Part 2: DESIGN BASIS REPORT

This section of the report provides an interpretation of the findings detailed in Part 1, in the form of a ground model, and then provides advice and recommendations with respect to foundation options and contamination issues.

6.0 INTRODUCTION

It is understood that it is proposed to redevelop the site through the demolition of the existing buildings at No 100 Grays Inn Road and No 127 Clerkenwell Road and subsequent construction of a new ten-storey mixed use commercial and residential timber framed building.

The existing basement will be retained and will be deepened by 0.5 m to 1.0 m to accommodate a new raft foundation, with formation level for the new raft understood be about 17.0 m OD and 16.5 m OD.

No 88 Grays Inn Road will be retained as part of the proposals and converted into residential apartments with office space.

7.0 GROUND MODEL

The desk study research indicates that the site has not had a potentially contaminative history, having had a mixed residential and retail use for its entire developed history. On the basis of the fieldwork, the ground conditions at this site can be characterised as follows:

- below a moderate to significant thickness of made ground, Lynch Hill Gravel is present over the London Clay which was found to be underlain by the Lambeth Group which extends to the maximum depth of the investigation, of 25.0 m (-6.81 m OD) below existing basement level;

- on the south-eastern part of the site, the made ground comprises light greyish brown silty sandy clay with frequent concrete, flint gravel and occasional clinker and extends to depths of between 3.6 m (17.74 m OD) and 4.2 m (17.14 m OD) below ground level;

- elsewhere, the made ground comprises light grey, dark brownish grey and reddish brown mottled black silty sandy clay with frequent clinker, brick, occasional concrete and flint gravel and extends to depths of between 1.2 m (17.07 m OD) and 1.5 m (16.71 m OD) below existing basement level;

- the underlying Lynch Hill Gravel comprises medium dense to very dense light yellowish-brown very sandy gravel or gravelly sand, and extends to a depth of 6.5 m (14.84 m OD) below ground level on the south-eastern part of the site and to depths of between 3.3 m (13.71 m OD) and 4.5 m (14.89 m OD), below existing basement level;

- in one location, within the southern part of the existing basement, an initial horizon of firm light brown silty sandy clay with rare fine to medium flint gravel is present to 1.5 m (16.78 m OD);

- the London Clay comprises an upper weathered horizon of firm brown silty clay, which was encountered to the base of the window sampler boreholes, at depths of 4.9 m (13.31 m OD), 4.5 m (13.78 m OD) and 4.3 m (13.97 m OD), but was proved in the two cable percussion boreholes to depths of 4.3 m (13.89 m OD) below existing basement level and 7.0 m (14.34 m OD) below existing ground level,. respectively;

- below this, the London Clay comprises stiff fissured high strength to very high strength grey silty clay with occasional to frequent mica, carbonaceous material, rare foraminifera and occasional silt pockets and fine to medium sand lenses, which was proved to depths of 19.1 m (-0.91 m OD) below existing basement level and 22 m (-0.66 m OD) below existing ground level,. respectively;

- the underlying Lambeth Group comprises very stiff high strength becoming very high strength multi-coloured silty clay and extends to the full depth of the investigation, of 25.0 m (-6.81 m OD) below existing basement level;

- high shrinkability clays should be assumed;

- groundwater is present within the Lynch Hill Gravel at a depth of 3.8 m (14.39 m OD) below basement level and 5.49 m (15.85 m OD) below ground level;

- the contamination testing has measured an elevated concentration of lead within a single sample of the made ground tested retrieved from Borehole No 1; and

- asbestos was not detected within any of the soil samples tested.

7.1 Recommended Parameters

The table below summarises the vertical soil parameters to be used in any subsequent analysis and is based on the findings of the investigation. Values of stiffness for the soils at this site are readily available from published data[11, 12, 13 & 14] and a well-established method has been used to provide the estimated values.

Stratum	Base of Stratum (m OD.l)	Bulk Unit Weight (kN/m³)	Effective Friction Angle (φ' °)	Undrained Cohesion (C_u - kN/m²)	Drained Young's Modulus* (E' - kN/m²)	Undrained Young's Modulus* (E_u - kN/m²)
Made Ground	17.0 (varies)	17	27	25	7,500	12,500
Lynch Hill Gravel	14.5	20	30	-	60,000	60,000
London Clay	-1.0	19.0	23	50 to 250	15,000 to 75,000	25,000 to 125,000
Lambeth Group	-7.0⁺	19.5	24	320 + 8.0	96,000 + 4000	160,000 + 2400

⁺Maximum depth of investigation. *Values based on the conservative relationship of $E_u = 500\ C_u$ and $E' = 300\ C_u$ from Padfield and Sharrock [8]. **An increase in cohesion of 8 kN/m² per metre increase in depth has been adopted to provide a conservative estimate of the likely increase in strength profile with the Lambeth Group below the depth of the investigation.

11 Padfield CJ and Sharrock MJ (1983) *Settlement of structures on clay soils*. CIRIA Special Publication 27
12 Butler FG (1974) *Heavily overconsolidated clays: a state of the art review.* Proc Conf Settlement of Structures, Cambridge, 531-578, Pentech Press, Lond
13 O'Brien AS and Sharp P (2001) *Settlement and heave of overconsolidated clays - a simplified non-linear method.* Part Two, Ground Engineering, Nov 2001, 48-53
14 Burland JB, Standing, JR, and Jardine, FM (2001) *Building response to tunnelling, case studies from construction of the Jubilee Line Extension.* CIRIA Special Publication 200

8.0 ADVICE AND RECOMMENDATIONS

Excavations for the proposed basement structure will require temporary support to maintain stability and to prevent any excessive ground movements. On the basis of the fieldwork and subsequent monitoring, groundwater protection measures are unlikely to be required during the basement excavation, although provision should be made to control possible perched water inflows from the made ground and Lynch Hill Gravel. Formation level for the proposed basement raft is likely to be close to the boundary between the made ground and the underlying Lynch Hill Gravel; deepening may be required in some areas to bypass any remaining made ground.

It is understood that it is proposed to adopt a raft foundation beneath the footprint of the new basement structure, whilst piled foundations, extending to the underlying London Clay are preferred for the proposed ground floor extension on the south-eastern part of the site.

End users will need to be protected from potentially contaminated soils in areas of soft landscaping and construction workers and future sites workers will also need protection.

8.1 Basement Excavation

8.1.1 Basement Construction

It is understood that the existing basement will be deepened by between 0.5 m and 1.0 m, to a level of between 17.0 m OD and 16.5 m OD, such that formation level is likely to be close to the boundary between the made ground and the underlying Lynch Hill Gravel; deepening may therefore be required in some areas, particularly where shallower excavations are proposed, to ensure the made ground is bypassed and all new foundations bear within the underlying gravel.

Based on the groundwater observations to date, groundwater is unlikely to be encountered within the excavation, although it would be prudent to continue monitoring of the standpipes to check seasonal fluctuations. Localised inflows may also be encountered from perched water tables within the made ground, particularly in the vicinity of existing foundation, but should be adequately controlled by sump pumping.

The design of basement support in the temporary and permanent conditions needs to take account of the requirement to maintain the stability of the excavation and surrounding structures and to protect against potential groundwater inflows. There are a number of methods by which the sides of the basement excavations could be supported, with the choice of wall will be governed, to a large extent, by whether it is to be incorporated into the permanent works and have a load bearing function and also by the limited available access. The final choice will depend on a number of factors, including the need to protect nearby structures from movements, the required overall stiffness of the support system and the potential need to control groundwater movement through the wall in the temporary condition. In this respect the stability of the adjacent buildings will be paramount.

As the excavations are expected to remain dry, the simplest method of lowering the existing basement will be to form the retaining walls by means of concrete underpinning using a traditional hit and miss approach. This is understood to be the preferred method of construction and will have the benefit of minimising the plant required and maximising usable space in the new basement.

Whilst the proposed construction will not result in a significant increase in foundation depth relative to the neighbouring properties, careful workmanship will still be required to ensure that movement of the surrounding structures does not arise. The contractor should also be required to provide details of how they intend to control groundwater and instability of excavations, should it arise.

The ground movements associated with the basement excavation will depend on the method of excavation and support and the overall stiffness of the basement structure in the temporary condition. Thus, a suitable amount of propping will be required to provide the necessary rigidity. In this respect the timing of the provision of support to the wall will have an important effect on movements. The stability of the adjacent foundations will need to be ensured at all times and the existing foundations will need to be underpinned prior to construction of the proposed new basements or will need to be supported by new retaining walls.

An assessment of the potential movements as a result of the proposed basement construction has been carried out as part of the Ground Movement Analysis, which is reported in Part 3.

8.1.2 Retaining Walls

The following parameters are suggested for the design of the permanent basement retaining walls.

Stratum	Bulk Density (kg/m³)	Effective Cohesion (c' – kN/m²)	Effective Friction Angle (Φ' – degrees)
Made Ground	1750	Zero	27
Lynch Hill Gravel	1850	Zero	34
London Clay	2000	Zero	23

Significant inflows of groundwater are unlikely to be encountered within the basement excavation, although monitoring of the standpipes should be continued to confirm this.

Consideration should, however, be given to the risk of surface water building up behind the retaining walls and unless adequate drainage can be incorporated to prevent such build-up, it is recommended that the basement is designed with a water level assumed to be 1.0 m below ground level.

Reference should be made to BS8102:2009[15] regarding requirements for waterproofing.

8.1.3 Basement Heave

Lowering of the existing basement by 0.5 m to 1.0 m will result in a net unloading of about 10 kN/m² to 20 kN/m², which will theoretically result in heave of the underlying clay. This will comprise immediate elastic movement, which will account for approximately 40 % of the total movement and be expected to be complete during the construction period, and long-term movements, which will theoretically take many years to complete, although these movements will to a certain extent be counteracted by the applied loads from the proposed development and the thickness of the overlying superficial deposits.

Further consideration is given to heave movements in Part 3.0 of this report.

15 BS8102 (2009) *Code of practice for protection of below ground structures against water from the ground*

8.2 Raft Foundation

It is understood that it is proposed to utilise a basement raft foundation, which provided that the loads can be relatively uniformly distributed, should provide a suitable solution. The suitability of a raft foundation will be governed by the net loading intensity, taking into consideration the weight of soil removed by the excavation. An analysis of the likely movements is included in Part 3 of this report.

Alternately, spread foundations, including underpinned foundations, could be adopted to bear on the very dense Kempton Park Gravel and may be designed to apply a net allowable bearing pressure of around 200 kN/m^2 at proposed basement level. This value incorporates an adequate factor of safety against bearing capacity failure and should ensure that settlement remains within normal tolerable limits and has been limited to ensure that the underlying London Clay is not overstressed.

8.3 Piled Foundations

For the ground conditions at this site, bored piles could be adopted. A conventional rotary augered pile could be utilised but consideration will need to be given to the possible instability and water ingress within the made ground and the Lynch Hill Gravel. The use of bored piles installed using continuous flight auger (cfa) techniques may therefore be the most appropriate and the limited site access may be a factor in the selection of most appropriate pile type. Consideration will also need to be given to minimising the noise and disruption to the existing structures and occupants during pile installation.

The following table of ultimate coefficients may be used for the preliminary design of bored piles, based on the SPT and cohesion / depth graph given in the appendix.

Stratum	Depth (m below ground level) [Level (m OD)]	kN / m^2
Ultimate Skin Friction		
Basement excavation / Made Ground	GL to 4.0 (varies) [17.0]	Ignore
Lynch Hill Gravel	4.0 to 6.5 [17.00 to 14.5]	40
London Clay	6.5 to 22.0 [14.5 to -1.0]	Increasing linearly from 25 to 125
Lambeth Group	22.0 to 25.0 [-1.0 m OD to -7.0]	110 (limit)
Ultimate End Bearing		
London Clay	15.0 to 22.0 [6.0 to -1.0]	Increasing linearly from 1440 to 2250
Lambeth Group	22.0 to 25.0 [-1.0 m OD to -7.0]	Increasing linearly from 2880 to 3600

In the absence of pile tests, guidance from the London District Surveyors Association (LDSA)[16] suggests that a factor of safety of 2.6 should be applied to the above coefficients in the computation of safe theoretical working loads and the average value of ultimate shaft

16 LDSA (2009) *Foundations No 1 – Guidance notes for the design of straight shafted bored piles in London Clay*. LDSA

friction should be limited to 110 kN/m^2. For the purpose of this design, groundwater level has been assumed to be just below the depth of the standpipes at a depth of 5.0 m (16.0 m OD).

On the basis of the above coefficients, the following pile capacities have been estimated.

Pile diameter mm	Depth (below ground level) [Level (m OD)]	Working Pile Length m	Safe Working Load kN
450	20 [1.0]	16	695
600			980

The above examples are not intended to constitute any form of recommendation with respect to pile size or type but merely to serve to illustrate the use of the above coefficients. Specialist piling contractors should be consulted with regard to the design of a suitable piling scheme and their attention should be drawn to potential groundwater inflows and instability within the made ground and Lynch Hill Gravel.

8.4 Basement Floor Slab

In the event that a raft foundation solution is not adopted, it should be possible to adopt a ground bearing slab, on the underlying Lynch Hill Gravel. However, it would be prudent to proof roll the stratum, with any soft spots revealed being removed and replaced with suitably compacted granular fill.

8.5 Shallow Excavations

On the basis of the borehole and trial pit findings it is considered that it will be generally feasible to form relatively shallow excavations terminating within the made ground or Lynch Hill Gravel without the requirement for lateral support, although localised instabilities may occur where more granular material or groundwater is encountered.

Significant inflows of groundwater into shallow excavations are not generally anticipated, although seepages may be encountered from perched water tables within the made ground, although such inflows should be suitably controlled by sump pumping.

If deeper excavations are considered or if excavations are to remain open for prolonged periods it is recommended that provision be made for battered side slopes or lateral support. Where personnel are required to enter excavations, a risk assessment should be carried out and temporary lateral support or battering of the excavation sides considered in order to comply with normal safety requirements.

8.6 Effect of Sulphates

Chemical analyses carried out on selected samples for water soluble sulphate have been compared with of Table C2 of BRE Special Digest 1: SD1 Third Edition (2005) in order to determine the sulphate class and are summarised in the table overleaf. The assessment has been based on static groundwater conditions and the guidelines contained in the above digest should be followed in the design of foundation concrete.

Stratum	No of samples	pH	SO_4 (mg/l)	Design Sulphate Class	ACEC Class
Made Ground	5	8.0 to 9.8	180 to 1800	DS-2	AC-1s
London Clay	3	8.0 to 8.6	10 to 290	DS-1	AC-1s

8.7 Site Specific Risk Assessment

The desk study has indicated that the site has not had a contaminative history, having had a mixed residential and commercial use throughout its developed history, in an area namely occupied by residential properties and small-scale businesses. However, the results of the contamination testing have identified an elevated concentration of lead within a single sample of made ground tested retrieved from Borehole No 1 within No 127 Clerkenwell Road.

The exact source of the contamination is unknown. However, the made ground was noted as containing variable amounts of extraneous material, including ash, and it is therefore likely that a fragment of such material was present within the samples tested, accounting for the elevated concentration. Information on Urban Soil Chemistry provided by the BGS also indicates that background concentrations for lead in the vicinity of the site are between 300 g/kg and 600 mg/kg, such that a significant proportion of the measured concentrations could be the result of residual airborne sources.

Lead compounds are relatively immobile and unlikely to be in a soluble form and are considered to be non-volatile or of a low volatility. The contamination does not therefore present a significant vapour risk or a significant risk of leaching and migration within any perched groundwater within the made ground. As the site is underlain by the London Clay, classified as Unproductive Strata, a risk to groundwater has not been identified.

In any case, it is anticipated that the majority of the made ground will be removed as part of the proposed development and end users will be isolated from direct contact with any contaminants remaining soils by the presence of the new building and areas of external hardstanding.

Remedial measures to protect sensitive receptors, including end users, are not therefore deemed necessary. However, in accordance with standard construction practice, a safe programme of working should be identified to protect workers handling any soil.

8.7.1 Protection of Site Workers

Site workers should be made aware of the potential contamination and a programme of working should be identified to protect workers handling any soil. The method of site working should be in accordance with guidelines set out by HSE[17] and CIRIA[18] and the requirements of the Local Authority Environmental Health Officer.

A watching brief should be maintained during the site works and if any suspicious soil is encountered, it should be inspected by a suitably qualified engineer and further testing carried out if required.

17 HSE (1992) HS(G)66 *Protection of workers and the general public during the development of contaminated land* HMSO

18 CIRIA (1996) *A guide for safe working on contaminated sites* Report 132, Construction Industry Research and Information Association

8.8 Waste Disposal

Under the European Waste Directive, waste is classified as being either Hazardous or Non-Hazardous and landfills receiving waste are classified as accepting hazardous or non-hazardous wastes or the non-hazardous sub-category of inert waste in accordance with the Waste Directive. Waste classification is a staged process and this investigation represents the preliminary sampling exercise of that process. Once the extent and location of the waste that is to be removed has been defined, further sampling and testing may be necessary. The results from this ground investigation should be used to help define the sampling plan for such further testing, which could include WAC leaching tests where the totals analysis indicates the soil to be a hazardous waste or inert waste from a contaminated site. It should however be noted that the Environment Agency guidance WM3[19] states that landfill WAC analysis, specifically leaching test results, must not be used for waste classification purposes.

Any spoil arising from excavations or landscaping works, which is not to be re-used in accordance with the CL:AIRE[20] guidance, will need to be disposed of to a licensed tip. Waste going to landfill is subject to landfill tax at either the standard rate of £98.60 per tonne (about £185 per m^3) or at the lower rate of £3.15 per tonne (roughly £5.85 per m^3). However, the classifications for tax purposes and disposal purposes differ and currently all made ground and topsoil is taxable at the 'standard' rate and only naturally occurring soil and stones, which are accurately described as such in terms of the 2011 Order, would qualify for the 'lower rate' of landfill tax.

Based upon on the technical guidance provided by the Environment Agency it is considered likely that the soils encountered during this ground investigation, as represented by the three chemical analyses carried out, would be generally classified as follows;

Soil Type	Waste Classification (Waste Code)	WAC Testing Required Prior to Landfill Disposal?	Current applicable rate of Landfill Tax
Made ground	Non-hazardous (17 05 04)	No	£96.60/tonne (Standard rate)
Natural soils	Inert (17 05 04)	Should not be required but confirm with receiving landfill	£3.15 / tonne (Reduced rate for uncontaminated naturally occurring rocks and soils)

Under the requirements of the European Waste Directive all waste needs to be pre-treated prior to disposal. The pre-treatment process must be physical, thermal, chemical or biological, including sorting. It must change the characteristics of the waste in order to reduce its volume, hazardous nature, facilitate handling or enhance recovery. The waste producer can carry out the treatment but they will need to provide documentation to prove that this has been carried out. Alternatively, the treatment can be carried out by an approved contractor. The Environment Agency has issued a position paper[21] which states that in certain circumstances, segregation at source may be considered as pre-treatment and thus excavated material may not have to be treated prior to landfilling if the soils can be segregated onsite prior to excavation by sufficiently characterising the soils in situ prior to excavation.

The above opinion with regard to the classification of the excavated soils is provided for guidance only and should be confirmed by the receiving landfill once the soils to be discarded have been identified.

19 Environment Agency 2015. *Guidance on the classification and assessment of waste.* Technical Guidance WM3 First Edition
20 CL:AIRE March 2011. *The Definition of Waste: Development Industry Code of Practice* Version 2
21 Environment Agency 23 Oct 2007 *Regulatory Position Statement Treating non-hazardous waste for landfill - Enforcing the new requirement*

The local waste regulation department of the Environment Agency (EA) should be contacted to obtain details of tips that are licensed to accept the soil represented by the test results. The tips will be able to provide costs for disposing of this material but may require further testing.