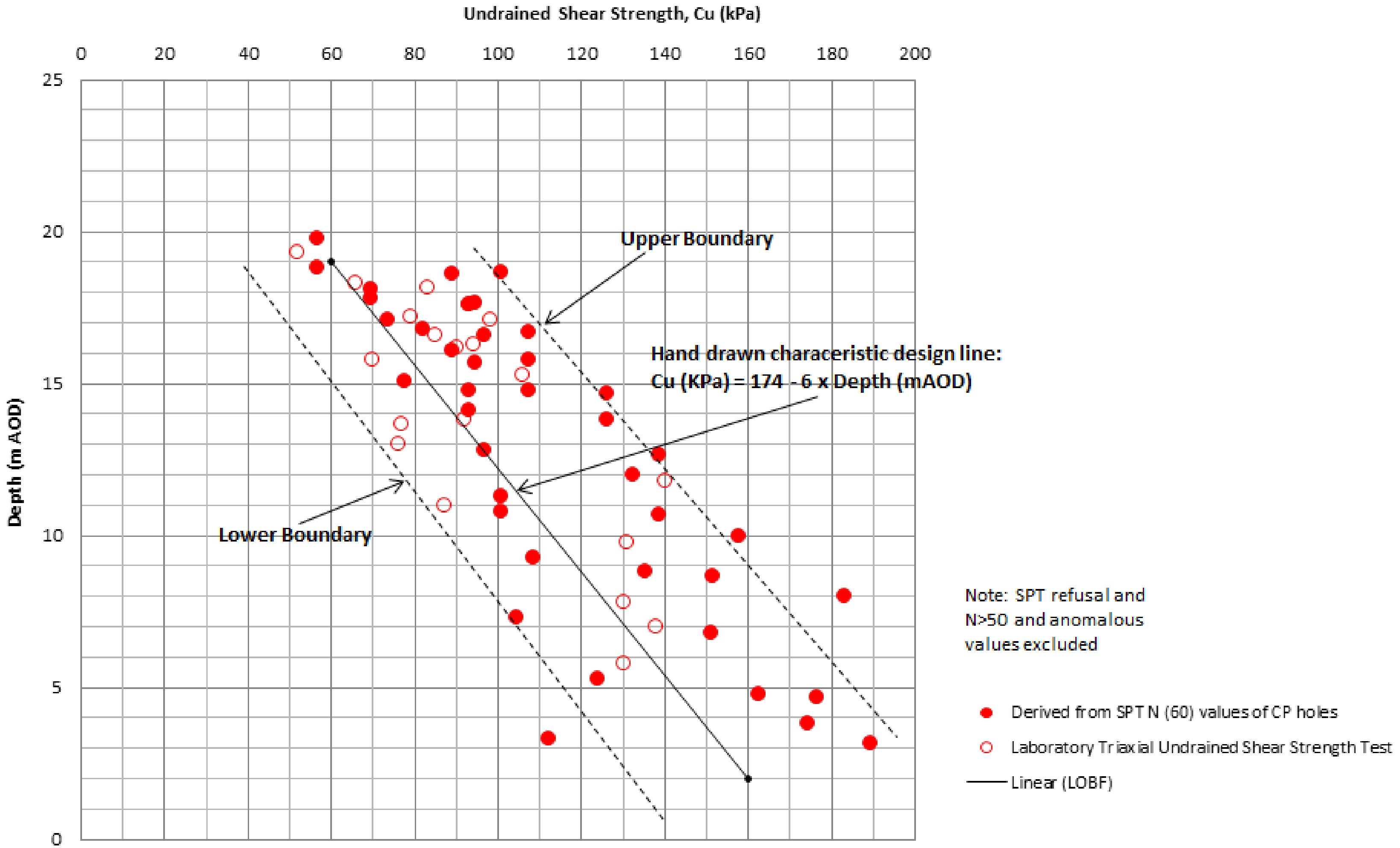

Project	Garden Halls, University of London	Title	Undrained Shear Strength versus Depth, London Clay		Scale	NTS
Client	University of London				Date	22-02-13
					Drawn	ED
		Stage	Drawing No.	Rev.	Checked	JA
Architect		-	Figure 6	A	Verified	JA

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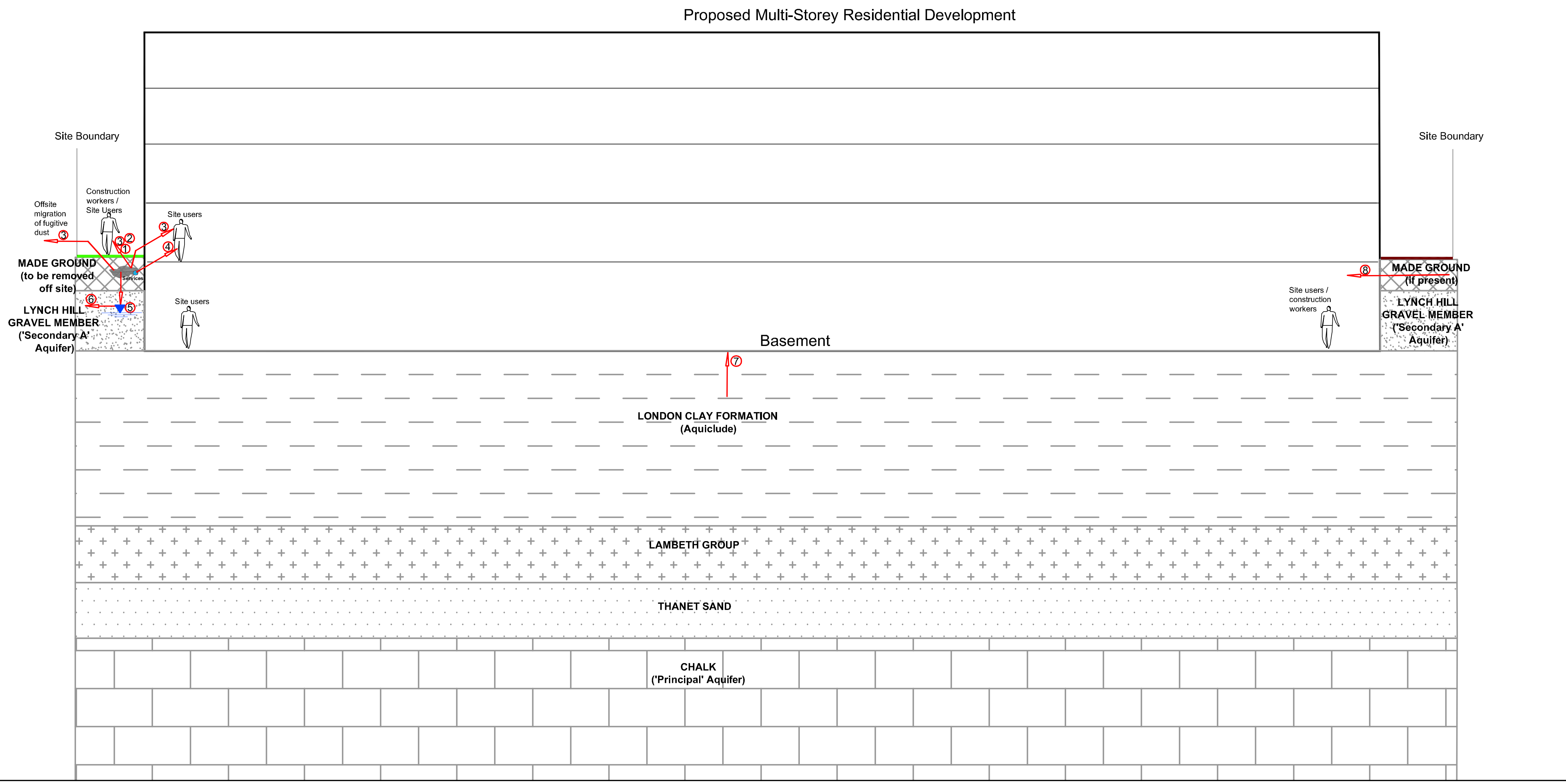
Facsimile: (0191) 213 1701



Contamination Source	Pathway	Receptor	Consequence of Pollutant Linkage	Significance of Pollutant Linkage	Overall Risk
Marginally elevated arsenic concentration	1. Dermal contact	Construction Workers / Site Users	Moderate to High	Negligible	Negligible
	2. Accidental ingestion	Construction Workers / Site Users	Moderate to High	Negligible	Negligible
	3. Inhalation of fugitive dust	Construction Workers / Site Users / Adjacent Site Users	Moderate to High	Negligible	Negligible
Recorded TPH concentration above the UKWIR threshold value (PE pipe material only)	4. Permeation of new water supply pipes	Site Users	Moderate to High	Negligible	Negligible
Marginally elevated leachable concentrations of benzo(a)pyrene and PAH (total) above their DWS threshold values	5. Leaching of mobile contaminants / migration of contaminated groundwater	Controlled Waters (the underlying 'Secondary A' aquifer)	Moderate to High	Negligible	Negligible
	6. Leaching of mobile contaminants / migration of contaminated groundwater	Controlled Waters (the Grand Union Canal located 756m north)	Moderate	Negligible	Negligible
Compounds aggressive to buried concrete	7. Direct attack of buried structures	Built Environment / Structures	Moderate	High	High
Recorded concentrations of ground gas	8. Accumulation in confined spaces and/or explosion	Construction Workers / Site Users / Built Environment	High	Negligible	Negligible

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NOTES

This Conceptual Site Model is based upon the *'Source - Pathway - Receptor'* linkages discussed in this report.

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A	22.02.13	For Information	ED	JA	JA
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Project: Garden Halls, University of London

Client: University of London

Architect

Job No. 1004327

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Status

CUNDALL
Consulting Engineers
Horsley House, Regent Centre, Gosforth, Newcastle NE3 3LU
Tel: (0191) 213 1515
Fax: (0191) 213 1701
Website: www.cundall.com

Title: Conceptual Site Model

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APPENDICES

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APPENDIX A

Geoenvironmental Risk Assessment Framework and Methodology

GEOENVIRONMENTAL RISK ASSESSMENT

For ‘contaminated land’ to exist a valid contaminant linkage must be present. That is, there should be a source of contamination, a receptor where ‘significant harm’ or ‘significant possibility of harm’ may be caused; or pollution of controlled waters is being, or likely to be caused, and a pathway which connects the two. Should any element of this contaminant linkage not be present (or severed) then the land may not be regarded as contaminated land, as defined in Part IIA of the Environmental Protection Act 1990 (amended).

Land Quality

Where contaminated land is suspected, the risk assessment should take into account site specific hazards (i.e. chemical composition of the soil and/or groundwater) and conceptual model for the site. Within the UK, DEFRA have produced a human toxicological risk assessment known as the Contaminant Land Exposure Assessment (CLEA) Model (Contaminated Land Research report series (CLR Report No’s 7, 9 and 10). It should be noted that with effect from August 2008, CLR Report No’s 9 and 10 were replaced by Environment Agency’s Science Reports SC050021/SR2 and SC050021/SR3, respectively. Also, CLR 7 has been withdrawn and no replacement has been published to date.

The CLEA model is used to derive site specific Soil Guideline Values (SGVs) based upon the current or proposed land use of the site, which are utilised as ‘intervention values’ within the regulatory framework. Some of the inputs of the CLEA model are the physical, chemical and toxicological properties of the contaminant. As the toxicology of contaminants can vary significantly, the Environment Agency (EA) has published guidance on toxicology for a limited number of contaminants and intends to publish other toxicological guidance for other selected contaminants in future.

The SGVs are derived using the CLEA model according to three typical land uses and are applicable to long-term human exposure to soil contaminants. The three ‘standard’ land uses are:

- Residential;
- Allotments; and
- Commercial.

The EA and the Department for Environment, Food and Rural Affairs (DEFRA) had previously released ten SGVs. In December 2006, DEFRA issued a discussion paper entitled *Soil Guideline Values: The Way Forward*. The paper sought views from key organisations and groups on various ideas for how non-statutory technical guidance might be amended to make it more useful to assessors carrying out risk assessments, and to make it clearer when land qualifies as contaminated land under Part 2A of the Environmental Protection Act 1990 in England and Wales. This exercise culminated in the publication by DEFRA of *Improvements to contaminated land guidance. Outcome of the “Way Forward” exercise* (DEFRA, 2008). Based on the outcome of the “Way Forward” document, the EA released an “*updated CLEA package”* in August 2008 which included the CLEA Software version 1.04 and updates on the CLR Reports No’s 9 and 10 (replaced by Science Reports SC050021/SR2 and SC050021/SR3, respectively) for use in contaminated land risk assessment. Due to the release of the *“updated CLEA package”*, the previously issued SGVs were withdrawn. In September 2009, the EA released a new version of the CLEA Software (version 1.06).

Since March 2009, the EA has released new and/or revised SGVs for a number of contaminants and are in the process of preparing SGVs for other contaminants using the new CLEA Guidance. Where available, the current SGVs for ‘residential’ land use have been used in the geoenvironmental risk assessment for the site.

Where an SGV is not available for a specific contaminant, Site-Specific Assessment Criteria (SSAC) can be derived using the current CLEA Software which follows the methodology laid out in the following reports:

- Contaminated Land Report (CLR 7) (now withdrawn and has not been replaced);
- Human health toxicological assessment of contaminants in soil (replaces CLR 9); and

- Updated technical background to CLEA model (replaces CLR 10).

LQM/CIEH GACs

In the absence of CLEA derived SGVs for some of the contaminants of concern, other sources of guidance can also be used as screening tools. These include Generic Assessment Criteria published by Land Quality Management Ltd (LQM) / Chartered Institute of Environmental Health (CIEH) in the document *'Generic Assessment Criteria (GACs) for Human Health Risk Assessment (Land Quality Press, 2nd edition 2009)'*. The LQM CIEH GACs have been derived using the current CLEA model and are in accordance with the current CLEA guidance. The LQM/CIEH GACs for 'residential' land use have been used in undertaking geoenvironmental risk assessment for the site, where no CLEA SGVs are available.

ATRISKSOIL Soil Screening Values (SSVs)

Standard Land Uses
Atkins have derived ATRISK^{soil} SSVs based on the current CLEA Guidance (Science Reports SC050021/SR3 (the CLEA Report) and SC050021/SR2 (the TOX report)) for 'allotment', 'commercial', and 'residential (with and without homegrown produce)' land uses. Atkins have based the SSVs on the default assumptions provided in the current CLEA Guidance which are being used in the development of further SGVs by Defra and the Environment Agency. Atkins have produced SSVs for a number of contaminants using the CLEA software. The Soil Screening Values (SSVs) produced by Atkins are generally applicable to the UK for common contaminants not currently covered by CLEA SGVs. The SSVs are commercially available and have been widely promoted for use by Local Authority Officers. The SSVs for 'residential without homegrown produce' land use have been used in the risk assessment of the site, where no CLEA SGVs or LQM/CIEH GACs are available.

Applicability of Screening Values

The application of screening values enables auditable, consistent evaluation of land contamination problems. Screening values designed to be consistent with SGVs, provide a preliminary, generic assessment of the risks to human health arising from the presence of contamination within the soil. The practical application of screening values is the facility to compare site data, which informs decision-making with regard to the need or otherwise for further site evaluation and/or remediation measures. Guideline (or Screening) values, if appropriately used, can reduce the cost of risk assessment and simplify decision-making. They are easy to understand and interpret by a wide variety of stakeholders.

Non-exceedance of any of the screening values described above will indicate that the soil contaminant levels are such as not to compromise human health thereby the risk is acceptable and that land is suitable for its proposed end use, with regard to the specific contaminants assessed. However, exceedance of a screening value can indicate that further assessment or remedial action may be needed. **Note**: exceedance of any of the relevant screening values does not constitute evidence of a significant possibility of significant harm (SPOSH).

Controlled Waters

Based upon current UK guidance, risk assessment of groundwater contamination should follow staged assessment and management (called Levels 1 to 4). The Environment Agency's (EA, 2006), '*Remedial Targets Methodology – Hydrogeological Risk Assessment for Contaminated Land'* presents a recommended methodology for undertaking groundwater risk assessment. The EA document also provides a methodology for deriving site-specific remedial objectives for contaminated soils and/or groundwater to protect the aquatic environment. The approach is underpinned by progressive data collection and analysis, structured decision making and cost-benefit assessment. The remedial target derived for each Level of assessment is compared with the target concentration to determine the need for remedial action.

For the purpose of this risk assessment, a Level 1 risk assessment has been carried out by comparing the measured soil leachate and groundwater concentrations with the adopted threshold values, as discussed below.

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Level 1 Risk Assessment

Where the risk may involve pollution of groundwater resources, the risk assessment should be performed in accordance with the guidance from the document *"Remedial Targets Methodology: Hydrogeological Risk Assessment for Land Contamination",* published by the EA.

In this risk assessment, the soil leachability test results have been compared with two UK standards, namely; the UK Drinking Water Standards (DWS) and the Environmental Quality Standard (EQS) (Freshwater) threshold values.

UK Drinking Water Standards (DWS)

The DWS threshold values, taken from the Water Supply (Water Quality) Regulations 2000, provide a means of assessing groundwater and leachable soil concentrations. The DWS threshold values provide an interpretation of the risk to controlled waters as well as the risk to human health via the ingestion of groundwater pathway. The Taplow Gravel (Lynch Hill Gravel Member) deposits indicated to be underlying the site is a 'Secondary A' aquifer – a sensitive receptor. Therefore, the DWS threshold values have been used for controlled waters risk assessment for the site, as a preference.

However, it should be noted that the use of the DWS values to assess the risk to controlled waters underlying the site is considered extremely conservative as they represent concentrations acceptable at the consumers' taps (not determinant concentrations prior to treatment). It should also be born in mind that no groundwater Source Protection Zones (SPZs) are recorded within 1km of the site. In addition, no groundwater abstraction points (for portable public water supply) are recorded within 1km of the site. The groundwater abstraction points recorded 73m north, 667m south and 668m south of the site are used for 'heat pump'.

Environmental Quality Standards (EQS)

Where a local surface water is present, the concentrations of contaminants dissolved in groundwater or leachable soil concentrations are compared to the EQS threshold values. The EQS threshold values for various contaminants are dependent on a number of factors including if the receiving surface water is freshwater or saltwater. No surface water receptors are recorded within 500m of the site, the nearest surface water feature (the Grand Union Canal (Regent's Canal)) is located some 756m north of the site. Therefore, the EQS (freshwater) threshold values have only been used in the controlled waters risk assessment for the site where no DWS threshold values exist.

Risk Assessment

In carrying out this risk assessment, reference has been made to the following documents in addition to the guidance documents aforementioned:

- CIRIA (2001). Contaminated Land Risk Assessment – A Guide to Good Practice Publication Code C552;
- DETR (July 2000). Guidelines for Environmental Risk Assessment and Management. HMSO;
- DoE (1994). Contaminated Land Report (CLR 1). A Framework for Assessing the Impact of Contaminated Land on Groundwater and Surface Water.

The following factors have been used to rank the potential consequence of a *contaminant – pathway – receptor* linkage and the potential significance for current and future land use.

Potential Consequence of Hazard – Receptor Linkage (in accordance with CIRIA C552)

Severe Short-term (acute) risk to human health likely to result in significant harm. Short-term risk of pollution of sensitive water resource. Catastrophic damage to

	buildings/property. A short-term risk to a particular ecosystem, or organism forming part of such ecosystem.
Medium	Long-term (chronic) damage to human health. Pollution of sensitive water resources. A significant in change in a particular ecosystem, or organism forming part of such ecosystem. Damage to sensitive buildings and structures.
Mild	Slight short term health effects to humans. Slight pollution of non-sensitive water resources. Some change to population densities but with no negative effects on the function of the ecosystem. Slight damage to sensitive buildings, structures and services.
Minor (Negligible)	Non-permanent effects to human health (easily prevented by means such as personal protective clothing etc). Easily repairable effects of damage to buildings, structures and services (e.g. discolouration of concrete).

Potential Significance: Risk Classification (in accordance with CIRIA C552)

Very High Risk	There is a high probability that severe harm could arise to a designated receptor from an identified hazard, or, there is evidence that severe harm to a designated receptor is currently happening.
High Risk	Harm is likely to arise to a designated receptor from an identified hazard at the site. Realisation of the risk is likely to present a substantial liability. Urgent investigation (if not undertaken already) is required and remedial works may be necessary in the short term and are likely over the longer term.
Moderate Risk	It is possible that harm could arise to a designated receptor from an identified hazard. However, it is either relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that the harm would be relatively mild. Investigation (if not undertaken already) is normally required to clarify the risk and to determine the potential liability. Some remedial works may be required in the long term.
Low Risk	It is possible that harm could arise to a designated receptor from an identified hazard, but it is likely that this harm, if realised, would at worst normally be mild.
Negligible (Very Low) Risk	There is a low possibility that harm could arise to a receptor. In the event of such harm being realised it is not likely to be severe.

APPENDIX B

Preliminary Assessment of Soil Waste Classification

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PRELIMINARY ASSESSMENT OF SOIL WASTE CLASSIFICATION

A preliminary assessment of the likely waste classification of the shallow soil materials have been undertaken using the laboratory soil test results, as discussed below. The procedures to be followed in carrying out the assessment of potentially hazardous waste are set out in the following documents:

- *Hazardous waste: Interpretation of the definition and classification of hazardous waste, Technical Guidance WM2 (second edition version 2.3), Environmental Agency 2005.*
- *Framework for Classification of Contaminated Soils as Hazardous Waste, version 1, Environment Agency 2004.*
- *How to find out if waste oil and wastes that contain oil are hazardous, Ref HWR08 Version 3.1, Environment Agency 2007.*
- *Guidance for waste destined for disposal in Landfills Version 2, 2006.*
- *Using the List of Wastes to Code Waste for Waste Transfer Notes, PPC Permits and Waste Management Licences in England & Wales. Living Guidance from the Environment Agency, Version 1. Environment Agency, April 2006.*

Using the above guidance, the made ground has been determined as 'directive waste' and it is not 'domestic waste' and initially classified as: *Mirror entry 17 05 04 – Soil and stones other than those mentioned in 17 05 03 (Soil and stones containing dangerous substances)*. The made ground at the site has been assessed to determine whether the samples tested possess hazardous properties based on the hydrocarbon and inorganic contaminants, as described below.

Determination of whether waste possesses hazardous properties – hydrocarbons (Made Ground)

An assessment has been made using the soil test results for hydrocarbons, for each of the following hazardous properties: *Harmful (H5), Carcinogenic (H7) and Ecotoxic (H14)*.

Harmful (H5)
According to EA Technical Guidance WM2, the relevant risk phrase for waste oil have been determined by the EA to be 'R65 Harmful'. The EA document (WM2) identifies that the appropriate threshold for R65 is 25% w/w or 250,000 mg/kg). This means that where the total quantity of oil in the waste exceeds this concentration the waste would be classified as hazardous.

The guidance notes that where the analysis shows that the contamination is from both fuel and lubricating/other oils, their concentrations will need to be added to produce the overall total. This is considered to be equivalent to TPH (total) concentrations. A maximum TPH (total) concentration of 360 mg/kg was recorded at the site during the current investigation, which is significantly less than the threshold of 250,000 mg/kg. Therefore the **made ground samples tested would not be classified as hazardous by the property H5**.

Carcinogenic (H7)
The assessment for this category is made in terms of two categories: fuels and unknown lubricating / other oil (shown by analysis not to be fuel).

Fuels
The EA Technical Guidance WM2 indicates the appropriate thresholds for fuels as follows:

- Petrol range organics (PRO, C6 to C10) threshold is 1,000mg/kg
- Diesel range organics (DRO, C10 to C25) threshold is 10,000mg/kg

This means that where the concentration of either PRO or DRO exceeds the relevant threshold, the waste would be classified as hazardous. The recorded TPH concentrations are well below the PRO and DRO threshold values. Consequently, the **made ground samples tested would not be classified as hazardous by the property H7**.

Lubricating / other oils
Where the lubricating / other oil concentration is 1,000 mg/kg or more, the waste would be hazardous by H7. This is assessed in terms of lubricating oil range organics (LRO, C25 to C40). The recorded TPH concentrations are well below the LRO threshold value, which indicate that the **made ground samples would not be classified as hazardous by the property H7**.

Ecotoxic (H14)
The assessment for this category is also made in terms of fuels and unknown lubricating/other oil. Where the total concentration of fuel in the waste is 25,000mg/kg or more, the waste would be hazardous by H14. This is assessed using the sum of PRO and DRO. Where the total concentration of lubricating/other oil in the waste is 250,000mg/kg or more, the waste would be hazardous by H14. This is assessed using the LRO concentration.

Based on the negligible/low TPH concentrations recorded, the **made ground samples tested would not be classified as hazardous by the property H14**.

Determination of whether the waste possesses hazardous properties – inorganic contaminants (Made Ground)

The recorded inorganic determinant concentrations have been used to determine whether the soil samples tested have the following relevant hazardous properties:

- *Irritant (H4), Harmful (H5), Toxic (H6), Carcinogenic (H7), Corrosive (H8), Toxic for Reproduction (H10), Mutagenic (H11) and Ecotoxic (H14)*

Since the anion-cation relationships in the contaminated soils are not known, the worst cases have been assumed as suggested in the EA guidance document 'Framework for the Classification of Contaminated Soils as Hazardous Waste'.

This assessment indicates that the **soil samples tested do not have hazardous inorganic properties**.

Asbestos

The EA Technical Guidance document (WM2) states that all forms of asbestos are regarded as hazardous waste, where the asbestos content is greater than the threshold concentration for Carc Car 1 of 0.1% w/w.

Four soil samples were screened for asbestos fibres during the current investigation. No asbestos was identified in these samples. Therefore, **these soil samples would not be classified as hazardous.**

Summary of Preliminary Soil Waste Classification Assessment

This preliminary soil waste classification assessment (based on the recorded soil concentrations) indicates that the **shallow soil materials at the site do not have hazardous properties**.