1923 Mortimer Estates Limited

Arthur Stanley House, Tottenham Street

Geotechnical and Geoenvironmental Interpretative Report

February, 2018

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EXECUTIVE SUMMARY

Card Geotechnics Limited (CGL) has been commissioned by Heyne Tillett Steel, on behalf of 1923 Mortimer Estates Limited (the Client), to review existing desk study information and undertake a geotechnical and geoenvironmental ground investigation to support the proposed redevelopment at Arthur Stanley House, Tottenham Street, London.

It is proposed to redevelop the existing building for office use by adding an additional storey to the existing structure and a constructing new seven storey extension to the building in the north. A new five storey residential building is also proposed in the north east of the site, including local lowering of the existing lower basement slab level.

Ground conditions generally comprised the Lynch Hill Gravel Member underlain the London Clay Formation and Lambeth Group. Made Ground was encountered in one borehole, which is considered likely to be reworked Lynch Hill Gravel and London Clay as a result of the existing basement construction. The depth to the surface of the London Clay was found to be deeper in the south of the site, potentially indicative of a buried river channel.

Groundwater was recorded within the Lynch Hill Gravel member at a level of +21mOD. However, it is likely that the groundwater levels observed have been affected by the ongoing dewatering of the basement and as such are not representative of groundwater level in its natural state. A design groundwater level of +22.5mOD is recommended.

Soil testing identified a marginally elevated concentration of lead within one sample of Made Ground however, based on the likely proposed end use of the site, and that hard standing will eliminate direct contact pathways to end users the results do not suggest an unacceptable risk.

Groundwater testing identified elevated concentrations of copper and zinc when screened against Environmental Quality Standards, however, given the nearest surface water feature lies some 1.2km from the site, and, as such, it is not considered to pose a significant risk. In addition, groundwater testing identified elevated concentration of phenols, TPH and ammoniacal nitrogen as NH_4 above Drinking Water Values, however, given the distance to the nearest potable water abstraction and the aquiclude afforded by the overlying London Clay formation to the deeper regional aquifer, the concentrations are not considered to pose a significant risk. Where piled foundations extend through the London Clay Formation, however, a specific piling works risk assessment will be required to review the risks associated with creation of preferential pathways and the requirements for mitigation.

Based on the anticipated size and structural loadings of the proposed development, it is recommended that piled foundations be used to support the proposed structure. Pile lengths and diameters will be dependent on the finalised loadings and design of these proposed structures.

An Aggressive Chemical Environment for Concrete (ACEC) class of AC-1 should be adopted for buried concrete not in contact with the London Clay (i.e. slabs and pile caps). An ACEC class of AC-2 should be adopted for piles, and any other buried concrete in contact with the London Clay. Should the depth of the proposed basement change, this recommendation would need to be reviewed in relation to the potential for oxidisation of the London Clay, which was found to be AC-4.

1. INTRODUCTION

It is proposed to redevelop Arthur Stanley House, Tottenham Street in the London Borough of Camden, London. The proposed redevelopment will include the reconstruction of the existing office roof structure on the seventh floor; a new seven storey concrete or steelwork extension to the existing office building in the north of the site; and a new five storey residential building in the northeast quarter of the site. The existing lower basement level will be reduced in the northeast quarter of the site by approximately 1.425m from +21.150m above Ordnance Datum (mOD) to approximately +19.725mOD, within a secant piled wall. The proposed buildings will be of mixed office and residential use.

Card Geotechnics Limited (CGL) has been commissioned by Heyne Tillett Steel on behalf of 1923 Mortimer Estates Limited (the Client) to review existing desk study information and undertake a geotechnical and geo-environmental ground investigation to support the proposed redevelopment at Arthur Stanley House.

The objectives of the assessment are to:

- Provide a desk based review of the ground conditions at the site and associated geotechnical and geoenvironmental risks based on available existing desk study material, published and unpublished data sources;
- Present factual information from the intrusive investigation, including engineering log, in-situ geotechnical data, chemical and geotechnical laboratory analysis and gas/groundwater monitoring data;
- Provide an assessment of chemical data and details of a conceptual site model and qualitative risk assessment based on potential contamination sources, pathways and receptors at the site;
- Provide an assessment of geotechnical data to establish design parameters and recommendations for foundation design, material re-use, and sulfate protection for buried concrete; and,
- Present recommendations for further works and/or mitigation of identified ground risks, if required.

It is intended that this report is used to support the pre-commencement planning conditions in respect of contamination for the proposed redevelopment of the site.

2. SITE LOCATION AND DESCRIPTION

2.1 Site Location

The site is located at Arthur Stanley House, Tottenham Street, W1T 4RN in the London Borough of Camden. The approximate National Grid Reference for the centre of the site is 529332, 181753 and the site covers an area of approximately 0.12 hectares (Ha). A site location plan is presented as Figure 1.

2.2 Site Description

Site walkovers were carried out on 23rd June and 25th October 2017 by CGL. The site is bounded by Tottenham Street to the south east and Tottenham Mews to the north east. The site is bounded by Middlesex House and a former hospital (14 to 17 Tottenham Mews) to the north west and by 24 to 32 Cleveland Street and 52 Tottenham Street to the south west. Photographs taken during the site walkovers are included in Appendix B. An existing site layout plan is presented as Figure 2.

The site is currently occupied by a two-storey basement with an eight-storey reinforced concrete (RC) frame structure over the southern half of the basement footprint. The building is currently not in use, however it formerly housed part of the Middlesex Hospital including laboratories. The basement previously housed plant and boiler rooms, serving the neighbouring hospital buildings.

The lower basement level is at approximately +21.25mOD; the basement at approximately +24.10mOD; and, existing ground level range is approximately +27.50mOD to +26.40mOD.

It is understood that the lower basement slab comprises a reinforced concrete slab, generally 400mm thick, locally increasing to 900-1100mm at column locations and at the perimeter. It is not known whether the structure is piled, or sits on shallow foundations (pads). Temporary raking props were present in the lower basement, propping Tottenham Street, where the upper basement slab had been locally removed, as illustrated on Figure 2.

The site footprint was covered entirely in reinforced concrete hardstanding, which was noted generally to be of good condition. However, three holes were observed in the lower basement slab in the northern half of the site and one in the southern half, with a groundwater pumping system in place. It is understood that pumping has been ongoing since at least January 2015 and there was evidence of historical flooding (rusting of lower part of the propping and water marks on the basement walls) in the basement that is understood to have occurred when pumping was paused for a period and groundwater levels were allowed to rise. During the walkovers, standing water to a depth of approximately 30mm to 50mm was observed in patches in the lower basement. It is understood that water rose some 0.3m above lower basement level during this period.

The basement appears to have been constructed as an RC box, restrained at basement level and retaining the highway. Inspection holes cut into the wall of the basement at lower basement level adjacent to the party walls to the west (No. 52 Tottenham Mews, and 24 to 32 Cleveland Street) and to the north (Middlesex House) show evidence of underpinning to the neighbouring property and of the external face of a neighbouring basement wall, to an approximate level of +19.4mOD. Middlesex House, 24 to 32 Cleveland Street and 52 Tottenham Mews are understood to have a single storey basement. 14 to 17 Tottenham Mews does not have a basement.

The following assumed lowest floor levels for the neighbouring buildings have been provided by the Structural Engineer:

- 14 to 17 Tottenham Mews +26.410mOD
- Middlesex House +22.820mOD
- 24 to 32 Cleveland Street +23.070mOD
- 52 Tottenham Street +23.070mOD

2.3 Proposed Development

It is proposed to remove the existing roof structure on the seventh floor, replacing it with a slab at a raised level to increase the floor to ceiling heights, with an intended office end use. A new seven storey concrete or steelwork extension to the office building is to be constructed in the north of the site, and a new five storey reinforced concrete residential building is to be constructed in the north-east quarter.

The office block lower basement level will not change from existing at approximately +21mOD, however, a lift pit is to be lowered locally. The new structure is to be supported by piled foundations to minimise differential settlement between the new and existing buildings.

In the north east of the site, the lower basement level is to be reduced by approximately 1.425m from approximately 21.15mOD to approximately 19.725mOD. This new area of basement is to be formed using a secant piled basement wall. There are no areas of soft landscaping proposed as part of the development.

Structural drawings of the proposed development are provided in Appendix B.

3. HISTORICAL DEVELOPMENT

3.1 Sources of Information

The historical development of the site has been traced from Ordnance Survey maps of various scales from 1872 to 2014. Details are summarised in *Table 1* below, and the historical maps are presented in Appendix C.

Table 1. Summary of the Development of the Site and Surrounding Area

Year	*On Site*	*Off Site*
1872	The site is occupied by several unlabelled buildings.	*Middlesex Hospital* is located approximately 70m southwest of the site. A *Workhouse* is located approximately 50m northwest.
1896	No significant change.	*Workhouse* replaced by *Sick Asylum. Cleveland Works (cabinet)* located 30m northwest of the site.
1916 – 1938	No significant change.	*Sick Asylum* now an *Infirmary. Cleveland Works (cabinet)* no longer shown.
1951 – 1954	*Ruin* in southern corner of site. *Timber yard* in northern corner of site.	*Brass foundry and metal warehouse* adjacent to the northern corner of the site. *Clothing factory* located approximately 200m south. *Mineral water factory, Optical works* and *Bottling works* located approximately 200m northeast. *Motion Picture Processing Works* and *Electrical Substation* approximately 120m north. *Printing works* are located approximately 150m east, 200m southwest and 250m west. *Metal works* located approximately 150m east. *Electrical Substation* located approximately 200m northwest. *Leather curing works* located approximately 300m southwest. There are also approximately 24 ruined buildings within 250m of the site.
1957 – 1962	*Timber yard* has been replaced by a *Depot*. The *Ruin* is still in the southern corner of the site.	One *ruin* remains approximately 200m south, all other *ruins* have been replaced by unlabelled buildings. The two *Electrical Substations* are no longer shown.
1966 – 1970	Site is now in its present day configuration and is occupied by *Arthur Stanley House*, part of the Middlesex Hospital.	*Middlesex Hospital Medical School* located approximately 100m northeast. The *leather curing works* has been replaced by *Knighton House*. A *timber yard* is located approximately 80m southeast. The *printing works* located approximately 250m west of the site is no longer shown.
1973 – 1977	No significant change.	The *brass foundry and metal warehouse,* the *clothing factory*, the *motion picture processing works* and the *printing works* approximately 200m southwest are all no longer shown.
1985 – 1990	No significant change.	No significant change.
1991 – 1995	No significant change. The Historical Garage and Motor Vehicle Repair Database (see Appendix C) indicates a garage on site in 1993 however this is not shown on historical maps and is likely to be an artefact of the search buffer.	No significant change.
2010 – 2014	No significant change.	No significant change.

Review of the available maps has identified that the site and surrounding areas were significantly redeveloped in the 1950s after the area was extensively damaged by bombing during the Second World War. The site was further redeveloped in the 1960s to its present configuration.

The review of the available maps has also indicated significant historical industrial land usage on and around the site. As such, there is the potential for contamination within the Made Ground around the perimeter of the site and within the shallow groundwater within the Lynch Hill Gravel Member. Whilst the site itself was historically occupied by industrial usages, the majority of affected soils are likely to have been removed in the excavation of the current double basement of Arthur Stanley House.

3.2 Unexploded Ordnance

From available bomb damage maps[1], the structure at the southern corner of the site was damaged beyond repair, while the surrounding structures sustained minor blast damage. The Bombsight.org (free online resource)[2] identified that 17 high explosive bombs were dropped within approximately 250m of the site.

The entire site footprint has been developed post war with the construction of Arthur Stanley House, which included the excavation of two basement levels and as such, the risk associated with encountering unexploded ordnance (UXO) is considered to be low.

Notwithstanding the above, UXO hazards should be included as part of the health and safety briefing and tool box talks during the works, such that if any suspicious articles are found, they can be quickly identified and treated appropriately by specialist inspection.

3.3 Buried Infrastructure

CGL's archive information indicates that the London Underground Limited (LUL) Northern Underground Line is located approximately 210m northeast of the site, and the LUL Victoria Line is located approximately 320m northwest of the site.

Thames Water sewers and water pipes are located underneath Tottenham St, approximately 5.4m from the site, and underneath Tottenham Mews, approximately 3m from the site.

CGL's archive information indicates that the historic Royal Mail underground tunnels are located approximately 220m northeast and 240m southwest of the site, however, based on available information none of the following are recorded within 250m of the site:

- Crossrail (1 or 2);
- High Speed 2;
- National Grid; and,
- Government Communications Tunnels.

[1] London Topographical Society, 2005. The London County Council bomb damage maps 1939 – 1945.
[2] www.bombsight.org (Accessed 31st March 2017).

4. ANTICIPATED GROUND CONDITIONS

4.1 Published Geology

With reference to the British Geological Survey (BGS) website[3] and BGS 1:50,000 map sheet for North London[4], the site is shown to be underlain by the Lynch Hill Gravel Formation, which is in turn underlain by the London Clay Formation, the Lambeth Group Formation, the Thanet Sand Formation and Chalk at depth. Given the site's historical development, it is also likely that Made Ground deposits are overlying the Lynch Hill Gravel. No known scour hollows were identified within 1km of the site[5].

The Lynch Hill Gravel Formation typically comprises sand and gravel with occasional lenses of silt, clay or peat[5].

The London Clay Formation typically consists of a firm to stiff blue grey fissured clay, weathering to brown near the surface. The London Clay Formation becomes sandier towards the base of the sequence. Locally it can contain claystone and small pockets of sand and silt and is pyritic in nature with selenite crystals present[6]. The BGS 1:50,000 map sheet for North London indicates that the base of the London Clay Formation is at approximately -5mOD in this location.

The Lambeth Group Formation is divided into three main beds[7], with the Upnor Formation as the basal bed. The Lambeth Group Formation is described as glauconitic sands at base (Upnor Formation) overlain by grey clays and sands with brackish fauna (Woolwich Beds), and interleaved red and variegated clays and sands (Reading Beds). The BGS 1:50,000 map sheet for North London indicates that the base of the Lambeth Group is located at approximately -20mOD.

The Thanet Sand Formation typically consists of glauconitic nodular flint at base, overlain by pale yellow-brown to grey, fine-grained sand that can be clayey and glauconitic with rare calcareous or siliceous sandstones[7]. The BGS 1:50,000 map sheet for North London indicates that the base of the Thanet Sand Formation is at approximately -30mOD.

The Chalk at the base of the sequence is described as being part of the White Chalk Subgroup[7]. The strata typically consists of chalk with flints, with discrete marl seams, nodular chalk, sponge-rich and flint seams throughout.

[3] http://www.bgs.ac.uk/discoveringGeology/geologyOfBritain/viewer.html (date accessed: 03/04/2017)
[4] British Geological Society (2006). *Geological Survey of England and Wales. Map no. 256 North London – Bedrock and Superficial map.* 1:50,000 scale.
[5] Berry, F G (1979) *Late Quaternary scour-hollows and related features in central London* Quarterly Journal of Engineering Geology vol. 12
[6] http://www.bgs.ac.uk/lexicon/ (accessed 4th April 2017)
[7] CIRIA C583 (2004) *Engineering in the Lambeth Group*

4.2 Unpublished Geology

A summary of available BGS borehole records and nearby ground investigation information held on CGL's database is presented in Table 2.

There are three BGS boreholes recorded within a 250m radius of the site. BGS mapping indicates that the geological sequence within the boreholes is the same as the sequence expected at the site. The Lambeth Group Formation (Woolwich and Reading Beds) was encountered in two of the boreholes, however the full sequence of the Lambeth Group Formation, Thanet Sands and Chalk was not recorded.

Table 2. Summary of BGS Borehole Records

Stratum	*Generalised Description*	*Depth to Top of Stratum (mbgl)** *[mOD]*	*Typical Thickness (m)*
[MADE GROUND]	Dark brown gravel and sand, becoming clayey with depth with brick, rubble, concrete, charcoal and ash.	0 [24.3]	2.1 – 7.3
[LYNCH HILL GRAVEL MEMBER]	Brown medium dense fine to coarse SAND and GRAVEL with occasional cobbles, becoming firm brown silty sandy CLAY with depth.	2.1 – 7.3 [23.6 to 19.5]	1.9 – 10.4
[LONDON CLAY FORMATION]	Stiff to very stiff dark grey brown fissured silty CLAY.	6.3 - 12.5 [17.2]	15.7 – 16.2
[LAMBETH GROUP[6]] (*TQ28SE981 AND TQ28SE982 only)*	Variable, but comprising: Stiff to very stiff mottled multi-coloured silty CLAY over, Grey sandy SILT.	25.6 – 28.6 [c. 0]	Base not proven. (encountered to 48.76mbgl)

*Note: *mbgl = metres below ground level.*

Groundwater was recorded during drilling within the Lynch Hill Gravel Member at approximately 20.0mOD.

Copies of the BGS borehole logs are available in Appendix D.

4.3 Historical Site Investigation

A previous ground investigation, carried out on the site from the lower basement level, is summarised in Table 3, below. The depths are given as metres below basement level (mbbl).

Table 3. Summary of Historic Ground Investigation on Site

Stratum	*Depth to Top of Stratum (mbbl) [mOD]*	*Typical Thickness (m)*
Concrete	0.0 [21.2 – 21.3]	0.7 – 1.3
Loose to medium dense clayey SAND and GRAVEL. Sand is fine to coarse. Gravel is fine to coarse subrounded to subangular flint. [LYNCH HILL GRAVEL MEMBER]	0.7 – 1.3 [19.9 – 20.6]	2.0 – 2.9

Stratum	*Depth to Top of Stratum (mbbl) [mOD]*	*Typical Thickness (m)*
Firm orangish brown occasionally mottled grey slightly gravelly CLAY [WEATHERED LONDON CLAY FORMATION]	3.3 - 3.6 [17.7 - 17.9]	1.7 – 1.9
Stiff to very stiff very closely fissured greyish brown CLAY with occasional claystone and rare pyrite nodules. [LONDON CLAY FORMATION]	5.0 – 5.5 [15.8 – 16.2]	14.2
Hard multi-coloured mottled CLAY with occasional lenses of sand. [LAMBETH GROUP – READING FORMATION, UPPER MOTTLED BEDS]	19.7 [1.57]	Base not encountered. Proven to 25mbbl [-3.7mOD]

Groundwater was recorded during drilling within the Lynch Hill Gravel Member from lower basement level (approx. 21.0mOD). Five rounds of groundwater monitoring were undertaken which recorded the groundwater level as between 21.2mOD and 21.4mOD. These records are consistent with observations made by CGL during the site walkover.

4.4 Hydrogeology and Hydrology

The Environment Agency[8] has produced an aquifer designation system consistent with the requirements of the Water Framework Directive. The designations have been set for superficial and bedrock geology and are based on the importance of aquifers for potable water supply, and their role in supporting surface water bodies and wetland ecosystems.

The Environment Agency[8] indicates that the superficial deposits on site (Lynch Hill Gravel Member) are classified as a Secondary A Aquifer, which comprises permeable material capable of supporting water supplies at a local level and may also be important as a source of base flow to rivers. The London Clay Formation is classified as Unproductive Strata, indicating rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.

An environmental disclosure report (GroundSure) obtained for the site indicates there are six active groundwater abstraction licences and two active potable water abstraction licences within 1km of the site. The nearest active groundwater abstraction is located approximately 500m west of the site. The nearest active potable water abstraction is located approximately 500m southwest of the site. There are no recorded active surface water abstraction licences within 1km of the site. The site is not located within a groundwater Source Protection Zone (SPZ).

[8] http://www.environment-agency.gov.uk/wiyby (accessed June 2017)

The nearest surface water body is the Boating Lake in Regent's Park located approximately 1.2km northwest of the site. The Boating Lake forms part of the lost River Tyburn, which passes approximately 980m southwest of the site at its closest point. The River Thames is approximately 1.6km southeast.

Mapping available on the Environment Agency website[8] indicates that the site is not located within a Zone 2 or Zone 3 floodplain (flooding from rivers and the Sea) and there are no known flood defences within a 250m radius of the site.

The site is within a 50m radius of a groundwater flooding zone, with a high susceptibility rating of shallow flooding below the ground surface within the Lynch Hill Gravel member. The site is considered to be at a low probability of flooding.

The groundwater level has previously been recorded at approximately 21.4mOD, which is above the level of the lower basement slab.

4.5 Ground Hazards

A geological disclosure report was obtained from GroundSure to provide information on the ground conditions and associated hazards at, and in the vicinity of, the site. A summary of the key information is set out in *Table 4* below, and the full report is included in Appendix C.

Table 4. Ground Risks Associated with the Site

Risk	***Hazard Rating***
Shrink-swell clays	Negligible
Landslides	Very low
Ground dissolution of soluble rocks	Negligible
Compressible deposits	Negligible
Collapsible deposits	Very low
Running sands	Very low

Note: An explanation of the hazard rating is provided within the GroundSure GeoInsight Report in Appendix C.

The GroundSure GeoInsight report identifies a 'negligible hazard' rating for the shrink-swell clays. The London Clay Formation, which underlies the Lynch Hill Gravel on site and typically comprises a highly plastic clay, is prone to shrinking or swelling depending on the moisture conditions, however as the London Clay Formation is approximately 7 to 10mbgl it is not expected that the shrinking or swelling of the London Clay Formation will pose a hazard to the development.

There are no records of mining, extraction or cavities within 1km of the site.

The following anticipated geotechnical hazards should also be considered:

- The potential for Made Ground and obstructions to be present on site associated with historical development;
- Ground movements associated with construction of the new building and the potential impact on nearby structures and infrastructure;
- The potential for on-site soils to be aggressive to buried concrete; and,
- Claystone bands may exist within the London Clay which can hamper piling.

5. ENVIRONMENTAL SETTING

5.1 Environmental Disclosure Report

The GroundSure report has been reviewed to provide information on the environmental setting of the site and possible sources of ground and groundwater contamination. A summary of the key points is set out below and the full report is included in Appendix C.

- There are 15 potentially contaminative historical land uses within a 250m radius of the site. These include two electrical substations, a brass foundry and metal warehouse immediately adjacent to the site and a timber yard on site.

- One historical tank has been identified within a 500m radius of the site, and was located approximately 460m northeast of the site and was identified on historical maps between 1951 and 1968.

- Seven electrical substations have been identified within a 500m radius of the site, the closest relates to a substation located approximately 130m north of the site. Another substation was located approximately 204m northwest of the site. The remaining electrical substations were located greater than 250m away from the site.

- 21 historical fuel/filling stations or garage and motor repair workshops were identified within a 500m radius of the site. The nearest is a historical garage located on the site, dated from 1993.

- There are no records of landfill sites or other waste sites within a 500m radius of the site.

- There are no records of licensed discharge consents within 500m of the study site.

- There are seven historical Part A (2) and Part B activities within 500m of the site, of which two are current. The current permits relate to Parkers Dry Cleaning and Fitzroy Cleaners which are 132m east and 364m northwest of the site respectively. Both have current part B process (dry cleaning) licenses.

- There are four Environment Agency recorded Pollution Incidents within 500m of the site. The closest relates to an incident involving acids, 92m south of the site, which was recorded on 2nd August 2002. The incident was recorded as a Category 4 (no impact) to land and water, and Category 2 (significant) to air.

- There are four Environment Agency recorded Pollution Incidents within 500m of the site. The closest relates to an incident involving acids, 92m south of the site, which was recorded on 2nd August 2002. The incident was recorded as a Category 4 (no impact) to land and water, and Category 2 (significant) to air.

- There are 56 historical Category 3 or 4 radioactive substance authorisations within 500m of the site, of which 12 are effective or valid. The nearest current license is located at Middlesex Hospital, approximately 47m southwest of the site.

5.2 Radon

The Building Research Establishment (BRE)[9] and Health Protection Agency (HPA)[10] guidance documents on radon indicate that the site is within a Radon Affected Area where less than 1% of properties in the area are above the action level. Therefore, no radon protection measures are considered necessary for developments at the site.

However, consideration should be given to the advice from Public Health England (PHE)[11], which suggests radon monitoring in basements with long term occupancy.

5.3 Regulatory Enquiries

Consultations are underway with Building Control, Planning and the Environmental Health Officer at London Borough of Camden. Responses have not been received.

[9] Building Research Establishment (2015). *Radon. Guidance on protective measures for new buildings.* BR2110. 5th Edition.
[10] Miles et al. (2007). *Indicative Atlas of Radon in England and Wales.* HPA-RPD-033. November 2007.
[11] Public Health England (2016). *Radon in workplace basements. An analysis of PHE measurement results and recommendations on when to test.* PHE-CRCE-028. July 2016.

6. PRELIMINARY RISK ASSESSMENT

6.1 Introduction

Historical contamination of land may present harm to human health and the environment. Current UK legislation stipulates that the risk associated with any potential land contamination is assessed and remediated, if necessary. Under the Town and Country Planning Act 1990 (as amended), potential land contamination is a "material planning consideration" together with the National Planning Policy Framework (March 2012) which means that a planning authority must consider contamination when it prepares development plans or considers individual applications for planning permission. It is the responsibility of the developer to carry out the remediation where it is required and satisfy the Local Authority that the remediation has been carried out as agreed.

Additionally, Part 2A of the Environmental Protection Act 1990 requires that a significant source-pathway-receptor linkage exists to determine a site as contaminated land. This means that there has to be a contaminant present, a receptor that could be harmed by this contaminant, and a pathway linking the two. Part 2A deals with the contamination risk from a site in its current use, however the planning system requires that the proposed use is considered. Where remediation is carried out under the planning system, it should be ensured that the site is in such a condition that it would still not meet the definition of contaminated land under Part 2A.

6.2 Preliminary Conceptual Site Model

A preliminary conceptual model has been compiled for the site for a *"residential"* land use to identify the potential sources of contamination and the associated potential pollutant linkages. This model also informs the potential need for further investigation at the site.

6.2.1 Potential Sources

Potential contamination sources can include current and historical activities on the site. The following potential sources have been identified at the site:

- *On site* – Based on the site's history, Made Ground is anticipated to be present, which may contain residual contamination arising from historical on-site and off-site uses. Plant and boiler rooms are known to have existed within the basement. Historically on the site there has been a garage, timber yard and depot, all of which are potential sources of contamination. The on-site activities have the potential to be the source of a wide range of contaminants including asbestos containing materials (ACMs), hydrocarbons, polychlorinated bi-phenyls (PCBs), heavy metals, volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). However, the majority of the Made Ground is likely to have been removed during the construction of the double level basement on site.

- *Off site* – Historical and current off-site activities include a hospital, workhouse, substation, timber yard and printing works. The off-site activities have the potential to be a source of a wide range of contaminants including hydrocarbons, ACMs, PCBs, heavy metals, VOCs and SVOCs which could migrate onto and beneath the site.

- *Ground gases/vapours* – If there is significant Made Ground in the vicinity of the site with an appreciable organic content, there may be a potential for ground gases.

- *Perched and shallow groundwater* – May contain residual contaminants that have leached from the Made Ground into the shallow groundwater table within the underlying Lynch Hill Gravel Member, particularly from off-site sources.

- *Asbestos* – Asbestos may be present within the Made Ground due to the historical redevelopment of the site. It is unknown whether ACMs are present within the existing structure on site. The asbestos register for the building should be consulted prior to any intrusive works or demolition.

6.2.2 Potential Pathways

The potential migration pathways that may be present at the site include:

- *Ingestion & inhalation* – contamination within Made Ground, if present, be ingested or inhaled in the form contaminated dust, including asbestos fibres, and ground gases/vapour.

- *Direct/dermal contact* – direct contact with contaminated soils, dusts or groundwater can result in uptake of contaminants through the skin or permeation through building materials.

- *Lateral/vertical migration* – ground gas and hydrocarbon vapours could migrate through the permeable soil matrix into proposed buildings.

- *Groundwater* – a shallow groundwater table is likely to be present within the Lynch Hill Gravel Member. The groundwater may act as a pathway for lateral migration of contaminated water, if encountered. A pathway may also be created between contaminated water in the Made Ground and Lynch Hill Gravel Member and the deep aquifer within the Chalk if piling extends into the Lambeth Group below the London Clay Formation.

- *Drainage/services* – could provide a preferential pathway for contamination and/or ground gases/vapours.

6.2.3 Potential Receptors

The main potential receptors at the site are likely to be:

- *Future sit occupiers* – considered to be primarily at risk from possible shallow contamination and ground gas accumulation within buildings, arising from Made Ground beneath the site and off-site sources.
- *Construction workers* – could be affected by potential contamination, in particular asbestos, within the Made Ground and groundwater during the site works. Such persons are likely to be in close contact with contaminated materials, especially during site enabling works.
- *Buildings & structures* – buried concrete and services, such as plastic water supply pipes, can be at risk from potentially chemically aggressive ground. Ground gases and vapours may also accumulate in buildings and structures, presenting an explosive risk.
- *Groundwater* – the Lynch Hill Gravel Member is designated a Secondary A Aquifer and may be a receptor to shallow contaminants. The deep aquifer within the Chalk stratum may also be a receptor to contaminants if piling extends into the Lambeth Group below the London Clay Formation, however this is considered to be unlikely. The nearest significant surface water body (the Regent’s Park Boating Lake) is located some 1.2km northwest of the site.
- *Vegetation & plants* – primarily at risk from phytotoxic contaminants such as boron, copper, nickel and zinc.
- *Off-site receptors* – primarily at risk from inhalation of dust particles and potential contaminants within the shallow groundwater.

6.3 Preliminary Qualitative Risk Assessment

A qualitative risk assessment has been undertaken based on the findings of the conceptual site model and the potential pollutant linkages that may exist at the site in accordance with Contaminated Land Report (CLR) 11[12]. The risks identified are in accordance with the DEFRA and Contaminated Land Report (CLR) 6[13], site prioritisation and categorisation rating system which is summarised in Table 5.

[12] The Environment Agency (2004) *Model Procedures for the Management of Land Contamination*, CLR 11
[13] M.J. Carter Associates (1995*) Prioritisation and Categorisation Procedure for Sites which may be Contaminated*, Department of the Environment, CLR 6

Table 5. Risk Rating Terminology

Risk Rating	*Description*
High Risk	Contaminants very likely to represent an unacceptable risk to identified targets Site probably not suitable for proposed use Enforcement action possible, Urgent action required
Medium Risk	Contaminants likely to represent an unacceptable risk to identified targets Site probably not suitable for proposed use Action required in the medium term
Low Risk	Contaminants may be present but unlikely to create unacceptable risk to identified targets Site probably suitable for proposed use Action unlikely to be needed whilst site remains in current use
Negligible Risk	If contamination sources are present they are considered to be minor in nature and extent Site suitable for proposed use No further action required

Based on the above terminology an assessment of the risks posed by the potential pollutant linkages at the site are outlined in *Table 6*, below.

Table 6. Qualitative Risk Assessment

Source/Medium	*Receptor*	*Potential Exposure Route*	*Risk Rating*
Explosive / asphyxiating gases and hydrocarbon vapours from within Made Ground	Internal building spaces & future occupiers	Migration of gases through the surface and via permeable soils	Low
	Off-site internal building spaces and residents		Low (assuming appropriate ground gas measures are incorporated in current buildings)
Asbestos within Made Ground	Future site occupiers	Inhalation of fibres	Low
	Construction workers		Low
	Off-site residents		Low
Asbestos Containing Materials within existing structure	Future site occupiers	Inhalation of fibres	Low (assuming current regulations are adhered to)
	Construction workers		Low to Medium
	Off-site residents		Low
Organic/inorganic contaminants e.g. Polycyclic Aromatic Hydrocarbons (PAHs), hydrocarbons, metals etc.) within Made Ground	Construction workers	Direct ingestion of soil & dust, inhalation of particulates & vapours and dermal contact	Low
	Future site occupiers		Low
	Off-site receptors		Low
	Vegetation and plants	Root uptake	Low

Source/Medium	***Receptor***	***Potential Exposure Route***	***Risk Rating***
	Buildings & structures	Migration & accumulation of ground gas (carbon dioxide within building spaces.	Low to medium
		Damage to concrete from pyritic soils.	Low to medium
	Lynch Hill Gravel Member (Secondary A Aquifer)	Lateral and vertical migration of contaminants	Low to medium
	Deep Chalk aquifer	Lateral and vertical migration of contaminants via pathway created by piled foundations	Low
	Local surface water bodies	Lateral migration of contaminants	Negligible
Organic/inorganic contaminants within groundwater (Secondary A Aquifer)	Construction workers	Inhalation of particulates & vapours and dermal contact	Low to medium
	Future site occupiers		Low
	Off-site receptors		Low
	Lynch Hill Gravel Member (Secondary A Aquifer)	Lateral and vertical migration of contaminants	Low to medium
	Local surface water bodies	Lateral migration of contaminants	Negligible
Off-site sources	Current site users	Migration of contaminants from off-site sources into underlying site	Low to medium
	Future site users		Low
	Construction workers		Low
	Controlled waters		Low
	On site buildings and structures		Low

Based on the findings of the desk study and the anticipated ground conditions, a generally low to medium risk is considered for the identified receptors based on the potential for general Made Ground contamination, including the potential for asbestos fibres or ACMs within the soil. Ground gas is expected to pose a low to medium risk on site.

In line with the phased process of assessment recommended in BS 10175[14] and BS 5930[15], a ground investigation should be carried out to appraise potential land contamination. This should include an investigation of the general site conditions and target the most likely potential pollutant linkages identified in the assessment and summarised in Table 6.

[14] British Standards Institution. (2011). *Investigation of potentially contaminated sites: Code of practice.* BS 10175:2011.
[15] British Standards Institution. (2015). *Code of practice for site investigations*. BS 5930:2015.

7. SITE INVESTIGATION

7.1 Summary

A site investigation was conducted by CGL between 2nd and 24th January 2018 comprising the excavation of four exploratory boreholes denoted BH1, BH3, BH4 and BH5 (BH2 was not drilled).

The cable percussion borehole rig was setup at existing ground floor level at approximately +27.5mOD, with tools lowered through the existing basement to lower basement level at approximately +21mOD, from which drilling through the soils commenced. The boreholes were undertaken from the higher level due to access constraints and the presence of water within the basement, which was being pumped at the time of the investigation to maintain water below the lower basement slab level.

Boreholes BH1, BH3 and BH4 were situated in the northern half of the site, outside of the reinforced concrete (RC) frame structure, while BH5 was situated within the ground floor of the existing RC structure. Concrete coring was undertaken prior to the commencement of drilling in all borehole locations through both the ground floor slab and lower basement floor slab from approximate levels of +27.5mOD and +21mOD respectively.

Boreholes BH1 and BH3 were excavated to depths of 36mbgl and 31mbgl respectively while BH4 and BH5 were excavated to depths of 26mbgl. The boreholes, upon completion, were installed with groundwater and gas monitoring standpipes.

The exploratory hole arising's were logged and representatively sampled by a suitably qualified engineer from CGL. Standard Penetration Tests (SPT) were undertaken in the boreholes and representative samples were taken for geoenvironmental and geotechnical laboratory testing to characterise the ground conditions encountered on site. The investigation was undertaken generally in accordance with the requirements set out within BS 5930:2015[16]; and BS 10175:2011[17].

The exploratory hole locations are presented in Figure 2 and the engineering logs are included within Appendix E.

7.1.1 Installation Details

The boreholes were installed with combined groundwater/ground gas monitoring standpipes. The installation details are summarised below in Table 7.

[16] British Standards Institution. (2015). *Code of practice for site investigations*. BS 5930:2015.
[17] British Standards Institution. (2011). *Investigation of potentially contaminated sites: Code of practice.* BS 10175:2011.

Table 7. Installation Details

	Strata	Exploratory Hole ID			
		BH1	BH3	BH4	BH5
Response Zone	Made Ground				x
	Lynch Hill Gravel Member	x	x		x
	London Clay Formation			x	

7.2 Monitoring

One return ground gas monitoring visit was undertaken on the 30th of January 2018, to record ground gas concentrations for oxygen, carbon dioxide and methane. VOCs were also monitored during the site visit using a Photo Ionisation Detector (PID). Groundwater levels within the CGL boreholes were also monitored and groundwater samples were retrieved for laboratory analysis. Monitoring records are available in Appendix F.

7.3 Laboratory Testing

7.3.1 Chemical

Representative soil and groundwater samples were sent to i2 Analytical Limited (a UKAS and MCERTS accredited laboratory) for chemical testing. The analysis included the following determinants and full results are presented in Appendix G:

- Soil Organic Matter (SOM) (soil only);
- Hardness (water only);
- Dissolved organic carbon (water only)
- Ammoniacal nitrogen as N (water only);
- pH;
- Sulfate;
- Heavy metals/metalloids including; arsenic, antimony, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium and zinc;
- Benzene, Toluene, Ethylbenzene and Xylene (BTEX compounds);
- Methyl tertiary butyl ether (MTBE);
- Total Petroleum Hydrocarbons by Criteria Working Group (TPH CWG);

- Polycyclic aromatic hydrocarbons (PAH);
- Total monohydric phenols;
- Total cyanide;
- Asbestos identification; and,
- 2:1 water soluble sulfate, acid soluble sulfate, total sulfur and pH (BRE SD1[18]).

7.3.2 Geotechnical

Representative soil samples were sent to Geolabs Limited (a UKAS accredited laboratory) for geotechnical testing. The geotechnical tests have been undertaken in accordance with BS 1377[19]. The following soil tests were undertaken, and the full results are presented in Appendix G.

- Particle size distribution (PSD);
- Moisture content;
- Atterberg Limit determination; and,
- Quick undrained triaxial tests.

Buried concrete testing was undertaken at i2 Analytical Limited, as described above.

[18] Building Research Establishment. (2005). *Concrete in aggressive ground*. Special Digest 1, 3rd Ed.
[19] British Standards Institution. (1990). *Methods of test for soils for civil engineering purposes. Classification tests* BS 1377-2:1990

8. GROUND AND GROUNDWATER CONDITIONS

8.1 Ground Conditions

The ground conditions encountered on site broadly corresponded to published and unpublished geology for the area. The ground conditions were found to comprise the superficial deposits of the granular Lynch Hill Gravel Member underlain by the solid geology of the London Clay Formation and the Lambeth Group. The base of the Lambeth Group and underlying solid geology was not proven. The ground conditions encountered are summarised in Table 8 below.

Made Ground was unexpectedly encountered in borehole BH5, immediately underlying the lower basement slab. It is considered, based on the soil description alongside chemical and geotechnical laboratory testing, that this is reworked Lynch Hill Gravel and London Clay that was disturbed during construction of the existing basement on site.

The depth to the surface of the London Clay was deeper in BH5 than the other boreholes, encountered at a level of 14.53mOD, compared to 17.97mOD to 18.42mOD in the other boreholes. Typically, the thickness of Lynch Hill Gravel recorded beneath the basement was between 1.8 to 2.4m, however, in BH5 4.9m was recorded. Upon review of the ground investigation, nearby BGS boreholes and ground investigation information held on CGL's database, the level of the surface of the London Clay was found to be typically between 17.7mOD and 19.2mOD. However, BH5 sunk on site and historic BGS borehole TQ28SE981, located approximately 100m west of the site (included in Appendix D), recorded the surface of the London Clay at 14.53mOD and 14.32mOD respectively. It is considered that this increased thickness of Lynch Hill Gravel could be representative of a potential buried river channel.

Table 8. Ground Conditions Summary

Stratum	*Sub-unit*	*Depth to Top of Stratum (mbgl) [mOD]*	*Typical Thickness (m)*
Reinforced concrete (Ground level). (All exploratory holes)	-	(0) [27.47 to 27.53]	(0.3 to 0.35)
Reinforced concrete (Lower Basement Slab). (All exploratory holes)		(6.5) [20.97 – 21.03]	(0.4 to 1.2)
Firm dark brownish gravelly clay becoming medium dense clayey gravel. Gravel is fine to coarse angular to sub-angular of brick, concrete and flint. [MADE GROUND] (BH5 only)	-	(6.9) [20.63]	(1.2)

Stratum	*Sub-unit*	*Depth to Top of Stratum (mbgl) [mOD]*	*Typical Thickness (m)*
Medium dense to very dense dark orange and yellowish brown sandy GRAVEL. Gravel is fine to coarse sub-angular to rounded flint. Common sub-rounded cobbles of flint between 8.7-9mbgl (BH5 only) Stiff dark orange brown slightly gravelly CLAY encountered in bottom 0.1m to 0.4m. [LYNCH HILL GRAVEL MEMBER] (All exploratory holes)	-	(6.9 to 8.1) [19.43 to 20.63]	(1.8 to 4.9)
Stiff becoming very stiff dark orange brown becoming dark grey closely fissured silty CLAY with occasional partings of fine silty sand. Occasional coarse selenite crystals throughout. Horizons of claystone encountered between 13.1mOD to 14.9mOD, 0.1m to 0.2m thick (BH1, BH3, BH4 only). [LONDON CLAY FORMATION] (All exploratory holes)	-	(9.1 to 13.0) [14.53 to 18.42]	(16.6 to 17.5) Proven in BH1 and BH3 only
[LAMBETH GROUP] (BH1 and BH3 only)	**Reading Formation (Undifferentiated) –** Hard dark blue grey mottled brownish red slightly sandy silty CLAY with occasional partings of fine sand. Rare shell fragments above -0.5m OD to 0.1mOD.	(26.1 to 26.8) [0.73 to 1.73]	(3.7 to 4.2)
	Reading Formation (Undifferentiated) – Hard dark grey mottled yellowish brown slightly sandy CLAY with rare calcareous horizons.	(30.3 to 30.5) [-2.83 to -2.97]	Thickness not Proven (5.7m recorded to -8.53mOD)

8.2 Concrete Coring

Concrete coring was undertaken prior to the commencement of drilling in all borehole locations through both the ground floor slab and lower basement floor slab from approximate levels of +27.5mOD and +21mOD respectively. The details of slab thickness encountered in each position are provided in *Table 9* below. Concrete coring in borehole BH5 encountered vertical reinforcement (suspected edge of pad foundation, slab edge thickening or pile cap) and as such initial position was terminated. Borehole BH5 was repositioned some 0.5m to the east. Borehole positions are illustrated in Figure 2.

Table 9. Summary of Concrete Thicknesses

Borehole	*Thickness of Ground Floor Slab (m)*	*Thickness of Lower Basement Slab (m)*
BH1	0.35	1.2
BH3	0.3	0.4
BH4	0.3	0.75

BH5	0.3	0.4

8.2.1 Geotechnical Test Results

Based on the results of the in-situ and laboratory testing data, a summary of the geotechnical results is presented in Table 10 below. A plot of SPT 'N_{60}' values against level is presented as Figure 3 and an undrained shear strength against level plot is presented as Figure 4. The results of the geotechnical laboratory testing are presented in Appendix G.

Table 10. Summary of Geotechnical Test Results

SPT 'N_{60}' Data			
Strata	**Range**	**Equivalent c_u (kPa)[a]**	**Classification [b]**
Made Ground	17	N/A	Medium dense
Lynch Hill Gravel Member	17 – 59	N/A	Medium dense to very dense
London Clay Formation	19 – 42	95 – 212	High to very high strength
Lambeth Group	55 – 141*	288 – 707*	Very high strength

Atterberg Limits						
Strata	**Moisture content (%)**	**Liquid Limit (%)**	**Plastic Limit (%)**	**% material <425µm**	**I'_p [c]**	**Volume change potential [c]**
London Clay Formation	17.0 – 29.0	57 - 82	20 – 27	98 – 100	37 - 55	Medium to high
Lambeth Group	13.7 – 22.4	43 - 61	16 - 21	99 -100	27 – 40	Medium to high

Shear Strength Rests		
Strata	**Undrained shear strength - c_u (kPa)**	**Strength Classification [b]**
London Clay Formation	73 - 504	Medium to very high strength
Lambeth Group	191 - 506	Very high strength

Particle Size Distribution Tests				
Strata	**Clay & Silt (%)**	**Sand (%)**	**Gravel (%)**	**Cobbles (%)**
Lynch Hill Gravel Member	0 to 1	3 - 58	41 - 97	0

Notes:
** Includes extrapolated SPT 'N' values based on depth of penetration achieved.*
[a] Based on f1 = 5 for London Clay Formation/Lambeth Group after Stroud, M A and Butler, F G (1975) The standard penetration test and the engineering properties of glacial materials. Proceedings of the Symposium of Glacial Materials.
[b] Based on British Standards Institution. Code of practice for Site Investigations. BS 5930:2015.
[c] Based on NHBC Standards Chapter 4.2 Building Near Trees (2016).

8.3 Ground Contamination

No significant visual or olfactory indicators of potential contamination were observed during intrusive investigative site works.

8.4 Groundwater

Groundwater was encountered in all exploratory boreholes within the Lynch Hill Gravel Member. A 'fast' water strike was encountered at the base of the lower basement slab within boreholes BH1, BH3 and BH4. Water beneath the lower basement slab was sealed before continuation of drilling in order to prevent flooding of the basement. It is noted that pumping of groundwater was being undertaken at the time of the ground investigation to maintain water below the lower basement slab level.

Water seepages were encountered within the London Clay in BH1 at 22.5mbgl, BH3 at 22.8mbgl, BH4 at 22mbgl and BH5 at 18mbgl and 22mbgl. A 'medium' water strike was also encountered within the London Clay in borehole BH4 at 10.7mbgl.

Groundwater monitoring results are summarised in Table 11 below. Results indicate that the groundwater is approximately at +21mOD. However, it is likely that the groundwater levels observed have been affected by the ongoing dewatering of the basement and as such are not representative of equilibrium groundwater level. The groundwater monitored within the London Clay in BH4 at 10.7mbgl (+21.02mOD) is likely in hydraulic continuity with the overlying Lynch Hill Gravel Member, or the standpipe was not properly sealed to exclude the overlying groundwater.

It should be noted that groundwater levels can vary seasonally and with time. However, due to the considerable thickness of the Lynch Hill Gravel Member and its potentially high permeability, which allows groundwater to dissipate relatively quickly, groundwater levels are not expected to vary significantly.

Table 11. Summary of Observed Groundwater Levels

Borehole	*Well Response Zone Depths (mbgl) [mOD]*	*Well Response Zone Stratum*	*Observed Groundwater Level (mbgl) [mOD]*
			31.01.18
BH1	(7.7 to 11.7) [19.77 to 15.77]	Lynch Hill Gravel Member	(6.5) [20.97]
BH3	(7.0 to 9.5) [20.53 to 18.03]	Lynch Hill Gravel Member	(6.68) [20.85]
BH4	(10.7 to 12.5) [16.82 to 15.02]	London Clay Formation	(6.5) [21.02]
BH5	(6.9 to 12.5) [20.63 to 15.03]	Lynch Hill Gravel Member	(6.5) [21.03]

8.5 Ground Gas

One ground gas monitoring visit was undertaken on site in atmospheric pressure conditions of 1002mb. A GA2000 gas analyser was used to measure gas flow, oxygen (O_2), carbon dioxide (CO_2) and methane (CH_4) concentrations, the findings of which are summarised inTable 12 below. VOCs were also monitored down-hole using a PID during the monitoring visit. Monitoring field data sheets are presented in Appendix F.

Table 12. Summary of Ground Gas Monitoring

Borehole ID	*Maximum Flow (l/hr)*	*Minimum O_2 (% vol)*	*Maximum CO_2 (% vol)*	*Maximum CH_4 (% vol)*	*Maximum VOC (ppm)*
BH1	<0.1	19.8	0.1	<0.1	0.4
BH3	<0.1	19.8	0.1	<0.1	0.6
BH4	< 0.1	19.1	0.2	<0.1	0.5
BH5	< 0.1	19.7	0.1	<0.1	0.4

8.6 Sulfate and pH Conditions

The results of soils sulfate and pH tests from the CGL investigation are summarised Table 13 below.

Table 13. Results of Soil Sulfate Testing

Strata	Number of Tests	Water Soluble Sulfate (mg/kg)	Total Sulphate as SO_4 (mg/kg)	Total Sulfur (mg/kg)	pH
Made Ground (BH5 only)	1	240	1200	640	8.1
Lynch Hill Gravel Member	2	16 – 31	150 – 200	150 – 430	8.9 – 9.1
London Clay Formation	5	66 – 430	270 – 1700	300 – 35000	8.3 – 8.8
Lambeth Group	2	27 – 48	160 – 170	130 – 180	9.2 – 9.3

Four samples of groundwater were also subject to pH and total sulfate as SO_4 testing, which recorded pH values in the range of 7.3 to 7.8 and total sulfate values in the range of 81.3 to 123mg/l.

9. CONTAMINATION ASSESSMENT

9.1 Introduction

This section evaluates risks to potential receptors at the site from identified chemical contamination. Potential receptors have been determined with reference to the Part 2A regime and associated DEFRA guidance[20]. As with the Part 2A regime, under the planning regime all receptors (humans, controlled waters, ecology, crops/livestock and buildings) have been considered if there is the potential for them to be adversely affected by exposure to contamination. CGL's approach and rationale to assessment criteria adoption for this site is presented in Appendix H, Table H1.

9.2 Risks to Human Health

9.2.1 Risks from Soils on Site

The laboratory test results have been compared against the published Generic Assessment Criteria (GAC) for a "*residential land use without homegrown produce consumption"* to assess the risk to human health from chemical contamination in the soils. The comparison of laboratory results of soil samples against GAC are presented in Appendix H, Tables H2 and H3.

A total of one sample of Made Ground and three samples of the underlying natural strata (Lynch Hill Gravel Member) were analysed. Comparison of the results against the relevant GAC indicate that concentrations below their relevant assessment criteria, with the exception of lead within the sample of Made Ground from borehole BH5 at a depth of 7.5mbgl. The GAC value for lead in this instance is 310mg/kg while the sample returned a value of 360mg/kg, suggesting a marginal exceedance.

The samples of the Made Ground and Lynch Hill Gravel Member were submitted for an asbestos screen. No asbestos fibres were identified in the tested samples.

The risk to future site users from contaminants in soil is therefore considered to be **negligible to low** based on the concentrations of determinands within the Made Ground and natural soils. It is understood that the development will not include any soft landscaping. The use of hardstanding will provide a barrier between future receptors and the underlying Made Ground, removing the pathway to the underlying soils.

The risk to construction workers is considered to be **low**. The risk posed to construction workers can be minimised by the use of appropriate health, safety and welfare provisions. These include, but are not limited to, the use of appropriate personal protective equipment (PPE) and good site hygiene. Although

[20] DEFRA (2012) *Environmental Protection Act 1990:Part 2A Contaminated Land Statutory Guidance*

no asbestos was detected within Made Ground, appropriate site control measures should still be taken to protect construction workers from potential asbestos within the existing building fabric.

9.3 Risks from Groundwater Contaminants (Vapour Pathway Only)

The groundwater laboratory analysis results have been compared against vapour assessment criteria for a residential land use, and the assessment indicates that the results are below the respective assessment criteria. Therefore, the risks to human health from volatile contaminants are considered to be **negligible**. The results of the assessment are presented in Appendix H, Table H4.

9.3.1 Risks from Ground Gases

Gas screening values have been calculated in accordance with CIRIA 665[21] using the data obtained during the ground gas monitoring visit. Using the maximum flow rate and maximum volume recorded on site, the gas screening values (GSV) along with corresponding characteristic situation (CS) for carbon dioxide and methane are included in Table 14.

Table 14. Gas Risk Assessment for Individual Wells

Borehole ID	Maximum Flow (l/hr)	Maximum CO_2 (% vol)	Maximum CH_4 (% vol)	Maximum GSV (l/hr)	Characteristic Situation
BH1	<0.1	0.1	<0.1	<0.0001	CS1
BH3	<0.1	0.1	<0.1	<0.0001	CS1
BH4	< 0.1	0.2	<0.1	<0.0002	CS1
BH5	< 0.1	0.1	<0.1	<0.0001	CS1

On this basis, a **low** risk to future users is associated with the concentrations and flow rates of potentially harmful ground gases such as methane and carbon dioxide as determined by the gas monitoring undertaken as part of the investigation. Therefore, no specific ground gas protection measures are considered to be required for the proposed development.

A secondary analysis was undertaken to consider the potential of the Made Ground to generate ground gases. This was completed by assessing the Total Organic Carbon (TOC) of the Made Ground, determined during chemical analysis. Based on the assumption that the Made Ground across the site has been in place for greater than 20 years and an average thickness of <3m, the TOC content of the Made Ground also suggests that a Characteristic Situation 1 (CS1) is applicable for the site.

9.4 Risk to Controlled Waters

The results of analytical laboratory testing of groundwater samples have been compared to the Drinking Water Values (DWV) and the Environmental Quality Standards (EQS) for freshwater sources.

[21] CIRIA (2007). Assessing risks posed by hazardous ground gases to buildings, CIRIA Report C665, London

Both these are considered to be conservative given the site is not situated within a groundwater Source Protection Zone and the nearest significant surface water feature is the Regents Park Lake some 1.2km north-east of the site. Results of EQS and DWS comparison are presented in Appendix H, Table H5.

Analytical laboratory testing of groundwater has identified concentrations of the following determinands to exceed that of EQS;

- Two samples recovered from boreholes BH4 and BH5 returned a bioavailable fraction of copper at 1.09μg/l and 1.55μg respectively. The EQS for copper is 1.0μg/l.
- One sample recovered from borehole BH4 returned a bioavailable fraction of zinc at 21.2μg/l. The EQS for zinc, while considering ambient background concentrations in the London area, is 12.9μg/l.

However, given the nearest surface water feature's distance from the site, Regents Park Lake situated some 1.2km to the north-west, the risk to surface waters is considered to be **negligible.**

Analytical laboratory testing of groundwater has identified concentrations of the following determinands that exceed the DWV;

- One sample recovered from borehole BH5 returned a concentration of phenols at 2.0μg/l. The DWS for phenols, formerly prescribed within the Water Supply (Water Quality) Regulations 1989, is 0.5μg/l.
- One sample recovered from borehole BH5 returned a concentration of TPH at 300μg/l. The DWS for TPH is 10μg/l.
- Three samples recovered from boreholes BH1, BH3 and BH5 returned concentrations of ammoniacal nitrogen as NH_4 at 14000μg/l, 3300μg/l, and 3800μg/l respectively. The DWS for ammoniacal nitrogen as NH_4 is 500μg/l.

The source of these groundwater contaminants is currently unclear though, given the site is confined to a relatively small area, and that significant Made Ground was not encountered during the investigation, it is considered possible the contaminants identified are derived from an off-site source. As such the test results may indicate that the wider groundwater quality is impacted.

The nearest potable water abstraction licence is located some 500m to the west of the site. As such, given its relative distance, contaminants identified within groundwater collected from site are unlikely to present a significant risk to this receptor.

In addition to the above, and with regards to groundwater abstractions, the very low permeability London Clay Formation (approximately 17 m thick) is considered to provide a suitable aquiclude between the shallow Secondary A aquifer of the Lynch Hill Gravel Member and the deeper regional aquifer within the underlying Thanet Sand Formation and Chalk. Hence, it is considered that there is no current viable migration pathway that may affect the deeper aquifer.

With regard to the above factors, risks to controlled waters (surface and the shallow Secondary A aquifer) from the site, based on the current data, are considered to be **negligible to low**. Although elevated lead was detected in the Made Ground from BH5 at 7.5mbgl, the concentration of dissolved lead in the shallow groundwater was less that the limit of detection which indicates low mobility and leaching potential of the lead at the site. Risks to the deeper Principal aquifer, within the Chalk, are similarly considered to be low, though consideration will need to be given to piled foundations and that the risks associated with potential creation of new or preferential pathways, through overlying low permeability strata, into the deep aquifer, are suitably managed.

9.5 Risks to Buildings and Structures

9.5.1 Buried Concrete

Underground concrete structures may be at risk from aggressive ground conditions from sulfate attack within the natural pyrite-bearing London Clay Formation strata. This can be mitigated through appropriate concrete design.

On this basis, a **medium** risk to buildings and structures is present at the site based on the ground conditions. This is discussed in more detail in Section 11.5.

9.6 Revised Conceptual Site Model

The semi qualitative risk assessment has been revised based on the findings of the intrusive investigation and the potential pollutant linkages identified at the site in accordance with Contaminated Land Report (CLR) 11. The risks at the site are considered to be predominately low to medium. Mitigation measures for the site are outlined in section 10. Table 15 presents the revised semi qualitative risk assessment. A diagrammatic Conceptual Site Model is presented in Figure 6.

Table 15. Revised Conceptual Site Model

Source/Medium	***Receptor***	***Potential Exposure Route***	***Risk Rating***
Explosive / asphyxiating gases and hydrocarbon vapours from within Made Ground	Internal building spaces & future occupiers	Migration of gases through the surface and via permeable soils	Low
	Off-site internal building spaces and residents		Negligible

Source/Medium	***Receptor***	***Potential Exposure Route***	***Risk Rating***
Asbestos within Made Ground (none identified in recent investigation)	Future site occupiers	Inhalation of fibres	Negligible to Low
	Construction workers		Low
	Off-site residents		Negligible to Low
Asbestos Containing Materials within existing structure	Future site occupiers	Inhalation of fibres	Low (assuming current regulations are adhered to)
	Construction workers		Low to Medium
	Off-site residents		Low
Lead within Made Ground	Construction workers	Direct ingestion of soil & dust, inhalation of particulates & vapours and dermal contact	Low
	Future site occupiers		Negligible to Low
	Off-site receptors		Negligible to Low
	Vegetation and plants	Root uptake	Negligible
	Buildings & structures	Migration & accumulation of ground gas (carbon dioxide within building spaces.	Low
		Damage to concrete from pyritic soils.	Low (assuming appropriate concrete design)
	Lynch Hill Gravel Member (Secondary A Aquifer)	Lateral and vertical migration of contaminants	Low
	Deep Chalk aquifer	Leaching and lateral and vertical migration of contaminants via pathway created by pile foundations	Negligible to Low (assuming piling risk assessment is completed where piles extend through the London Clay)
	Local surface water bodies	Lateral migration of contaminants	Negligible
Copper, zinc, phenols, TPH and ammoniacal nitrogen within groundwater (Secondary A Aquifer)	Construction workers	Inhalation of particulates & vapours and dermal contact	Low to Medium
	Future site occupiers		Low
	Off-site receptors		Low
	Lynch Hill Gravel Member (Secondary A Aquifer)	Lateral and vertical migration of contaminants	Low
	Local surface water bodies	Lateral migration of contaminants	Negligible
	Deep Chalk aquifer	Vertical migration of contaminants via pathway created by pile foundations	Low (assuming piling risk assessment is completed where piles extend through the London Clay)

Source/Medium	Receptor	Potential Exposure Route	Risk Rating
Off-site sources	Current site users	Migration of contaminants from off-site sources into underlying site	Low
	Future site users		Low
	Construction workers		Low to Medium
	Controlled waters		Low
	On site buildings and structures		Low

10. GEOENVIRONMENTAL RECOMMENDATIONS

10.1 General

The proposed development will include residential properties with no private gardens and no communal soft landscaping. As such the recommendations are based on the worst-case scenario of a '*residential land use without homegrown produce consumption'* end use.

10.2 Contaminated Land and Remediation

Based on the concentrations recorded in soil and groundwater samples and given that hardstanding will be present across the footprint of the site, it is considered that the risk to future site-users and neighbours is considered to be negligible to low while risks to construction workers is considered low to medium.

Should potential contamination be present at depth, the lower basement slab would act as a barrier between this contamination and future site users. The Made Ground and natural soils, removed as part of the basement excavation and piling operations, will require disposal or treatment at an appropriate facility.

Elevated concentrations of determinands within the shallow groundwater on site are likely associated with an off-site source(s) and, as such, the risks assigned to the site associated with controlled waters are considered to be negligible to low. Specific groundwater remediation measures are, therefore, not considered necessary. Where piled foundations are proposed that extend beneath the London Clay Formation, however, a specific piling works risk assessment is recommended to review the risk to the underlying aquifers and detail specific mitigation measures that may be required.

If materials are encountered that are not consistent with the findings of this investigation, further inspection and possible testing should be undertaken by a suitably qualified geoenvironmental engineer.

10.3 Gas Protection Measures

Based on the proposed end use of the building and results of the ground gas monitoring undertaken, specific ground gas protection measures are not required as part of the proposed development.

10.4 Asbestos

No asbestos fragments or fibres were encountered within the Made Ground samples tested during the ground investigation. However, it is recommended that a watching brief is maintained during excavations in the Made Ground as asbestos is understood to be present within the buildings on site.

Should visible pieces of asbestos (including tiles/lagging) be encountered during excavations, within soils that require off-site disposal, it is recommended that an appropriately licensed contractor, experienced in the identification of asbestos, is appointed to remove these visual fragments from the soil, in accordance with current regulations[22] and guidance[23, 24], under controlled conditions and disposed of as hazardous waste.

10.5 Material Management

As indicated in The Waste (England and Wales) Regulations (2011), the "waste hierarchy" should be used to rank waste management options according to what is best for the environment. Top priority should be given to preventing waste in the first place, for example during the pre-construction and planning stages of a new development. However, if waste is created, priority should be given to preparing it for re-use, then recycling, then recovery, and last of all disposal.

10.5.1 Re – use, Recycling and Recovery

In order to minimise the volumes of soils being disposed to landfill facilities, it is prudent to consider material management options prior to waste disposal. Screening of uncontaminated natural arisings may permit recycling/reuse of the material on site or for other sites under the WRAP protocol[25] (uncontaminated granular soils only) or the CL:AIRE protocol[26] and would lead to a reduction in disposal requirements.

10.5.2 Waste Classification

Based on the total soils analysis of the Made Ground and natural soils, the soils underlying the site are deemed as *not-hazardous* in accordance with WM3 guidance. Uncontaminated natural materials can be classified as inert for waste disposal purposes. Made Ground on site would either be acceptable to a non-hazardous or inert landfill subject to WAC testing of the material.

It is recommended that the proposed landfill site is consulted and provided with the chemical testing results and waste descriptions prior to the removal of waste to confirm that the waste meets the requirements of the landfill.

Made Ground containing soil and foreign objects such as timber, plastic, rubber, metal, paper, plasterboard, asbestos, etc., regardless of the results of chemical analysis for waste classification

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[22] Health and Safety Executive (2012) *The Control of Asbestos Regulations*.
[23] HSG247 (2006) *Asbestos: The licensed contractors' guide*
[24] HSE (2006). Work with materials containing asbestos- *Control of Asbestos Regulations 2006- Approved Code of practice and guidance*, HSE 2006.
[25] WRAP. (n.d.) *The Quality Protocol.*
[26] CL:AIRE.(2011). *The Definition of Waste: Development Industry Code of Practice.* Version 2.

purposes, will be eligible for the standard (higher) rate of landfill tax. Therefore, to maximise eligibility for lower rate of landfill tax on waste construction spoil/reworked ground, careful waste segregation and controls are necessary.

If any surplus natural soils are excavated then these soils could be offered for re-use via the CL:AIRE register of material. The material will require transporting and disposal in accordance with the Environmental Protection (Duty of Care) Regulations, 1990. CGL is able to provide guidance on the best code of practice for such activities, and submit a Materials Management Plan (MMP) if required.

10.6 Buried Services

In accordance with current UKWIR[27] guidance, the use of barrier pipes, wrapped steel pipes, wrapped ductile iron pipes or copper pipes for water supply may be required, such as Protectaline, to prevent possible permeation of residual contaminants into drinking water supplies. This should be confirmed with the local water supply company.

10.7 Watching Brief and Discovery Strategy

It is recommended that a watching brief is maintained by the Main Contractor. Where unexpected gross contamination, such as oily material, asbestos or material of an unusual colour or odour, is encountered, the following discovery strategy is recommended:

1. Work to cease in that area.
2. Notify geoenvironmental engineer, to attend site and sample material for appropriate analysis. Notify Contaminated Land Officers of the Local Authority as appropriate.
3. Geoenvironmental engineer to supervise the excavation of contaminated material, which should be placed in a bunded area and covered to prevent rainwater infiltration.
4. Soil samples should be obtained by the geoenvironmental engineer from both the excavated material, and the soils in the sides and base of the excavation to demonstrate that the full area of contamination has been excavated. In-situ testing should be undertaken on the sides and base of the excavation, as appropriate, to assess the presence of residual contamination in the soils.
5. On receipt of chemical test results, the soils may be appropriately classified for disposal, or treatment if appropriate, and dealt with accordingly.

[27] UK Water Industry Research (2010) Guidance for the selection of water supply pipes to be used in brownfield sites.

6. Detailed records of the stockpile sizes, source and location should be kept and regularly updated to allow materials to be easily tracked from excavation until leaving the site.

7. Records of excavated areas and the results of chemical testing should be incorporated within the final verification report for the site.

8. 8. To facilitate appropriate waste disposal and potential re-use of materials all excavated soils should be segregated and stockpiled depending on their soil classification.

10.8 Health and Safety

All site works should be undertaken in accordance with the guidelines prepared by the Health and Safety Executive (HSE, 1991)[28] and CIRIA Reports 132[29] and C650[30]. All work should also be carried out in accordance with the Contractor's Construction Health and Safety Plan.

During the redevelopment, precautions should be taken to minimise exposure of workers and the general public to potentially harmful substances. Attention should also be paid to restricting possible off-site nuisance such as dust and odour emissions. Such precautions should include, but not be limited to:

1. Personal hygiene, washing and changing procedures.

2. Adequate personal protective equipment, including disposable overalls, gloves and particulate filter masks/vapour respirators, where required.

3. Measures to avoid surface water ponding and positive collection and disposal of all on-site run-off.

4. Regular cleaning of all site roads, access roads and the public highway including dust suppressions methods (e.g. water spraying), if necessary.

5. All waste haulage vehicles should be covered and washed when leaving the site to minimise the release of airborne particulates. The washings should be returned to stockpiled material and not allowed to enter the public drains where drying out could release dusts.

6. Continuous dampening of arisings stockpiles and excavations given the presence of asbestos.

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[28] HSE (1991). Protection of Workers and the General Public during the development of contaminated land. Guidance Note HS(G)66, Health and Safety Executive, HMSO, 1991.

[29] CIRIA (1996). A guide for safe working on contaminated sites. Steeds JE, Shepherd E & Barry DL. CIRIA Report 132.

[30] CIRIA (2005). Environmental good practice – Site guide, 2nd Edition. CIRIA Report C650.

Excavations should be planned and inspected regularly by a competent person. No operatives should be permitted to enter un-shored or otherwise protected excavations identified as unstable by a competent person, however shallow they are.

Site staff undertaking groundworks should be advised of the potential for asbestos fragments being present and be trained in basic visual recognition of asbestos.

11. GEOTECHNICAL RECOMMENDATIONS

11.1 General

The following sections provide geotechnical recommendations for the site, based on the proposed development plans, information obtained during the intrusive investigation and the laboratory results.

11.2 Geotechnical Design Parameters

Geotechnical design parameters for the soils encountered on site are summarised in Table 16 below. These are based on the borehole records from the site, the results of the in-situ/laboratory testing and on published data for the well-studied London geology.

The parameters in Table 16 are unfactored (Serviceability Limit State) and are considered to be 'moderately conservative' design values.

Table 16. Geotechnical Design Parameters

Stratum	Design Level (mbgl) [mOD]	Bulk Unit Weight γ_b (kN/m^3)	Undrained Cohesion c_u (kPa) [c']	Friction Angle ϕ' (°)	Young's Modulus E_u (MPa) [E']
Lynch Hill Gravel Member (Granular)	(7) [+20.5]	19	-	36[d]	[70][e]
London Clay (Cohesive)	(9) [+18.5]	20	100 + 7z[a] [5][e]	21[h]	60+4.2z[a,b] [45+3.2z[a,c]]
Lambeth Group (Cohesive)	(26.5) [+1]	20	250	23[h]	200[f] [160][g]

Notes:
[a] *z = level below surface of stratum.*
[b] *Based on 600 c_u - Burland, Standing J.R., and Jardine F.M. (eds) (2001), Building response to tunnelling, case studies from construction of the Jubilee Line Extension London, CIRIA Special Publication 200.*
[c] *Based on 0.75Eu - Burland, Standing J.R., and Jardine F.M. (eds) (2001), Building response to tunnelling, case studies from construction of the Jubilee Line Extension London, CIRIA Special Publication 200.*
[d] *Peck, R.B., Hanson, W.E., and Thornburn, T.H., Foundation Engineering, 2nd Edn. John Wiley, New York, 1967.*
[e] *Burland, Standing J.R., and Jardine F.M. (eds) (2001), Building response to tunnelling, case studies from construction of the Jubilee Line Extension London, CIRIA Special Publication 200.*
[f] *Based on 800 c_u - Burland, Standing J.R., and Jardine F.M. (eds) (2001), Building response to tunnelling, case studies from construction of the Jubilee Line Extension London, CIRIA Special Publication 200.*
[g] *Based on 0.8Eu - Burland, Standing J.R., and Jardine F.M. (eds) (2001), Building response to tunnelling, case studies from construction of the Jubilee Line Extension London, CIRIA Special Publication 200.*
[h] *BS 8002:2015 Code of practice for Earth retaining structures, British Standards institution.*

The design level of the London Clay Formation has been adopted across the site at +18.5mOD, however, a greater depth to the surface of the London Clay was encountered in borehole BH5 at +14.53mOD. Upon review of the ground investigation, nearby BGS boreholes and ground investigation information held on CGL's database, the level of the surface of the London Clay was found to be typically between 17.7mOD and 19.2mOD. However, BH5 sunk in the south of the site and historic BGS borehole TQ28SE981, located approximately 100m west of the site (included in Appendix D), recorded the surface of the London Clay at 14.53mOD and 14.32mOD respectively. The variation in London Clay level and increased thickness of Lynch Hill Gravel could be representative of a buried river channel, the orientation and form of which remains not fully investigated. As such variation in the level of the London Clay formation may be encountered during construction.

Based on groundwater monitoring results outlined in Section 8.4, a design groundwater level of +22.5mOD is recommended. The design groundwater level has been adopted 1.5m above monitored level to account for seasonal fluctuation, the effect of on-going dewatering and water level rise in the event of a water pipe leak. The design level also takes into account that historically water has risen 0.3m above the lower basement slab to +21.3mOD and was monitored during the historic site investigation between +21.2mOD and +21.4mOD.

11.3 Piled Foundations

To minimise differential settlement between the new and existing building, the new structural loads are to be supported on piles. The new basement excavation in the north east corner is proposed to be supported by a secant piled wall.

Preliminary pile working load profiles for a range of pile diameters between 450mm to 750mm are presented in Figure 8 and Figure 9 based on the use of Continuous Flight Auger (CFA) or bored cast in place piles constructed on site with an adhesion value of 0.6 within the London Clay Formation, an adhesion value of 0.5 within the Lambeth Group and partial factors as recommended by Eurocode 7 (EC7)[31]. These are based on EC7 Design Approach 1 Combination 2 and should be compared against appropriately factored actions as detailed in EC0 and EC7. The pile capacities in Figure 8 assume no working tests piles undertaken on site. Figure 9 assumes working test piles will be undertaken on site.

The preliminary pile capacities outlined in Figure 8 are based on the following partial factors:

Pile Capacities with no working load tests/explicit verification of SLS on site:

- Factor of safety = Eurocode 7 partial factoring:
- q_{sf} (skin friction) of 1.6;
- q_{bs} (base capacity) of 2.0;
- MF (model factor) of 1.4;
- Skin friction on the piles has been restricted to 140kPa;
- Cut-off level at 19mOD;
- Structural capacity of piles should be verified at proposed loads.

[31] British Standards Institution. (2006) *National Annex to Eurocode 7: Geotechnical Design* BS EN 1997-1

The preliminary pile capacities outlined in Figure 9 are based on the following partial factors:

<u>Pile capacities with working load tests/explicit verification of SLS on site:</u>

- Factor of safety = Eurocode 7 partial factoring:
- q_{sf} (skin friction) of 1.4;
- q_{bs} (base capacity) of 1.7;
- MF (model factor) of 1.4;
- Skin friction on the piles has been restricted to 140kPa;
- Cut-off level at 19mOD;
- Structural capacity of piles should be verified at proposed loads.

Consideration should be given to the presence of groundwater at approximately 22.5mOD (above existing lower basement slab) during pile construction. It is recommended that due to the presence of groundwater at this depth on site, Continuous Flight Auger (CFA) method of drilling would be deemed more appropriate or alternatively casing during drilling.

Early consultation with an appropriate piling contractor is recommended to confirm pile working capacities and to ensure the piling contractor can achieve the required depths and capacities. Specialist piling contractors may potentially show greater load capacity than those shown in Figures 8 and 9 based on specific knowledge of their piling equipment, supported by testing evidence that may be acceptable to the local authority.

11.4 Excavations

It is not anticipated that excavations required during the development will encounter difficulties with conventional excavators and earthmoving equipment. Shallow excavations in the Made Ground, Lynch Hill Gravel Member and London Clay formation are likely to require support/battering also in the short term. Temporary retention of the existing basement wall, to be retained as part of the proposed development, will also likely be required during construction.

Significant groundwater was encountered in the Lynch Hill Gravel Member within all boreholes and the basement is currently subject to pumping to maintain water below lower basement slab level. Therefore, significant groundwater ingress is expected to occur during excavations within this stratum and within the upper horizons of the London Clay formation (thought to be in hydraulic continuity), which should be considered during design.

Excavations should be suitably shored or otherwise supported or battered and should be inspected regularly by a competent person. No operatives should enter un-shored or otherwise unprotected excavations identified as unstable by a competent person, however shallow they are, in accordance with the guidelines presented in CIRIA Report 97[32].

The redevelopment of the site which includes construction of the new basement; demolition and application of new structural loads; as well as control of groundwater ingress (which may involve temporary dewatering); are likely to give rise to ground movements around the site. The impact of these ground movements should be taken into consideration with respect to neighbouring properties and infrastructure.

11.5 Buried Concrete

The availability of total potential sulfate (TPS) in pyritic soils (i.e. London Clay) is dependent on the extent to which the soils are disturbed, and the level to which the soils may oxidise, resulting in sulfate ions that may reach the concrete. In this regard, BRE SD1 guidance[33] states that:

"Concrete in pyritic ground which is initially low in soluble sulfate does not have to be designed to withstand a high potential sulfate class unless it is exposed to ground which has been disturbed to the extent that contained pyrite might oxidise and the resultant sulfate ions reach the concrete. This may prompt redesign of the structure or change to the construction process to avoid ground disturbance; for example, by using precast or cast-in-situ piles instead of constructing a spread footing within an excavation".

On this basis, the appropriate DS and ACEC class for the pyritic soils, i.e. based on water soluble sulfate (WSS) or total potential sulfate (TPS), should be adopted dependant on the extent to which the soils will be disturbed during construction. The appropriate DS and ACEC classes for the site are summarised in Table 17 below, based on the currently available data.

Total sulfur and acid soluble sulfate testing was undertaken to allow an assessment to be made in relation to the potential thaumasite form of concrete attack. All oxidisable sulphide values within the Made Ground, Lynch Hill Gravel and Lambeth Group were less than 0.3%, which indicates this form of concrete attack can be discounted. However, four of the five values within the London Clay were in excess of 0.3%, and as such the thaumasite form of concrete attack cannot be discounted. A modification to DS-4 for London Clay would need to be adopted for concrete placed in excavations where the pyrite in the clay could oxidise. The modified DS value for the London Clay has been reduced from DS-5 (which the results indicate) to DS-4 on the basis that the pH and sulfate results for the groundwater indicate a DS-1 classification.

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[32] CIRIA (1992). *Trenching Practice (Second Edition).* Construction Industry Research and Information Association Report 97.
[33] Building Research Establishment. (2005). *Concrete in aggressive ground*. Special Digest 1, 3rd Ed.

Table 17. Summary of DS and ACEC Classes

Stratum	Water Soluble Sulfate (Non-pyritic Soil)		Total Potential Sulfate (Pyritic Soil)	
	DS Class	ACEC Class	DS Class	ACEC Class
Made Ground (BH5 only)	DS-1	AC-1	DS-1	AC-1
Lynch Hill Gravel Member	DS-1	AC-1	DS-1	AC-1
London Clay Formation	DS-2	AC-2	DS-4	AC-4
Lambeth Group	DS-1	AC-1	N/A	

N/A – not applicable as stratum unlikely to be oxidised during construction

At the time of writing, the lower basement level is to be reduced by 1.425m to approximately 19.725mOD. In this location, a 350mm thick flor slab is proposed with a central 750mm deep pile cap. As such the deepest level of dig is approximately 18.975mOD, which is within the Lynch Hill Gravel. It is therefore considered that the London Clay will not be oxidisable and that slabs and pile caps can be designed to AC-1 and piles to AC-2. Should the depth of the proposed basement change, this recommendation would need to be reviewed in relation to the potential for oxidisation of the London Clay.