DESK STUDY & BASEMENT IMPACT ASSESSMENT REPORT

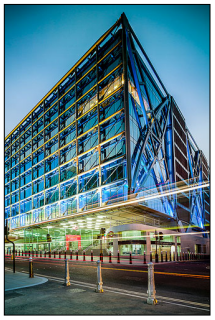
The Honourable Society of Gray's Inn
8 South Square
London
WC1R 5ET

Client: The Honourable Society of Gray's Inn

J20048

March 2020



GEA

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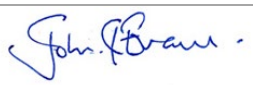
With input from				
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	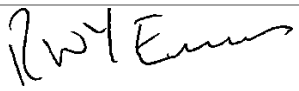			
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This report is intended as a Ground Investigation Report (GIR) as defined in BS EN1997-2, unless specifically noted otherwise. The report is not a Geotechnical Design Report (GDR) as defined in EN1997-2 and recommendations made within this report are for guidance only.

CONTENTS

Part 3: GROUND MOVEMENT ASSESSMENT

Part 4: BASEMENT IMPACT ASSESSMENT

EXECUTIVE SUMMARY

This executive summary contains an overview of the key findings and conclusions. No reliance should be placed on any part of the executive summary until the whole of the report has been read. Other sections of the report may contain information that puts into context the findings that are summarised in the executive summary.

BRIEF

This report describes the findings of a site investigation carried out by Geotechnical and Environmental Associates Limited (GEA) on the instructions of Gilmore Hankey Kirke (GHK) Ltd, on behalf of the Honourable Society of Gray's Inn, with respect to the construction of a small chiller plant room within the footprint of some existing basement vaults, which will involve the lowering of the existing floor level by 1.0 m to 1.5 m, to a formation level of approximately 16.5 m OD. The purpose of the investigation has been to research the history of the site with respect to possible contaminative uses, to determine the ground conditions and hydrogeology, to carry out an assessment of ground movements resulting from the excavation of the proposed basement and to provide information to assist with the design of the basement structure and suitable foundations. The report also includes information required to comply with London Borough of Camden (LBC) Planning Guidance, relating to the requirement for a Basement Impact Assessment (BIA).

An investigation and impact assessment has previously been carried out by GEA on the southern part of the site (J15193, dated November 2016) and information from this report, along with archive information of other nearby sites and the British Geological Survey (BGS), have been used to form the basis of this assessment.

PREVIOUS DESK STUDY FINDINGS

The desk study findings indicate that the site does not have a potentially contaminative history as it has apparently been developed with the existing building since the mid-1800s.

There is, therefore, assessed to be a VERY LOW RISK of contamination at this site.

GROUND CONDITIONS

The previous investigation confirmed the expected ground conditions in that, below a variable, but generally significant thickness of made ground, Hackney Gravel was encountered over the London Clay Formation.

Any made ground is likely to comprise brown gravelly sand, very sandy clayey silt and silty sandy gravelly clay, with variable amounts of extraneous material, and is expected to be encountered to existing lower ground floor level, or approximately 17.5 m OD. Below this, medium dense becoming dense sand and gravel of the Hackney Gravel is expected to be present to a depth of at least 6.5 m (approx. 13.0 m OD), where it is then underlain by stiff becoming very stiff silty clay of the London Clay Formation.

Groundwater is present within the Hackney Gravel at a level of between 14.5 m OD and 15.0 m OD.

RECOMMENDATIONS

Formation level for the proposed plant room is likely to be within the Hackney Gravel at a level of approximately 16.5 m OD, which should provide an eminently suitable bearing stratum for spread foundations. Excavations for the proposed basement structure will require temporary support to maintain stability and to prevent any excessive ground movements. Significant groundwater inflows are not anticipated.

End users will be effectively isolated from direct contact with the identified contaminants by the building and areas of external hardstanding. However, in accordance with standard construction practice, a safe programme of working should be identified to protect workers handling any soil as a precautionary measure.

BASEMENT IMPACT ASSESSMENT

The BIA has not indicated any concerns with regard to the effects of the proposed basement on the site and surrounding area. It has been concluded that the impacts identified can be mitigated by appropriate design and standard construction practice.

Part 1: INVESTIGATION REPORT

This section of the report details the objectives of the report and presents the information and data obtained from the desk study research and previous investigations. Interpretation of the findings is presented in Part 2 and an assessment of the ground movements associated with the basement excavation are included in Part 3.

1.0 INTRODUCTION

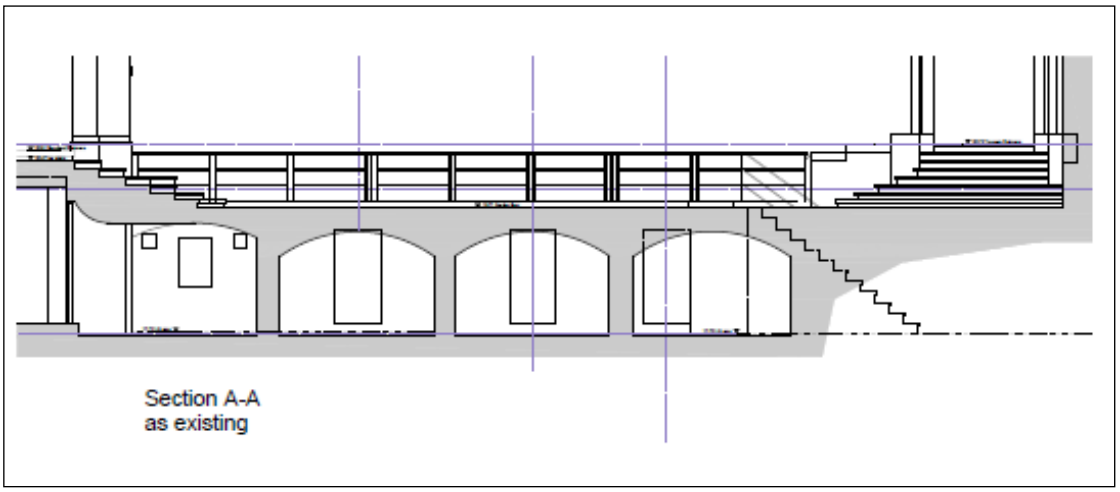
Geotechnical and Environmental Associates Limited (GEA) has been commissioned by Gilmore Hankey Kirke (GHK) Ltd, on behalf of the Honourable Society of Gray's Inn, to carry out a Basement Impact Assessment (BIA) and ground movement assessment at Gray's Inn, 8 South Square, London, WC1R 5ET.

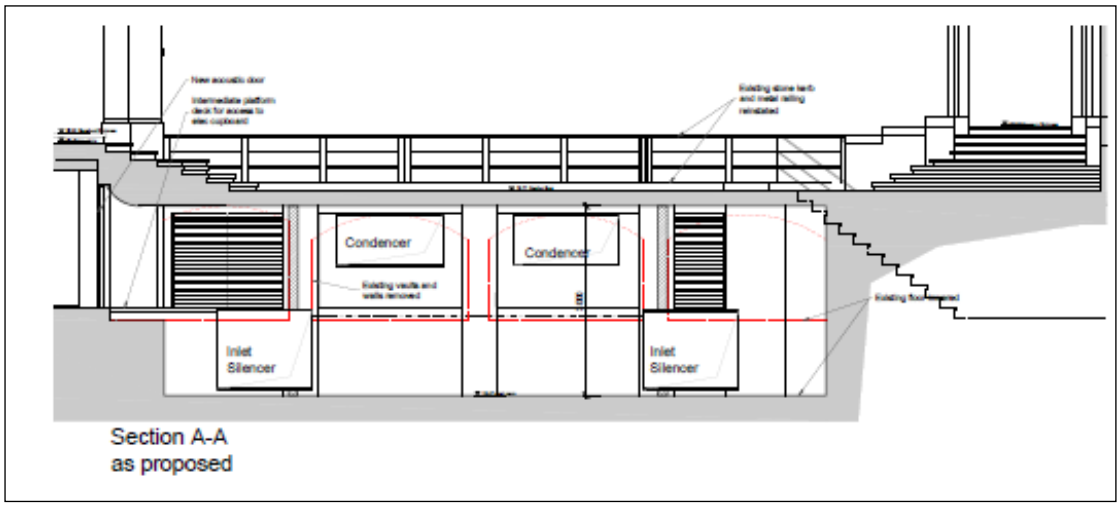
A site investigation and BIA (report ref J15193, dated November 2016) has previously been completed by GEA for the development of Nos 19-20 High Holborn, immediately to the south of the new development area. The findings of this report are referred to where appropriate and have been supplemented with published data and our own experience of the local ground conditions, to assist in the derivation of parameters for use in this assessment.

The BIA has been carried out in accordance with guidelines from the London Borough of Camden (LBC) in support of a planning application.

1.1 Proposed Development

It is understood that it is proposed to replace a series of basement vaults that extend beyond the frontage of the existing building with a new chiller plant room, which will extend to a depth of between 1.0 m to 1.5 m below existing basement level, as shown on the drawing extracts included below





This report is specific to the proposed development and the advice herein should be reviewed if the proposals are amended.

1.2 Purpose of Work

The principal technical objectives of the work carried out were as follows:

- to check the history of the site with respect to previous contaminative uses;
- to provide information on the level of Unexploded Ordnance (UXO) risk;
- to determine the ground conditions and their engineering properties;
- to provide advice and information with respect to the design of suitable foundations and retaining walls; and
- to assess the impact of the proposed basement on the local hydrogeology, hydrology and stability of the surrounding natural and built environment.

1.3 Scope of Work

In order to meet the above objectives, a desk study and Basement Impact Assessment has been carried out, comprising, in summary, the following activities:

- a review of readily available geological & hydrogeological maps;
- a review of GEA's archives of nearby sites and publicly available borehole data sourced from the British Geological Society (BGS);
- a preliminary UXO assessment undertaken by 1st Line Defence;
- a review of the previous GEA report completed for the southern part of the Gray's Inn site;
- a ground movement and building damage assessment; and
- provision of a report presenting and interpreting the above data, together with our advice and recommendations with respect to the proposed development.

The report includes a contaminated land assessment which has been undertaken in accordance with the methodology presented in Contaminated Land Report (CLR) 11[1] and involves identifying, making decisions on, and taking appropriate action to deal with, land contamination in a way that is consistent with government policies and legislation within the United Kingdom.

The exploratory methods adopted in this investigation have been selected on the basis of the constraints of the site including but not limited to access and space limitations, together with any budgetary or timing constraints. Where it has not been possible to reasonably use an EC7 compliant investigation technique a practical alternative has been adopted to obtain indicative soil parameters and any interpretation is based upon engineering experience, local precedent where applicable and relevant published information.

1.3.1 Basement Impact Assessment

The work carried out includes a Hydrological and Hydrogeological Assessment and Land Stability Assessment (also referred to as Slope Stability Assessment). These assessments form part of the BIA procedure specified in the London Borough of Camden (LBC) Planning Guidance CPG[2] and their Guidance for Subterranean Development[3] prepared by Arup (the "Arup report") in accordance with Policy A5 of the Camden Local Plan 2017. The aim of the work is to provide information on surface water, groundwater and land stability and in particular to assess whether the development will affect neighbouring properties or groundwater movements and whether any identified impacts can be appropriately mitigated by the design of the development.

1.3.2 Qualifications

The land stability element of the Basement Impact Assessment (BIA) has been carried out by Martin Cooper, a BEng in Civil Engineering, a chartered engineer (CEng), member of the Institution of Civil Engineers (MICE), and Fellow of the Geological Society (FGS) who has over 20 years' specialist experience in ground engineering. The subterranean (groundwater) flow assessment has been carried out by John Evans, MSc in Hydrogeology, Chartered Geologist (CGeol) and Fellow of the Geological Society of London (FGS). The surface water and flooding assessment has been carried out by Rupert Evans, a hydrologist with more than ten years consultancy experience in flood risk assessment, surface water drainage schemes and hydrology / hydraulic modelling. Rupert Evans is a Chartered Environmentalist, Chartered Water and Environmental Manager and a Member of CIWEM.

The assessments have been made in conjunction with Steve Branch, a BSc in Engineering Geology and Geotechnics, MSc in Geotechnical Engineering, a Chartered Geologist (CGeol) and Fellow of the Geological Society (FGS) with some 30 years' experience in geotechnical engineering and engineering geology.

All assessors meet the qualification requirements of the Council guidance.

1 *Model Procedures for the Management of Land Contamination* issued jointly by the Environment Agency and the Department for Environment, Food and Rural Affairs (DEFRA) Sept 2004
2 London Borough of Camden Planning Guidance CPG (March 2018) *Basements*
3 Ove Arup & Partners (2010) *Camden geological, hydrogeological and hydrological study. Guidance for Subterranean Development.* For London Borough of Camden November 2010

1.4 Limitations

The conclusions and recommendations made in this report are limited to those that can be made on the basis of the investigation. The results of the work should be viewed in the context of the range of data sources consulted, the number of locations where the ground was sampled and the number of soil, gas or groundwater samples tested; no liability can be accepted for information in other data sources or conditions not revealed by the sampling or testing. Any comments made on the basis of information obtained from the client or other third parties are given in good faith on the assumption that the information is accurate; no independent validation of such information has been made by GEA.

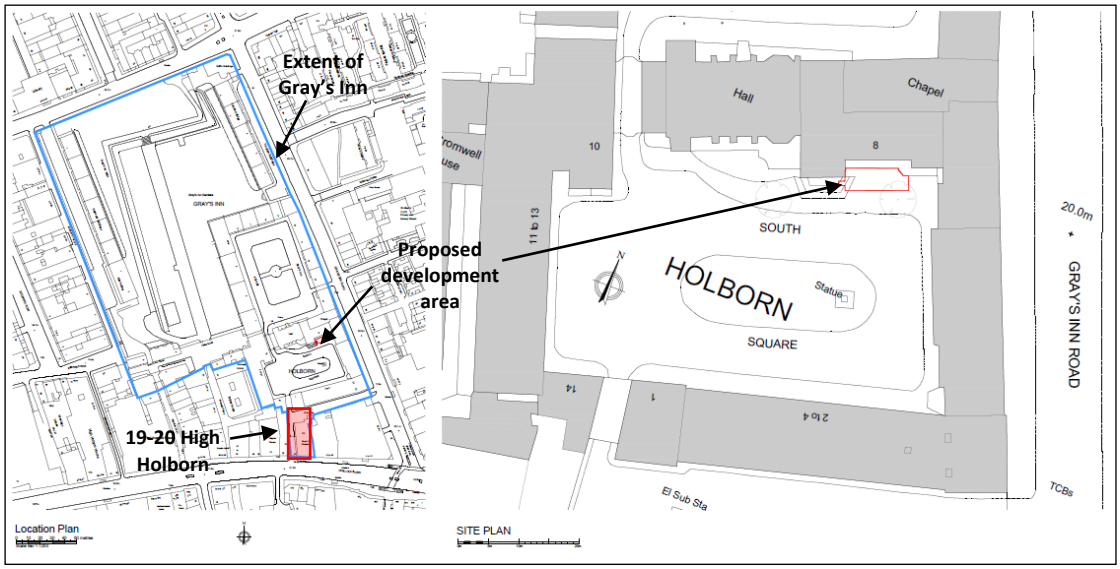
2.0 THE SITE

2.1 Site Description

The site is located approximately 125 m northwest of Chancery Lane London Underground station and approximately 500 m to the east of Holborn London Underground station and Farringdon Station respectively.

The site is situated within the southern part of the grounds of The Honourable Society of Gray's Inn on the north side of South Square. It comprises a series of existing basement vaults that extend beneath the pavement on the northern part of South Square and is bounded on its remaining sides by the existing two-storey to three-storey brick building of No 8 South Square, which includes an existing lower ground floor / basement level.

The site may additionally be located by National Grid Reference 531064, 181724 and is shown on the map extracts below.



The site is roughly rectangular in shape and measures approximately 10 m east-west by 4 m north-south and is entirely covered by existing paving, as shown on the Street View extract overleaf. The site is essentially level, with a ground level of approximately 19.5 m OD.

The existing vaults beneath the pavement, extend to a depth of approximately 2.0 m (approx. 17.5 m OD) and are accessed from existing lower ground floor level via an external lightwell.

The site itself is devoid of vegetation. However, a mature deciduous tree of approximately 5 m in height is present immediately adjacent to the south-eastern corner of the site, as shown on the street map extract below.

The Central Line of London Underground runs directly under High Holborn, approximately 80 m to the south of the site.

2.1.1 Adjoining Structures

The adjoining structure of No 8 South Square, as well as the nearby building of No 5-7 South Square to the southeast, are all known to have existing lower ground floor / basement levels, extending to a depth of approximately 2.0 m below existing ground level.

2.2 Site History

The history of the site and surrounding area has been researched by reference to archive historical maps and Ordnance Survey (OS) maps sourced from the Envirocheck database as part of the aforementioned previous desk study.

The earliest map studied, dated 1851, shows South Square and the majority of the existing buildings of Gray's Inn in their existing configuration, with High Holborn 80 m to the south and Gray's Inn Lane approximately 20 m to the west. By the next map, dated 1975, the majority of the buildings around South Square are clearly labelled as 'Chambers', with the existing Chapel and Hall immediately to the north and west respectively.

The site and immediate surrounding area then remined essentially unaltered until sometime between 1940 and the aerial photograph dated 1948, when the site and surrounding buildings suffered extensive bomb damage due to a nearby bomb strike, which completely destroyed No 5-7 South Square, as well as the former chambers on the southeast corner of the square. It is understood that following this, the damaged buildings of No 8 South Square and the adjoining Hall were quickly repaired, as can be seen by the map dated 1952, whilst the adjoining Chapel and nearby buildings to the south and southeast remained in ruins until 1957, when the Square had been fully restored.

The site and surrounding area have since remained essentially unchanged.

2.3 Other Information

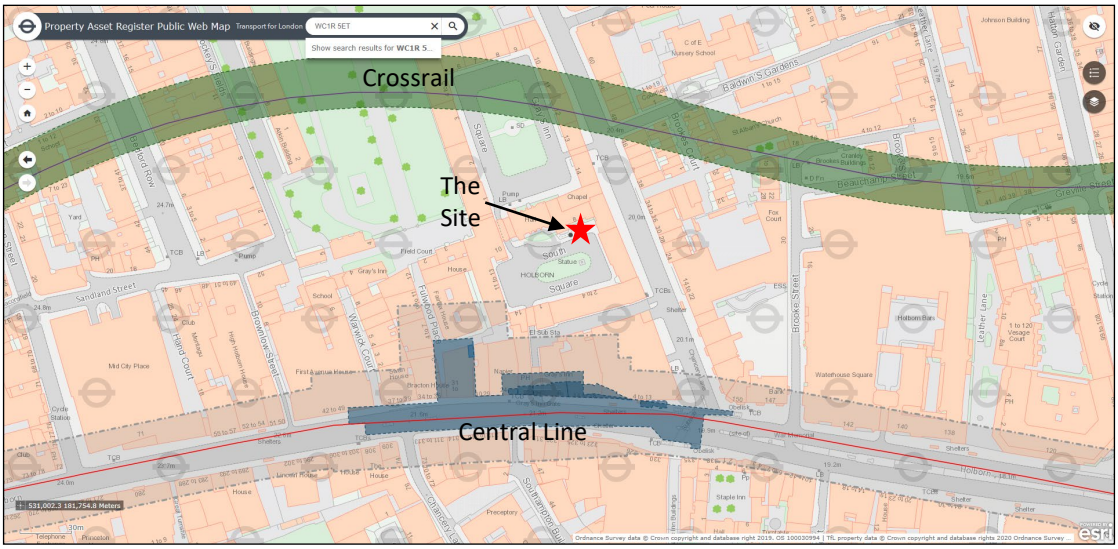
The previous desk study revealed that there are no historic or active landfills, waste management, transfer, treatment or disposal sites within 250 m of the site. There have been no pollution incidents to controlled waters within 500 m of the site, or any records of pollution controls, discharge consents or potentially contaminative substances that present a concern.

The search has indicated that the site is located in an area where less than 1% of homes are affected by radon emissions, which is the lowest classification given by the Health Protection Agency (HPA), and therefore no radon protective measures will be necessary.

The site is not located within a nitrate vulnerable zone or any other sensitive land use.

There are no fuel station entries listed within 500 m of the site and contemporary trade directory entries for potentially contaminative activities that could have had an adverse impact on the site

The Central Line of the London Underground runs beneath High Holborn, approximately 80 m to the south of the site, with Crossrail approximately 60 m to the north, as shown on the map extract below.

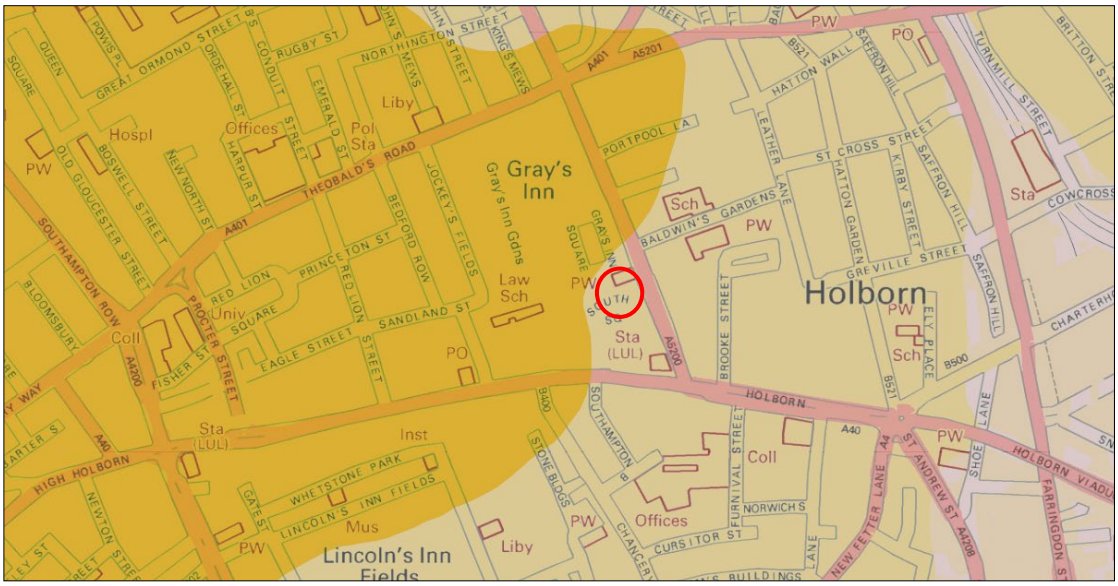


As can be seen from the map, the site lies outside the zone of influence of both of these potentially sensitive assets, such that there should not be any potential impact. However, it would be prudent to confirm this formally by notifying Crossrail and London Underground of the proposed development prior to undertaking any site works.

The previous investigation at No 19-20 High Holborn revealed that there are potentially a number of former post office tunnels, now belonging to British Telecom, in the vicinity of the High Holborn. Whilst the exact location of these assets is confidential, they are understood to be located at significant depth below the LU assets and given the limited scale and depth of the proposed development and distance from High Holborn, they are unlikely to be affected. However, as the precise details of the tunnels are not known, it would be prudent to confirm this with BT Openreach before the design proposals are finalised.

2.4 Geology

The British Geological Survey (BGS) map of the area (Sheet 256) indicates the site to be directly underlain by the Hackney Gravel over the London Clay, although the map also shows that the site is close to the boundary with the Lynch Hill Gravel, as shown on the map extract below.



According to the BGS memoir the Lynch Hill and Hackney Gravels predominantly comprise sand and gravel, with localised lenses of clay and silt and are characteristically free-draining. The London Clay Formation is homogenous, slightly calcareous silty clay to very silty clay, with some beds of clayey silt grading to silty fine-grained sand.

GEA has previously carried out a ground investigation approximately 50 m to the southeast of the site on Gray's Inn Road, which, beneath the existing basement, or a moderate thickness of made ground, encountered Hackney Gravel, which was in turn underlain by the London Clay and finally the Lambeth Group, which was proved to the full depth of the investigation, of 25.70 m (-11.20 m OD).

The Hackney Gravel comprised an initial horizon of medium dense brown very clayey very gravelly fine and medium sand to a level of 3.75 m (15.05 m OD), over medium dense and dense brown slightly clayey very sandy gravel, locally very gravelly sand to depths of between 7.70 m (11.10 m OD) and 3.20 m (11.30 m OD).

The London Clay comprised an initial weathered horizon of firm medium strength brown clay with occasional mica to depths of between 10.00 m (8.80 m OD) and 3.60 m (10.90 m OD). The underlying unweathered London Clay comprised very thickly interbedded very stiff very high strength dark grey slightly sandy clay with pale brown sand lenses and foraminifera, and very stiff very high strength fissured dark grey clay, to levels of between 17.20 m (-2.70 m OD) and 23.90 m (-5.10 m OD).

The Lambeth Group comprised very stiff very high strength and hard extremely high strength fissured yellowish brown, red and bluish grey mottled clay to the maximum depth investigated. In a single borehole only, very dense light grey and light brown silty fine and medium sand, possibly interbedded with brown slightly sandy clayey silt, was encountered to the maximum depth investigated of 25.70 m (-11.20 m OD).

An historical BGS borehole carried out roughly 150 m west of the site encountered gravels to a depth of 2.1 m over London Clay to a depth of 23.4 m. Below this, the Lambeth Group was encountered to a depth of around 44 m.

2.5 Hydrology and Hydrogeology

The Hackney Gravel and Lynch Hill Gravel are classified as Secondary 'A' Aquifers, referring to permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

The underlying London Clay is classified as 'Unproductive Strata', as defined by the Environment Agency (EA) as rock or drift deposits with low permeability that have negligible significance for water supply or river base flow.

The nearest surface water feature is located 414 m to the southeast of the site although the nature of the feature is not known.

Reference to the Lost Rivers of London[4] indicates that a tributary of the River Fleet flowed in a southerly direction, approximately 400 m to the east of the site, along the present course of Farringdon Road, whilst a small tributary rose close to Holborn Circus, approximately 350 m to the southeast.

Any surface water runoff that infiltrates the shallow made ground and Hackney or Lynch Hill Gravels above the London Clay is likely to flow southwards along the surface of the London Clay towards the River Thames, which is located roughly 800 m to the south of the site.

The permeability of the Hackney Gravel is expected to range between about 1 x 10^{-6} m/s and 1 x 10^{-4} m/s, whereas in contrast, published data for the permeability of the London Clay indicates the horizontal permeability to generally range between 1 x 10^{-10} m/s and 1 x 10^{-8} m/s, with an even lower vertical permeability. The London Clay cannot therefore support groundwater flow and as such do not support a "water table" or continuous piezometric surface.

Subsequent monitoring at the nearby site on Gray's Inn Road, measured groundwater within the Hackney Gravel at levels of between 14.64 m OD and 15.27 m OD.

The site is not at risk of flooding from rivers or sea, as defined by the EA. However, South Square is identified as having a low risk from surface water flooding, although records held by the Honourable Society of Gray's Inn indicate that this area has never flooded.

The site is not located within a Groundwater Source Protection Zone, as defined by the EA.

As the development does not result in a change to the present conditions, for example through the loss of any permeable areas, there will not be an increase in runoff rate or volume into the existing sewer system, or that could have a potentially adverse impact on the surrounding area. There should not, therefore, be any requirement for any mitigation measures.

[4] Nicholas Barton & Stephen Myers (2016) The *Lost Rivers of London.* Historical Publications Ltd

2.6 Previous Investigation

The previous ground investigation completed on behalf of The Honourable Society of Gray's Inn for the redevelopment of No 19-20 High Holborn, comprised a single 20 m deep cable percussion borehole and a 5.0 m deep, opendrive borehole. These boreholes were supplemented by a series of twenty-eight external and internal trial pits, completed over two separate phases to investigate the existing foundations, basement wall and basement floor slab construction.

A copy of the site investigation report, including borehole and trial pit records and site plan, is included in the appendix.

2.6.1 Summary of Ground Conditions

The investigation generally encountered the expected ground conditions in that, beneath a significant thickness of made ground, Hackney Gravel was encountered overlying the London Clay, which was proved to the full depth of the investigation, of 20.0 m (-0.15 m).

The following table summarises the ground conditions.

Stratum	Depth to base (m below ground level)	Level of base (m OD)	Description
Made Ground	3.40 to 4.00	17.04 to 15.85	Brown gravelly sand, very sandy clayey silt and silty sandy gravelly clay with frequent crushed brick, concrete, ash, tile, shell fragments and coal
Hackney Gravel	6.60	13.05	Medium dense to dense brown and pale brown slightly silty sand and gravel
London Clay	20.0*	-0.15	Firm brown clay over stiff becoming very stiff fissured high strength dark brownish grey silty clay over fissured dark brown very silty clay with occasional fine shell fragments, medium selenite crystals and black carbonaceous material

**Maximum depth of investigation.*

Contamination testing identified a single elevated concentration of lead, within the 11 samples of made ground tested as part of the investigation. However, as these soils would be removed from site as part of the proposed basement construction, no further action was recommended with respect to contamination and the protection of end users.

2.6.2 Summary of Groundwater Conditions

Groundwater was encountered as strikes during drilling in Borehole No 1 at depths of 5.50 m and 14.30 m, rising to 5.00 m (14.85 m OD) and 14.00 m (5.85 m OD) respectively. Groundwater was not encountered during drilling within Borehole No 2 and was not encountered within any of the trial pits.

Standpipes were installed into both boreholes and the results of the subsequent groundwater monitoring visits are summarised in the table below.

Date	Borehole No	Depth to water (m) [Level (m OD)]
25/07/15 (Fieldwork)	1	5.00 [14.85]
	2	DRY
07/08/15	1	5.04 [14.81]

Date	Borehole No	Depth to water (m) [Level (m OD)]
	2	No reading due to no standpipe access
24/08/15	1	5.05 [14.80]
	2	DRY
14/09/15	1	5.02 [14.83]
	2	DRY

2.7 UXO Risk Assessment

A Preliminary UXO Risk Assessment has been completed by 1st Line Defence (report ref EP2542-00, dated March 2020), and a copy of the report is included in the appendix.

The risk assessment has been carried out in accordance with the guidelines provided by CIRIA[5], which state that the likelihood of encountering and detonating UXO below a site should be assessed along with establishing the consequences that may arise. The first phase comprises a preliminary risk assessment, which should be undertaken at an early stage of the development planning. If such an assessment identifies a high level of risk then a detailed risk assessment should be carried out by a UXO specialist, which will identify an appropriate course of action with regard to risk mitigation.

During World War II (WWII), the site was located within the Metropolitan Borough of Holborn, which sustained a very high bombing density according to official statistics. London Bomb Census mapping for the area records a number of bomb strikes within the immediate vicinity of the site. LCC bomb damage mapping records serious levels of damage to the adjacent structures, with the northern chapel labelled as *Chapel (Remains of)* on post-WWII OS mapping. Given this, it is not anticipated that access would have been particularly frequent within the area due to the resulting rubble and debris. As such, post-raid checks for evidence of UXO are thought to have decreased significantly.

On this basis, the report recommends that further research in the form of a Detailed UXO Risk Assessment should be undertaken for this site. Prior to or in lieu of a Detailed Assessment, on-site supervision should be provided throughout intrusive works.

2.8 Preliminary Risk Assessment

Part IIA of the Environmental Protection Act 1990, which was inserted into that Act by Section 57 of the Environment Act 1995, provides the main regulatory regime for the identification and remediation of contaminated land. The determination of contaminated sites is based on a "suitable for use" approach which involves managing the risks posed by contaminated land by making risk-based decisions. This risk assessment is carried out on the basis of a source-pathway-receptor approach.

2.8.1 Source

The desk study research has indicated that the site is likely to have been occupied with the existing vaults since at least the mid-19th Century and is not therefore considered to have had a potentially contaminative history. No sources of soil gas have been identified on site or in the surrounding area.

5 CIRIA C681 (2009) *Unexploded ordnance (UXO) A guide for the construction industry*

2.8.2 Receptor

The site will continue to have a commercial end use following the excavation of the basement and no new receptors will result.

Buried services are likely to come into contact with any contaminants present within the soils through which they pass, and site workers are likely to come into contact with any contaminants present during construction works.

The site is underlain by a Secondary 'A' Aquifer and therefore groundwater is considered to be a relatively sensitive receptor. Similarly, perched water may also exist in the made ground or in the vicinity of existing foundations.

2.8.3 Pathway

As the site is to remain covered by the footprint of the proposed new plant room, below a surface covering of hardstanding, there will be limited potential contaminant exposure pathways as the proposed structures will effectively form a barrier between any contaminants within the near-surface soils and end-users or infiltration of surface water.

Soluble contaminants within the made ground could potentially migrate onto adjacent sites through groundwater movements in the Hackney Gravel, although this pathway is already in existence. The presence of London Clay beneath the site results in a low potential for the percolation of soluble contaminants down to a sensitive aquifer at depth, and as such it is considered unlikely for a pathway to exist to a principal aquifer.

Buried services may be exposed to any contaminants present within the soil through direct contact and site workers will come into contact with the soils during construction works.

There is thus considered to be a low potential for a contaminant pathway to be present between any potential contaminant source and a target for the particular contaminant.

2.8.4 Preliminary Risk Appraisal

On the basis of the above it is considered that there is a VERY LOW risk of there being a significant contaminant linkage at this site, which would result in a requirement for major remediation work. Furthermore, as there is no evidence of filled ground within the vicinity of the site and no landfill sites, there is not considered to be a significant potential for hazardous soil gas to be present on or migrating towards the site.

3.0 SCREENING

The LBC guidance suggests that any development proposal that includes a basement should be screened to determine whether or not a full BIA is required.

3.1 Screening Assessment

A number of screening tools are included in the Arup document and for the purposes of this report reference has been made to Appendices E1, E2 and E3 which include a series of questions within screening flowcharts for surface flow and flooding, subterranean (groundwater) flow and land stability. The flowchart questions and responses to these questions are tabulated below.

3.1.1 Subterranean (groundwater) Screening Assessment

Question	Response for 8 South Square
1a. Is the site located directly above an aquifer?	*Yes. The site is located above a Secondary 'A' Aquifer as designated by the EA.*
1b. Will the proposed basement extend beneath the water table surface?	Unlikely. *Groundwater is expected to be present within the Hackney Gravel at a level of approximately 14.5 OD to 15.0 m OD, which is below proposed formation level of the new plant room of approx. 16.5 m OD.*
2. Is the site within 100 m of a watercourse, well (used/ disused) or potential spring line?	No. Topographical maps acquired as part of the desk study and Figures 11 and 12 of the Arup report confirm this.
3. Is the site within the catchment of the pond chains on Hampstead Heath?	No. Figure 14 of the Arup report confirms that the site is not located within this catchment area.
4. Will the proposed basement development result in a change in the proportion of hard surfaced / paved areas?	No. The existing vaults and proposed plant will extend beneath an existing area of external hardstanding and will not therefore result in a significant change in the proportion of hard surfaced / paved areas.
5. As part of the site drainage, will more surface water (e.g. rainfall and run-off) than at present be discharged to the ground (e.g. via soakaways and/or SUDS)?	No. Site drainage will continue to be directed to public sewer, as per the existing situation.
6. Is the lowest point of the proposed excavation (allowing for any drainage and foundation space under the basement floor) close to or lower than, the mean water level in any local pond or spring line?	No. Topographical maps acquired as part of the desk study and Figures 11 and 12 of the Arup report confirm this.

The above assessment has identified the following potential issues that need to be assessed:

Q1a The site is located directly above an aquifer.

3.1.2 Stability Screening Assessment

Question	Response for 8 South Square
1. Does the existing site include slopes, natural or manmade, greater than 7°?	No, as indicated on the Slope Angle Map Fig 16 of the Arup report.
2. Will the proposed re-profiling of landscaping at the site change slopes at the property boundary to more than 7°?	No. The site is not to be significantly re-profiled as part of the development.
3. Does the development neighbour land, including railway cuttings and the like, with a slope greater than 7°?	No. As indicated on the Slope Angle Map Fig 16 of the Arup report.
4. Is the site within a wider hillside setting in which the general slope is greater than 7°?	No. As indicated on the Slope Angle Map Fig 16 of the Arup report.
5. Is the London Clay the shallowest strata at the site?	No. As indicated on the geological map and Figures 3, 5 and 8 of the Arup report
6. Will any trees be felled as part of the proposed development and / or are any works proposed within any tree protection zones where trees are to be retained?	No. There is an existing tree within the pavement area immediately adjacent to the site, which will be retained.
7. Is there a history of seasonal shrink-swell subsidence in the local area and / or evidence of such effects at the site?	No. Existing and nearby site investigations confirm that the site is underlain by the Hackney Gravel.
8. Is the site within 100 m of a watercourse or potential spring line?	No. Not according to Figure 12 of the Arup report, extracts from the Envirocheck report and Ordnance Survey maps.
9. Is the site within an area of previously worked ground?	No. Not according to Figure 3 of the Arup report.
10a. Is the site within an aquifer?	*Yes. The site is located above a Secondary 'A' Aquifer as designated by the EA.*

Question	Response for 8 South Square
10b. Will the proposed basement extend beneath the water table such that dewatering may be required during construction?	Unlikely. *Groundwater is expected to be present within the Hackney Gravel at a level of approximately 14.5 to 15.0 m OD, which is below proposed formation level of the new plant room of approx. 16.5 m OD.*
11. Is the site within 50 m of Hampstead Heath ponds?	No. Figure 14 of the Arup report confirms that the site is not located within this catchment area.
12. Is the site within 5 m of a highway or pedestrian right of way?	No. Whilst the site extends beneath part of the existing pavement of South Square, this does not comprise a public highway or pedestrian right of way.
13. Will the proposed basement significantly increase the differential depth of foundations relative to neighbouring properties?	No. The neighbouring properties include existing basement or lower ground floor levels, such that the development is unlikely to increase the foundation depths relative to the neighbouring properties.
14. Is the site over (or within the exclusion zone of) any tunnels, e.g. railway lines?	No. Not according to Figure 18 of the Arup report and information obtained on nearby by London Underground and Crossrail assets. A deep-level (former post office) tunnel is understood to be in the vicinity of the site. However, this is at a depth and distance unlikely to be affected by the proposed development.

The above assessment has identified the following potential issues that need to be assessed:

Q10a The site is located directly above an aquifer.

3.1.3 Surface Flow and Flooding Screening Assessment

Question	Response for 8 South Square
1. Is the site within the catchment of the pond chains on Hampstead Heath?	No. Figure 14 of Arup report confirms that the site is not located within this catchment area.
2. As part of the proposed site drainage, will surface water flows (e.g. volume of rainfall and peak run-off) be materially changed from the existing route?	No. There will not be an increase in impermeable area across the ground surface above the proposed plant room, so the surface water flow regime will be unchanged. The structure will be beneath the footprint of the existing building and areas of hardstanding, therefore the 1m distance between the roof of the basement and ground surface as recommended by section 3.2 of the CPG Basements 2018 does not apply across these areas.
3. Will the proposed basement development result in a change in the proportion of hard surfaced / paved areas?	No. There will not be an increase in impermeable area across the ground surface above the basement.
4. Will the proposed basement development result in changes to the profile of the inflows (instantaneous and long term) of surface water being received by adjacent properties or downstream watercourses?	No. There will not be an increase in impermeable area across the ground surface above the proposed plant room, so the surface water flow regime will be unchanged. The structure will be beneath the footprint of the existing building and areas of hardstanding, therefore the 1m distance between the roof of the basement and ground surface as recommended by section 3.2 of the CPG Basements 2018 does not apply across these areas.
5. Will the proposed basement result in changes to the quality of surface water being received by adjacent properties or downstream watercourses?	No. The proposed development is very unlikely to result in any changes to the quality of surface water being received by adjacent properties or downstream watercourses as the surface water drainage regime will be unchanged and the land uses will remain the same.
6. Is the site in an area identified to have surface water flood risk according to either the Local Flood Risk Management Strategy or the Strategic Flood Risk Assessment or is it at risk	*Yes. The findings of this BIA together with the Camden Flood Risk Management Strategy dated 2013 and Figures 3i, 4e, 5a and 5b of the SFRA dated 2014, in addition to the*

Question	Response for 8 South Square
of flooding, for example because the proposed basement is below the static water level of nearby surface water feature?	*Environment Agency online flood maps show that the site has a low flooding risk from surface water. The flood depth during low risk events would be <0.3m and 0.9m at ground level.* *There is a very low risk from sewers, and reservoirs (and other artificial sources), and fluvial/tidal watercourses.* *It is possible that the basement will be constructed within perched groundwater and the recommendations outlined in the BIA with regards to waterproofing and tanking of the basement will reduce the risk to acceptable levels.* *In accordance with paragraph 6.16 of the CPG a positive pumped device and non-return valve will be installed in the basement in order to further protect the site from sewer flooding.* *The Honourable Society of Gray's Inn have no records of any flooding within South Square and provided that statutory requirements and best practice are adopted with regard to waterproofing and tanking and mitigation measures are included to restrict or prevent surface water entry into the new plant room, as already achieved by the existing drainage, then this risk would be reduced to acceptable levels.*

The above assessment has identified the following potential issues that need to be assessed:

Q6 There is a low risk of flooding from surface water across the site.

4.0 SCOPING AND SITE INVESTIGATION

The purpose of scoping is to assess in more detail the factors to be investigated in the impact assessment. Potential impacts are assessed for each of the identified potential impact factors.

4.1 Potential Impacts

The following potential impacts have been identified by the screening process

Potential Impact	Consequence
The site is located above a Secondary 'A' Aquifer as designated by the EA.	The basement may extend into the underlying aquifer and thus affect the groundwater flow regime.
There is a low risk of flooding from surface water	In the event of a 1 in 100 or 1 in 100 flood events, there is a potential for surface wate inflows to enter the proposed new plant room from the adjoining lightwell area.

These potential impacts have been investigated through the site investigation, as detailed in Section 12.0.

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.

5.0 INTRODUCTION

It is understood that it is proposed to replace the existing vaults that extend beyond the frontage of No 8 South Square, with a new chiller plant room, which will extend to a depth of between 1.0 m to 1.5 m below existing lower ground floor level, to a level of approximately 16.5 m OD.

Anticipated loads are not known at this stage. However, given the nature of the proposals, they are expected to be light.

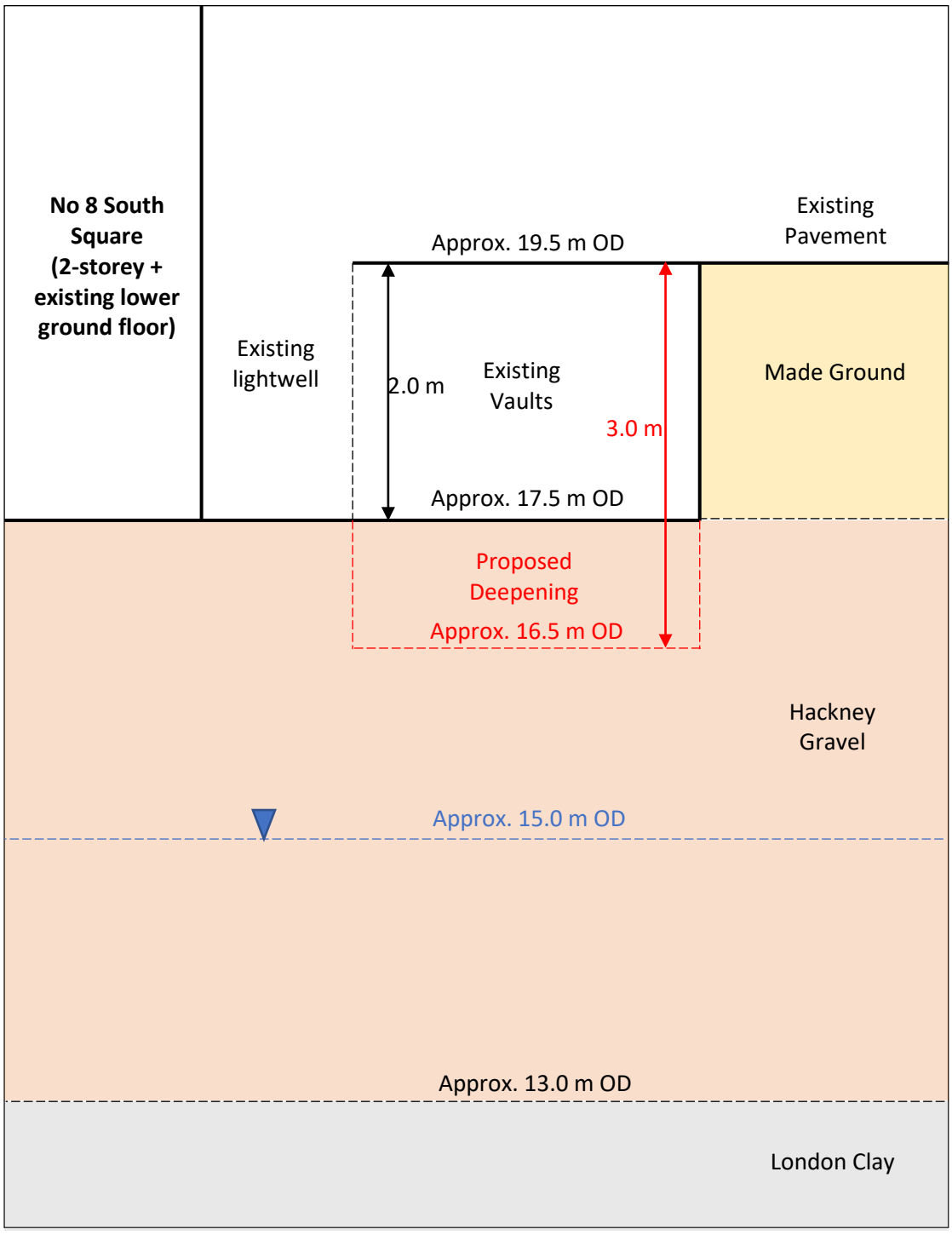
6.0 GROUND MODEL

The desk study research indicates that the site has not had a potentially contaminative history. On the basis of the previous investigation and nearby sites, the ground conditions at this site can be characterised as follows:

- below a variable and potentially significant thickness of made ground, Hackney Gravel is expected to be present overlying the London Clay Formation;
- made ground, comprising brown gravelly sand, very sandy clayey silt and silty sandy gravelly clay, with variable amounts of extraneous material, is likely to be present to existing lower ground floor level at a depth of at least 2.0 m (17.5 m OD) to 2.5 m (17.0 m OD) below existing ground level;
- Hackney Gravel, comprising medium dense to dense brown and pale brown slightly silty sand and gravel is expected to extend below the existing structures to a depth of between 6.5 m (13.0 m OD) and 8.5 m (11.0 m OD) below existing ground level;
- the underlying London Clay, generally comprising stiff becoming very stiff fissured high strength silty clay, is expected to extend to a depth of at least 22.0 m (-2.5 m OD) beneath the site;
- groundwater is expected to be present within the Hackney Gravel at a level of between 14.5 m OD and 15.0 m OD; and
- there is a very low risk of contamination at the site, in addition to which, end users will be completely isolated from the surrounding soils by the proposed structure and areas of existing hardstanding.

6.1 Conceptual Site Model

A section through the proposed scheme with the above ground model is shown below.



6.2 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[6, 7, 8 & 9] and a well-established method has been used to provide the estimated values. All depths are given relative to existing garden level.

Stratum	Base of Stratum (m bg.l)	Level (m OD)	Bulk Unit Weight (kN/m^3)	Effective Friction Angle (φ' °)	Undrained Cohesion (C_u - kN/m^2)	Drained Young's Modulus* (E' - kN/m^2)	Undrained Young's Modulus* (E_u - kN/m^2)
Made Ground	2.0 (varies)	17.5	17	27	-	10,000	-
Hackney Gravel	6.5	13.0	18.0	30 to 35	-	60000 to 70000	-
London Clay	22.0	-2.5	19.5	23	70 + 7.5	39375 + 4218	52500 + 5625

+Maximum depth of investigation. *Values based on a relationship of E_u = 750 C_u and E' = 0.75 E_u from Burland et al[9]. **An increase in cohesion of 7.5 kN/m^2 per metre increase in depth has been adopted to provide a conservative estimate of the likely strength profile of the London Clay.

7.0 ADVICE AND RECOMMENDATIONS

Excavations for the proposed basement structure will require temporary support to maintain stability and to prevent any excessive ground movements. Groundwater is not expected to be encountered within the proposed excavation, although seepages may be encountered from any pockets of perched groundwater within the made ground.

Formation level for the proposed development is likely to be within the Hackney Gravel, which should provide an eminently suitable bearing stratum for spread foundations excavated from proposed formation level.

7.1 Basement Excavation

7.1.1 Basement Construction

The proposed excavations are expected to extend to a depth of about 1.0 m to 1.5 m below existing lower ground floor level, or approximately 3.0 m below existing ground level, such that formation level should be within the Hackney Gravel, which is expected to extend to a depth of at least 6.5 m (13.0 m OD) beneath the site.

Groundwater is unlikely to be encountered within the proposed excavations, such that it should be possible to lower the existing floor without the need for any groundwater protection measures. Perched groundwater inflows may be encountered from within the made ground, particularly in close proximity to existing foundations; however, such inflows are unlikely to be prolonged or of significant volume and should be adequately controlled using conventional methods, such as sump pumping, although it would be prudent for the chosen contractor to have a contingency in place should more significant inflows be encountered.

6 Padfield CJ and Sharrock MJ (1983) *Settlement of structures on clay soils*. CIRIA Special Publication 27
7 Butler FG (1974) *Heavily overconsolidated clays: a state-of-the-art review.* Proc Conf Settlement of Structures, Cambridge, 531-578, Pentech Press, Lond
8 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
9 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

There are a number of methods by which the sides of the basement excavation could be supported in the temporary and permanent conditions. 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.

It is understood that the preferred method of retaining wall construction is through a mixture of underpinning of the existing foundations and / or replacement of the existing vault structure with reinforced concrete retaining walls, which will have the benefit of minimising the plant required and maximising usable space in the new basement construction.

Whilst the proposed construction will not result in foundation depths being increased relative to the neighboring properties to any significant degree, 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. A Ground Movement Analysis has been carried out in accordance with the requirements of CPG Basements and is presented in Part 3 below.

7.1.2 Retaining Walls

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

Stratum	Bulk Density (kg/m^3)	Effective Cohesion ($c' - kN/m^2$)	Effective Friction Angle (Φ' – degrees)
Made Ground	1700	Zero	27
Hackney Gravel	1800	Zero	32
London Clay	1950	Zero	23

Groundwater is unlikely to be encountered within the proposed excavations. However, consideration should be given to the risk of surface water building up within any made ground 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[10] regarding requirements for waterproofing.

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

7.1.3 Basement Heave

The 1.0 m to 1.5 m deep excavations to lower the floor for the proposed new plant room will result in a net unloading of up to approximately 20 kN/m², which, due to the granular nature and thickness of the underlying Hackney Gravel, is unlikely to result in significant heave of the underlying soils

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

7.2 Spread Foundations

Spread foundations, including underpinned foundations, extending form proposed formation level to bear within medium dense sand and gravel of the Hackney Gravel may be designed to apply a net allowable bearing pressure of 175 kN/m². This value incorporates an adequate factor of safety against bearing capacity failure and should ensure that settlement remains within normal tolerable limits.

7.3 Basement Floor Slabs

Following deepening of the existing vault structures, it should be possible to adopt a ground bearing floor slab, bearing on the natural soils, provided that it can be suitably reinforced to accommodate the potential ground movements predicted in Part 3 of this report.

It would be prudent to proof roll the stratum, with any soft spots revealed being removed and replaced with suitably compacted granular fill.

7.4 Shallow Excavations

It is considered that shallow excavations for foundations and services that extend through the made ground and into the underlying Hackney Gravel should remain generally stable in the short term, although some instability may occur. 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.

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

7.5 Hydrogeological Assessment

The proposed excavations for the new plant room are expected to extend to a depth of approximately 1.0 m to 1.5 m below existing lower ground floor level, such that formation level will be within the Hackney Gravel at a depth of approximately 3.0 m below existing ground level, or 16.5 m OD.

Groundwater is expected to be present within the Hackney Gravel at a level of between 14.5 m OD and 15.0 m OD, such that the proposed excavations will not extend below the water table.

As the interface between the Hackney Gravel and the essentially impermeable London Clay below, was found to be at a depth of around 13.0 m OD, the lowering of the existing floor level to form the new plant room will not provide a cut-off to groundwater flows by keying into the London Clay, such that there will be sufficient space for groundwater to continue flowing beneath the proposed basement.

In conclusion, as the new basement does not close a pathway, it is considered that the groundwater will follow a pathway below the proposed basement and will not build up significantly behind it. The basement should not, therefore, have a significant effect on groundwater flow.

7.6 Site Specific Risk Assessment

The desk study has indicated that the site has not had a contaminative history, such that the presence of significant contamination and a requirement for remediation is not envisaged.

Furthermore, the nature of the proposed development will mean that any potentially contaminated soils encountered within the proposed excavations will be removed from site, whilst end users will be effectively isolated from any potential contamination by the extent of the existing and proposed structures and areas of external hardstanding, further eliminating any potential risk. However, in accordance with standard construction practice, a safe programme of working should be identified to protect workers handling any soil.

7.6.1 Protection of Site Workers

As with any site 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[11] and CIRIA[12] 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.

7.7 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[13] 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[14] 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 £91.35 per tonne (about £219 per m^3) or at the lower rate of £2.90 per tonne (roughly £6.95 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

11 HSE (1992) HS(G)66 *Protection of workers and the general public during the development of contaminated land* HMSO
12 CIRIA (1996) A *guide for safe working on contaminated sites* Report 132, Construction Industry Research and Information Association
13 Environment Agency 2015. *Guidance on the classification and assessment of waste.* Technical Guidance WM3 First Edition
14 CL:AIRE March 2011. *The Definition of Waste: Development Industry Code of Practice* Version 2

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 EA it is considered that the soils likely to be encountered during the proposed development, 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	£91.35/tonne (Standard rate)
Hackney Gravel	Should be Inert (17 05 04)	Should not be required but confirm with receiving landfill	£2.90 / 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[15] 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 insitu 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.

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.

15 Environment Agency 23 Oct 2007 Regulatory *Position Statement Treating non-hazardous waste for landfill - Enforcing the new requirement*

Part 3: GROUND MOVEMENT ANALYSIS

This section of the report comprises an analysis of the ground movements arising from the proposed basement and foundation scheme discussed in Part 2 and the information obtained from the investigation, presented in Part 1 of the report.

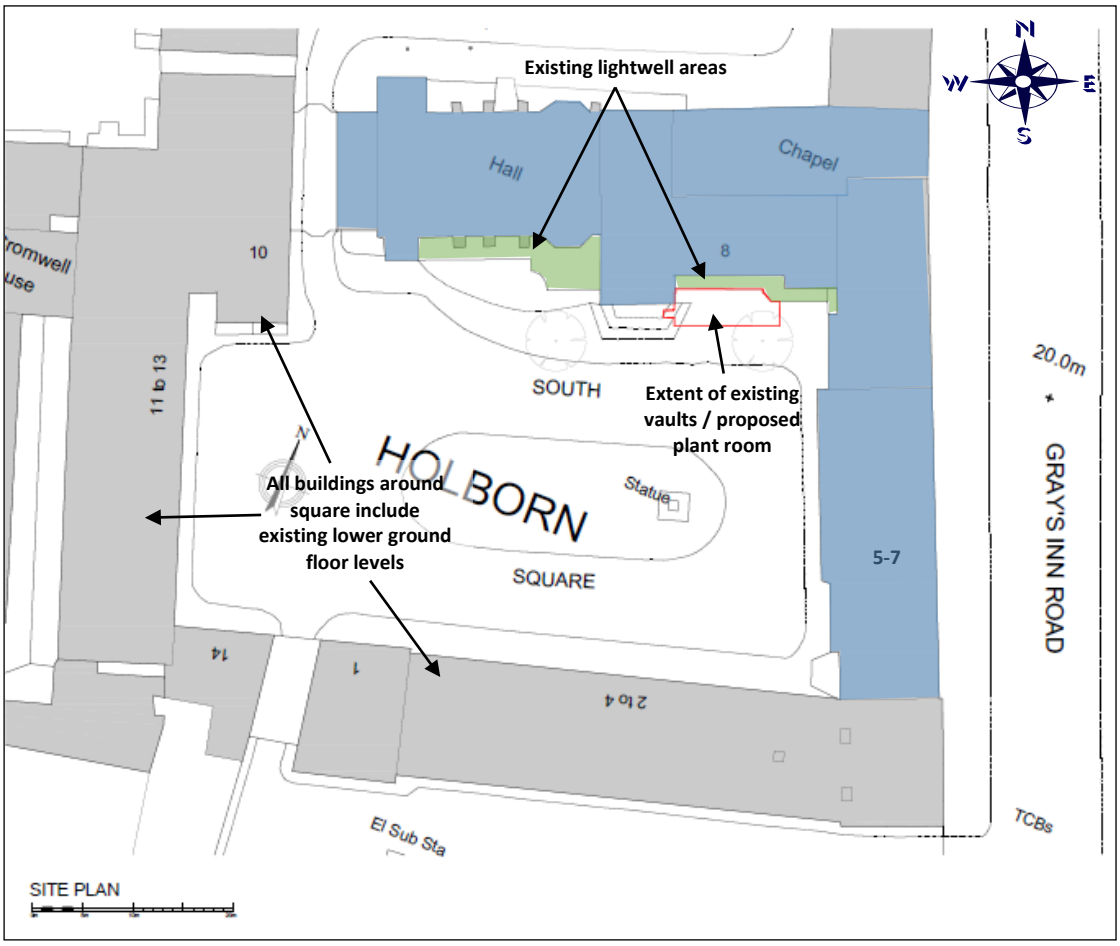
8.0 INTRODUCTION

The sides of an excavation will move to some extent regardless of how they are supported. The movement will typically be both horizontal and vertical and will be influenced by the engineering properties of the ground, groundwater level and flow, the efficiency of the various support systems employed during underpinning and the efficiency or stiffness of any support structures used.

An analysis has been carried out of the likely movements arising from the proposed excavation and the results of this analysis have been used to predict the effect of these movements on surrounding structures.

8.1 Basis of Ground Movement Assessment

A plan showing the nearby sensitive structures (in blue) is shown below.



Sensitive structures relevant to this assessment include the adjoining structures of No 8 South Square and No 5-7 South Square, along with the nearby Chapel and Hall to the north and northwest respectively.

The exact nature of the foundations of the adjoining structures is not known and a cautious approach has therefore been adopted with the assumption that the buildings are supported on relatively shallow spread foundations, extending to a depth of no more than 0.5 m below existing lower ground floor level and therefore at a level of approximately 17.0 m OD.

8.2 Construction Sequence

Consideration is being given to the conversion of the existing vaults beneath the existing pavement to the front of No 8 South Square, with a new chiller plant room, which will require lowering of the existing floor level by a depth of approximately 1.0 m to 1.5 m.

From the information provided, it is understood that a mixture of traditional mass concrete underpinning and reinforced concrete retaining walls will be used to support the proposed excavations.

The following sequence of operations has been derived to enable analysis of the ground movements around the basement, both during and after construction, and is based on the information provided by the structural engineer.

Essentially the sequence of works may be considered as two groups of activities, the first comprising the short-term temporary works, whilst the second represents the construction of the permanent works.

The detail of the support provided to adjacent walls is beyond the scope of this report at this stage and the structural engineer will be best placed to agree a methodology with the piling contractor(s) once appointed. However, it is assumed that propping of all walls will take place throughout the temporary and permanent works.

8.2.1 Temporary Support to Reinforced Concrete Retaining Walls

A reinforced concrete retaining wall will be used to replace part of the existing vault structures along the frontage with South Square, which is expected to be undertaken in an underpinning type 'hit and miss' sequence. All temporary shoring and propping is to be inspected by a suitably qualified person.

The retaining wall will be adequately laterally propped and sufficiently dowelled together, and the concrete will be cast and adequately cured prior to excavation of the basement and removal of the formwork and supports. It is assumed that the corners of the excavation will be locally stiffened by cross-bracing or similar and that the new retaining walls will not be cantilevered at any stage during the construction process.

It is assumed that adequate temporary propping of the new retaining walls, particularly at the top level, will occur at all times during excavation of the proposed basement and will remain in place until the construction of permanent concrete floor slabs.

8.2.2 Temporary Support to Underpinned Walls

It is understood that underpinning to lower the existing lower ground floor of the proposed plant room will be undertaken in a 'hit and miss' sequence, in stages to be agreed with the temporary works engineer and under party wall agreement, and due to the limited size of the development will be concurrent with the bulk excavations.

Underpinning should generally be undertaken in short sections not exceeding 1.00 m to 1.20 m in length, with no adjacent pin to be excavated until a minimum of 48 hours after the adjacent pin has been cast and dry-packed placed, with the sides of the excavation adequately shored and propped.

The underpins will be adequately laterally propped and sufficiently dowelled together, and the concrete will be cast and adequately cured prior to excavation of the basement and removal of the formwork and supports. It is assumed that the corners of the excavation will be locally stiffened by cross-bracing or similar and that the new retaining walls will not be cantilevered at any stage during the construction process.

It is assumed that adequate temporary propping of the new retaining walls, particularly at the top level, will occur at all times during excavation of the proposed basement and will remain in place until the construction of permanent concrete floor slabs.

8.2.3 Permanent Works

When the final excavation depths have been reached, the permanent works will be formed, which are likely to comprise reinforced concrete walls with a drained cavity lining the inside of the newly formed retaining walls.

Reinforced concrete will be used for floor slabs and it is anticipated that the floor slabs, which will act as permanent props, will be constructed lowest level first and when each floor has achieved adequate strength, the temporary props will be removed, and the subsequent walls and floors cast until the structure is complete.

9.0 GROUND MOVEMENTS

An assessment of ground movements within and surrounding the excavation has been undertaken using the XDisp and PDisp computer programs licensed from the OASYS suite of geotechnical modelling software from Arup. These programs are commonly used within the ground engineering industry and are considered to be appropriate tools for this analysis.

The XDisp and PDisp programs have been used to predict ground movements likely to arise from the construction of the proposed basement. This includes the heave / settlement of the ground (vertical movement) and the lateral movement of soil behind the proposed retaining walls (horizontal movement).

For the purpose of these analyses, the corners have been defined by x and y coordinates, with the x-direction parallel with the orientation east-west, whilst the y-direction is parallel with Gray's Inn Road (approx. north-south). Vertical movement is in the z-direction.

For this movement analysis, the proposed new plant room has been modelled as a polygon, with maximum dimensions of 10.0 m by 4.0 m, with a formation level of approximately 16.5 m OD.

It is understood that propping will be provided during the construction and in the permanent condition, such that the walls can be considered to be stiff for the purpose of the ground movement modelling.

Full input data and selected outputs of all the analyses are included within the appendix.

9.1 PDisp Model

Unloading of the underlying soils, particularly the clay soils of the London Clay, will take place as a result of the excavation to lower the existing lower ground floor level and the reduction in vertical stress will cause heave to take place. Undrained soil parameters have been used to estimate the potential short-term movements, which include the "immediate" or elastic movements as a result of the basement excavation. Drained parameters have been used to provide an estimate of the total long-term movement.

The elastic analysis requires values of soil stiffness at various levels to calculate displacements. Values of stiffness for the soils at this site are readily available from published data[9] and a well-established method has been used to provide estimated values. Relationships of $E_u = 750\ C_u$ and $E' = 0.75\ E_u$ for the cohesive soils and 2000 x SPT N (estimated from soil description) for granular soils have been used to obtain values of Young's modulus.

The excavation of an approximately 1.0 m to 1.5 m thickness of soil to reduce the existing floor level will result in a net unloading of around 20 kN/m^2.

The soil parameters used in this analysis and tabulated below have been primarily derived from the previous investigation of No19-20 High Holborn to the south but supplemented with the data from the nearby GEA investigations and BGS data.

Stratum	Depth Range (m)	Level (m TBM)	Cu (KN/m^2)	Eu (KN/m^2)	E'(KN/m^2)
Made Ground	GL to 2.0	19.5 to 17.5	-		10,000
Hackney Gravel	LGFL to 6.5	17.5 to 13.0	-	-	60,00 to 70,000
London Clay	6.5 to 22*	13.0 to -2.5	70 to 180	52,500 to 135,000	39,375 to 101,250

*Maximum depth of investigation.

A rigid boundary for the analysis has been set within the London Clay at a depth of 22.00 m, below which, essentially incompressible soils of the Lambeth Group are expected to be present. As per Section 6.2, an increase in cohesion of 7.5 kN/m^2 for each metre of depth has been adopted to provide a conservative estimate of the likely strength profile within the London Clay below the site.

9.2 Ground Movements surrounding the Excavation

The magnitude of the settlement resulting from the proposed basement construction will be controlled to a large extent by the quality of workmanship of the underpins and by the existing building that is likely to provide additional rigidity.

For the purpose of this assessment a high quality of construction has been assumed, with continued loading from the existing building and propping of the proposed excavations, such that potential movements are expected to be kept to a minimum.

9.2.1 Installation of reinforced concrete retaining wall

For the XDisp analysis, the installation curves for the panel-like planar diaphragm wall have been adopted as most appropriate for the soil movement relationship for the new reinforced concrete walls which will be used along the frontage with South Square to replace the existing vault walls.

9.2.2 Excavation to proposed formation level

The ground movement curves for 'excavations in front of a stiff wall in stiff clay' have been adopted to represent the combined underpinning and bulk excavations to lower the existing lower ground floor and as this provides a conservative assessment of the likely vertical and horizontal movements from these excavations.

In order to address the potential impact of the proposed excavations, the vertical movements obtained from the excavation and subsequent long-term stages of the PDisp analysis have been also imported into XDisp to enable a damage assessment to be undertaken of all the potential movements.

9.2.3 Results

The results are presented to the degree of accuracy required to allow predicted variations in ground movements around the structure(s) to be illustrated but may not reflect the anticipated accuracy of the predictions.

Phase of Works	Maximum Movements due to Wall Deflection (mm)	
	Vertical Settlement	Horizontal Movement
Wall installation	1.5	1.5
Combined movements from wall installation and excavation / underpinning to proposed formation level	1.0 to 1.5	2.5 to 3.0

The analysis has indicated that the maximum vertical and horizontal settlements that will result from the retaining wall installation are likely to be about 1.5 mm. The movements arising from the combined wall installation and excavation are likely to range between up to 1.0 mm to 1.5 mm of vertical settlement and 2.5 mm to 3.0 mm of horizontal movement.

The movements set out in the table and discussed above are the maximum movements and the analysis has indicated that they occur immediately or just outside the line of the retaining walls.

9.3 Ground Movements within the Excavation (Heave / Settlement)

9.3.1 Results

PDisp analysis indicates that, by the time the basement construction is complete, up to 1.5 mm of heave is likely to have taken place at the centre of the proposed excavations, reducing to 1.0 mm at the edges. In the long term, following completion of the basement construction, a further 0.5 mm of heave is estimated as a result of long term swelling of the underlying London Clay.

The predicted movements are summarised in the table below.

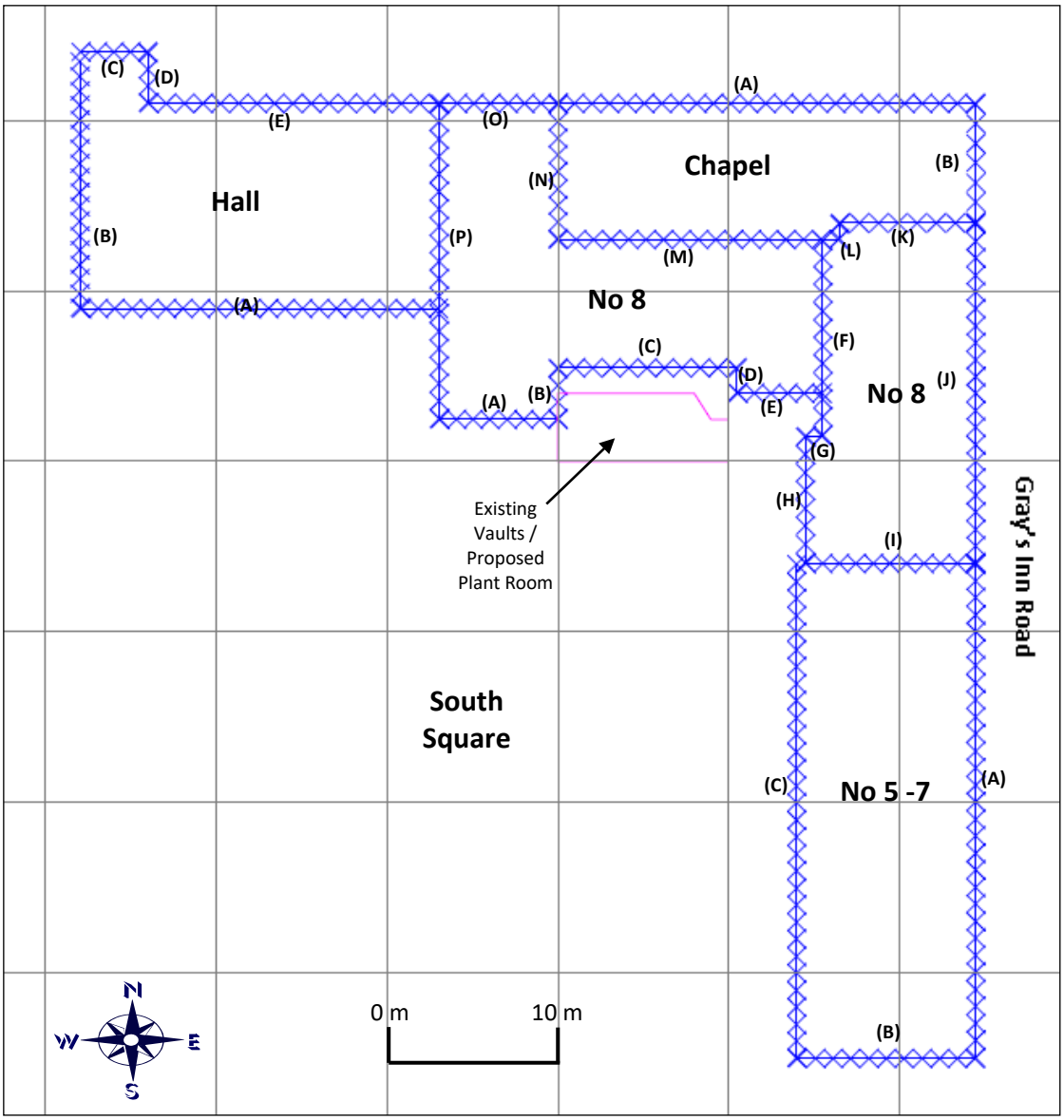
Location	Movement (mm)		
	Short-term Heave (Excavation Phase)	Long-term Heave (post construction)	Total Heave
Centre of excavations	1.5	0.5	2.0
Edge of excavations	1.0	0.5	1.5
At 5 m from edge of excavations	<0.5	<0.5	<0.5

If a compressible material is used beneath the slab, it will need to be designed to be able to resist the potential uplift forces generated by the ground movements. In this respect, potential heave pressures are typically taken to equate to around 40% of the total unloading pressure.

10.0 DAMAGE ASSESSMENT

In addition to the above assessment of the likely movements that will result from the proposed development, any neighbouring buildings within the zone of influence of the excavations are considered to be sensitive structures, requiring Building Damage Assessments, on the basis of the classification given in Table 6.4 of CIRIA report C760[16].

The sensitive structures outlined in Section 8.1 have been modelled as displacement lines in the analysis along which the damage assessment has been undertaken. For clarity, these critical lines are shown on the plan below.



[16] Gaba, A, Hardy, S, Powrie, W, Doughty, L and Selemetas, D (2017) *Embedded retaining walls – guidance for economic design.* CIRIA Report C760

For the analyses, a foundation depth of approximately 17.0 m OD has been assumed, based on the observed depth of the adjoining lower ground floor structures.

10.1 Damage to Neighbouring Structures

The combined movements resulting from retaining wall construction, underpinning and excavation for the proposed new plant room structure, calculated using the XDisp and PDisp modelling software have been used to carry out an assessment of the likely damage to adjacent properties.

The building damage reports for sensitive structures highlighted above are included in the appendix and indicate that the damage to the adjoining and nearby structures due to short and total movements would not exceed Category 0 (negligible).

The results discussed above are based on individual building lines, or walls, that have been further divided up into a series of 1.0 m segments that can move independently of one another. In reality, this is unlikely to be the case as the walls will behave as single elements that are also joined continuously with the rest of the structure. The above results therefore provide a conservative estimate of the behaviour of each of the sensitive structures and are likely to overestimate the degree of damage, although they provide a useful indication of the most critical structures within the adjoining properties.

10.2 Utilities and buried services

As any public services along Gray's Inn Road are outside the 1 mm contour, it is deemed that none of the known services will be affected by the works. Any private services on site that are to be affected by the works are to be redirected.

10.3 Monitoring of Ground Movements

The predictions of ground movement based on the ground movement analysis should be checked by monitoring of the adjacent properties and structures. The structures to be monitored during the construction stages should include the existing property and the neighbouring structure assessed above.

The precise monitoring strategy will be developed at a later stage and it will be subject to discussions and agreements with the owners of the adjacent properties and structures. Contingency measures will be implemented if movements of the adjacent structures exceed predefined trigger levels. Both contingency measures and trigger levels will need to be developed within a future monitoring specification for the works.

11.0 GMA CONCLUSIONS

The analysis has concluded that the predicted damage to the neighbouring properties from the construction of the basement retaining walls and excavation would be 'Negligible'.

On this basis, the damage that has been predicted to occur as a result of the construction the proposed basement falls within the acceptable limits, although careful construction, including the careful control of the proposed excavations will be required to ensure that no excessive movements occur that would lead to damage in excess of these limits.

Part 4: BASEMENT IMPACT ASSESSMENT

This section of the report evaluates the direct and indirect implications of the proposed project, based on the findings of the previous screening and scoping, site investigation and ground movement assessment.

12.0 INTRODUCTION

The screening identified a number of potential impacts. The desk study and ground investigation information has been used below to review the potential impacts, to assess the likelihood of them occurring and the scope for reasonable engineering mitigation.

12.1 Potential Impacts

The table below summarises the previously identified potential impacts and the information that is available from the previous ground investigation in consideration of each impact.

Potential Impact	Assessment Conclusions
The site is located above a Secondary 'A' Aquifer as designated by the EA.	Groundwater is expected to be present within the Hackney Gravel at a level of approximately 14.5 OD to 15.0 m OD, which is below proposed formation level of the new plant room of approx. 16.5 m OD.
There is a low risk of flooding from surface water	The are no records of flooding of the site or the adjoining area of South Square and provided that statutory requirements and best practice are adopted with regard to waterproofing and tanking and mitigation measures are included to restrict or prevent surface water entry into the new plant room, as already achieved by the existing drainage. then this risk would be reduced to acceptable levels.

The results of the previous site investigation have been used below to review the remaining potential impacts, to assess the likelihood of them occurring and the scope for reasonable engineering mitigation.

The site is located above a Secondary 'A' Aquifer

The proposed excavations for the new plant room are expected to extend to a depth of approximately 1.0 m to 1.5 m below existing lower ground floor level, such that formation level will be within the Hackney Gravel at a depth of approximately 3.0 m below existing ground level, or 16.5 m OD.

Groundwater is expected to be present within the Hackney Gravel at a level of between 14.5 m OD and 15.0 m OD, such that the proposed excavations will not extend below the water table.

As the interface between the Hackney Gravel and the essentially impermeable London Clay below was found to be at a depth of around 13.0 m OD, the lowering of the existing floor level to form the new plant room will not provide a cut-off to groundwater flows by keying into the London Clay, such that there will be sufficient space for groundwater to continue flowing beneath the proposed basement.

In conclusion, as the new basement does not close a pathway, it is considered that the groundwater will follow a pathway below the proposed basement and will not build up significantly behind it. The basement should not, therefore, have a significant effect on groundwater flow.

The site has a low flooding potential from surface water

Whilst the site is located within an area identified as having a low flood risk, anecdotal evidence from records kept by the Honourable Society of Gray's Inn confirm that there have not been any incidents of flooding within South Square, or within the existing lightwell or vault structures that make up the site.

Therefore, provided that statutory requirements and best practice are adopted with regard to waterproofing and tanking, and mitigation measures are included to restrict or prevent surface water entry into the new plant room, as already achieved by the existing drainage, then this risk would be reduced to acceptable levels, although it would be prudent to consider undertaking a site-specific Flood Risk Assessment to confirm this.

In accordance with paragraph 6.16 of the CPG, a positive pumped device and non-return valve will be installed in the basement in order to further protect the site from sewer flooding.

12.2 BIA Conclusion

A Basement Impact Assessment has been carried out following the information and guidance published by the London Borough of Camden.

It is concluded that the proposed development is unlikely to result in any specific land or slope stability issues.

12.3 Non-Technical Summary of Evidence

This section provides a short summary of the evidence acquired and used to form the conclusions made within the BIA.

12.3.1 Screening

The following table provides the evidence used to answer the subterranean (groundwater flow) screening questions.

Question	Evidence
1a. Is the site located directly above an aquifer?	Aquifer designation maps acquired from the Environment Agency as part of the desk study and Figures 3 and 8 of the Arup report.
1b. Will the proposed basement extend beneath the water table surface?	Previous nearby GEA investigations and BGS archive borehole records.
2. Is the site within 100 m of a watercourse, well (used/ disused) or potential spring line?	Topographical and historical maps acquired as part of the desk study, Figures 11 and 12 of the Arup report and the Lost Rivers of London book.
3. Is the site within the catchment of the pond chains on Hampstead Heath?	Topographical maps acquired as part of the desk study and Figures 12, 13 and 14 of the Arup report.
4. Will the proposed basement development result in a change in the proportion of hard surfaced / paved areas?	Existing and proposed plans of the site have confirmed that the basement development will only replace existing hardstanding areas.

Question	Evidence
5. As part of the site drainage, will more surface water (e.g. rainfall and run-off) than at present be discharged to the ground (e.g. via soakaways and/or SUDS)?	The details of the proposed development do not indicate the use soakaway drainage.
6. Is the lowest point of the proposed excavation (allowing for any drainage and foundation space under the basement floor) close to or lower than, the mean water level in any local pond or spring line?	Topographical maps acquired as part of the desk study and Figures 11 and 12 of the Arup report.

The following table provides the evidence used to answer the slope stability screening questions.

Question	Evidence
1. Does the existing site include slopes, natural or manmade, greater than 7°?	Topographical maps and Figures 16 and 17 of the Arup report and confirmed during a site walkover.
2. Will the proposed re-profiling of landscaping at the site change slopes at the property boundary to more than 7°?	The details of the proposed development provided do not include the re-profiling of the site to create new slopes.
3. Does the development neighbour land, including railway cuttings and the like, with a slope greater than 7°?	Topographical maps and Figures 16 and 17 of the Arup report and confirmed during a site walkover.
4. Is the site within a wider hillside setting in which the general slope is greater than 7°?	
5. Is the London Clay the shallowest strata at the site?	Geological maps and Figures 3 and 8 of the Arup report.
6. Will any trees be felled as part of the proposed development and / or are any works proposed within any tree protection zones where trees are to be retained?	Reference to existing and proposed site plans.
7. Is there a history of seasonal shrink-swell subsidence in the local area and / or evidence of such effects at the site?	Knowledge on the ground conditions of the area and reference to NHBC guidelines were used to make an assessment of this.
8. Is the site within 100 m of a watercourse or potential spring line?	Topographical maps acquired as part of the desk study, Figures 11 and 12 of the Arup report and the Lost Rivers of London book.
9. Is the site within an area of previously worked ground?	Geological maps and Figures 3 and 8 of the Arup report.
10a. Is the site within an aquifer?	Aquifer designation maps acquired from the Environment Agency as part of the desk study and Figures 3 and 8 of the Arup report.
10b. Will the proposed basement extend beneath the water table such that dewatering may be required during construction?	Previous nearby GEA investigations and BGS archive borehole records.
11. Is the site within 50 m of Hampstead Heath ponds?	Topographical maps acquired as part of the desk study and Figures 12, 13 and 14 of the Arup report.
12. Is the site within 5 m of a highway or pedestrian right of way?	Existing site plans and information provided by Gray's Inn.
13. Will the proposed basement significantly increase the differential depth of foundations relative to neighbouring properties?	Camden planning portal and the site records confirmed the position of the proposed basement relative the neighbouring properties.
14. Is the site over (or within the exclusion zone of) any tunnels, e.g. railway lines?	Maps and plans of infrastructure tunnels were reviewed.

The following table provides the evidence used to answer the surface water flow and flooding screening questions.

Question	Evidence
1. Is the site within the catchment of the pond chains on Hampstead Heath?	Topographical maps acquired as part of the desk study and Figures 12, 13 and 14 of the Arup report.
2. As part of the proposed site drainage, will surface water flows (e.g. volume of rainfall and peak run-off) be materially changed from the existing route?	The existing plans of the site have confirmed that the proposed basement scheme will not increase the amount of hardstanding.
3. Will the proposed basement development result in a change in the proportion of hard surfaced / paved areas?	
4. Will the proposed basement development result in changes to the profile of the inflows (instantaneous and long term) of surface water being received by adjacent properties or downstream watercourses?	As above.
5. Will the proposed basement result in changes to the quantity of surface water being received by adjacent properties or downstream watercourses?	
6. Is the site in an area identified to have surface water flood risk according to either the Local Flood Risk Management Strategy or the Strategic Flood Risk Assessment or is it at risk of flooding, for example because the proposed basement is below the static water level of nearby surface water feature?	Flood risk maps acquired from the Environment Agency as part of the desk study, Figure 15 of the Arup report, the Camden Flood Risk Management Strategy dated 2013 and SFRA dated 2014.

12.3.2 Scoping and Site Investigation

The questions in the screening stage that there were answered 'yes', were taken forward to a scoping stage and the potential impacts discussed in Section 4.0 of this report, with reference to the possible impacts outlined in the Arup report.

A ground investigation has previously been carried out, which has allowed an assessment of the potential impacts of the basement development on the various receptors identified from the screening and scoping stages. Principally the investigation aimed to establish the ground conditions, including the groundwater level and the engineering properties of the underlying soils to enable suitable design of the basement development.

The findings of the investigation are discussed in Part 2 of this report and summarised in the Executive Summary.

12.3.3 Impact Assessment

Section 14.0 of this report summarises whether, on the basis of the findings of the investigation, the potential impacts still need to be given consideration and identifies ongoing risks that will require suitable engineering mitigation. Section 9.0 of this report also provides recommendations for the design of the proposed development.

A ground movement analysis and building damage assessment has been carried out and its findings are presented in Part 3.

13.0 OUTSTANDING RISKS AND ISSUES

This section of the report aims to highlight areas where further work is required as a result of limitations on the scope of this investigation, or where issues have been identified by this investigation that warrant further consideration. The scope of risks and issues discussed in this section is by no means exhaustive but covers the main areas where additional work may be required.

The ground is a heterogeneous natural material and variations will inevitably arise between the locations at which it is investigated. This report provides an assessment of the ground conditions based on the discrete points at which the ground was sampled, but the ground conditions should be subject to review as the work proceeds to ensure that any variations from the Ground Model are properly assessed by a suitably qualified person.

As discussed, groundwater is unlikely to be encountered during the basement excavation although it would be prudent for the chosen contractor to have a contingency in place should more significant inflows be encountered.

The desk study has indicated that the site has not had a contaminative history, such that a requirement for additional site work and contamination testing is not envisaged. However, as with any site there is a potential for areas of contamination to be present within the made ground beneath the site and it is recommended that a watching brief is maintained during any groundworks for the proposed new foundations. If any suspicious soils are encountered, they should be brought to the attention of a geoenvironmental engineer and further assessment may be required.

Contamination testing may be required as part of the groundworks package in order to confirm the waste disposal classification, particularly if greater quantities of made ground are encountered.

Consideration could be given to the completion of a flood risk assessment (FRA) by a suitably qualified person, to fully address any potential surface water flood risk.

A detailed UXO assessment should be undertaken in accordance with the recommendations of the preliminary UXO assessment prior to any potentially intrusive works, such as (but not limited to) groundworks or basement construction works.

The findings of the ground movement analysis and damage assessment should be reviewed once the design proposals have been finalised, particularly if any changes are made to the proposed basement construction.

These items should be drawn to the attention of prospective contractors and further investigation will be required or sufficient contingency should be provided to cover the outstanding risk.

APPENDIX

Existing and Proposed Drawings of the Development

Previous Investigation for 19-20 High Holborn (J15193)

Preliminary UXO Assessment

Ground Movement Assessment

SOIL DISPLACEMENT MODEL RESULTS

P-DISP ANALYSIS

Short Term Movement
(Tabular Input & Contour Plot)

Total Movement
(Tabular Input & Contour Plot)

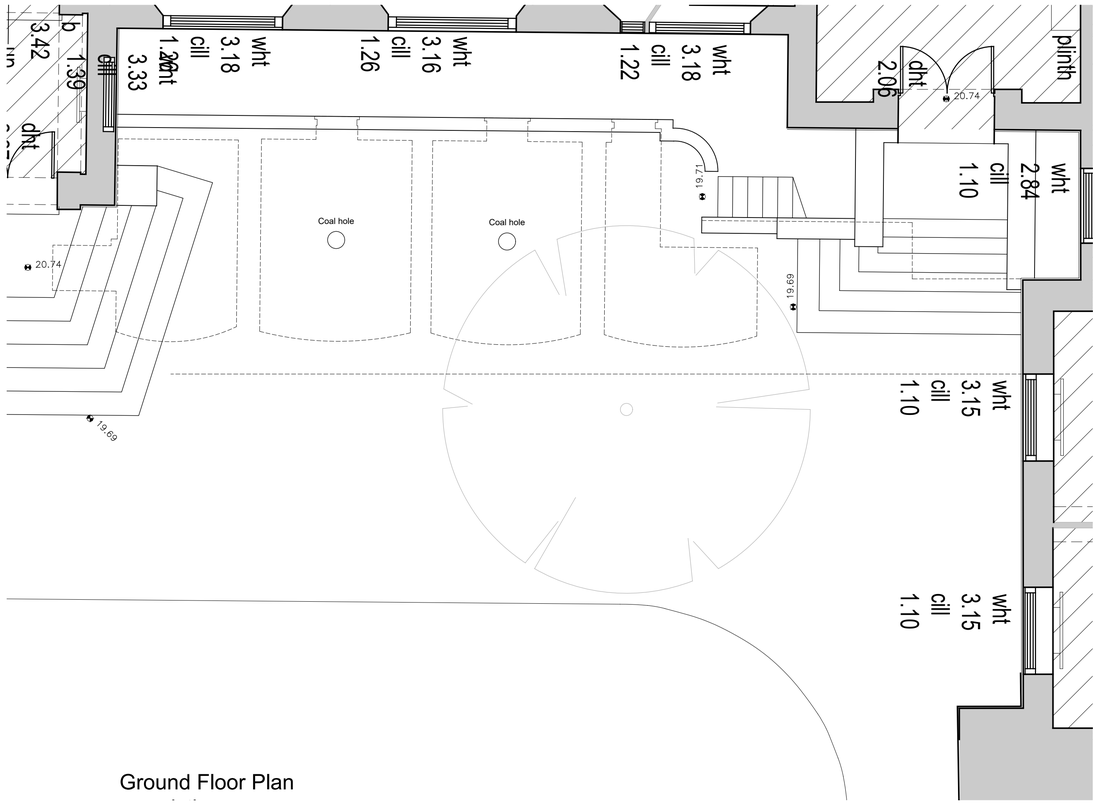
X-DISP ANALYSIS

RC Wall Installation
(Tabular Input & Contour Plots)

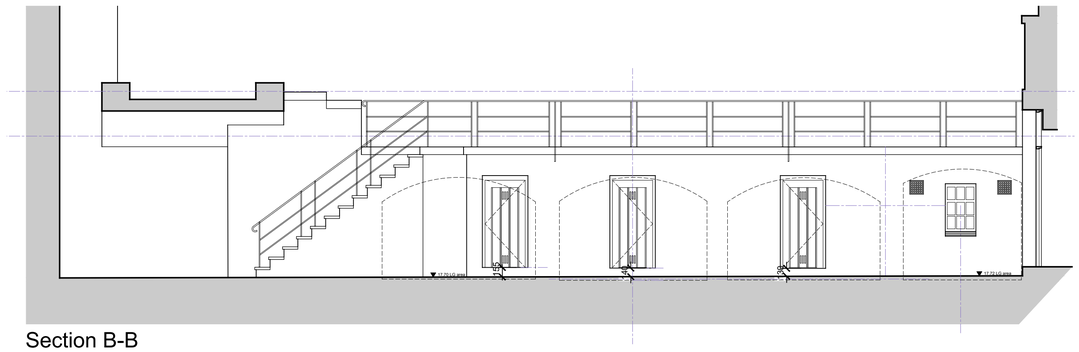
Underpinning and Excavation
(Tabular Input & Contour Plots)

BUILDING DAMAGE ASSESSMENT (X-DISP)

Tabular Output of Results



Ground Floor Plan



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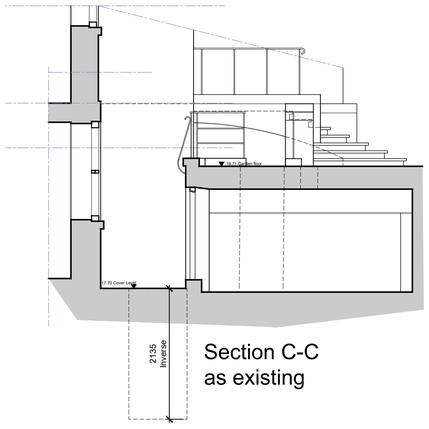

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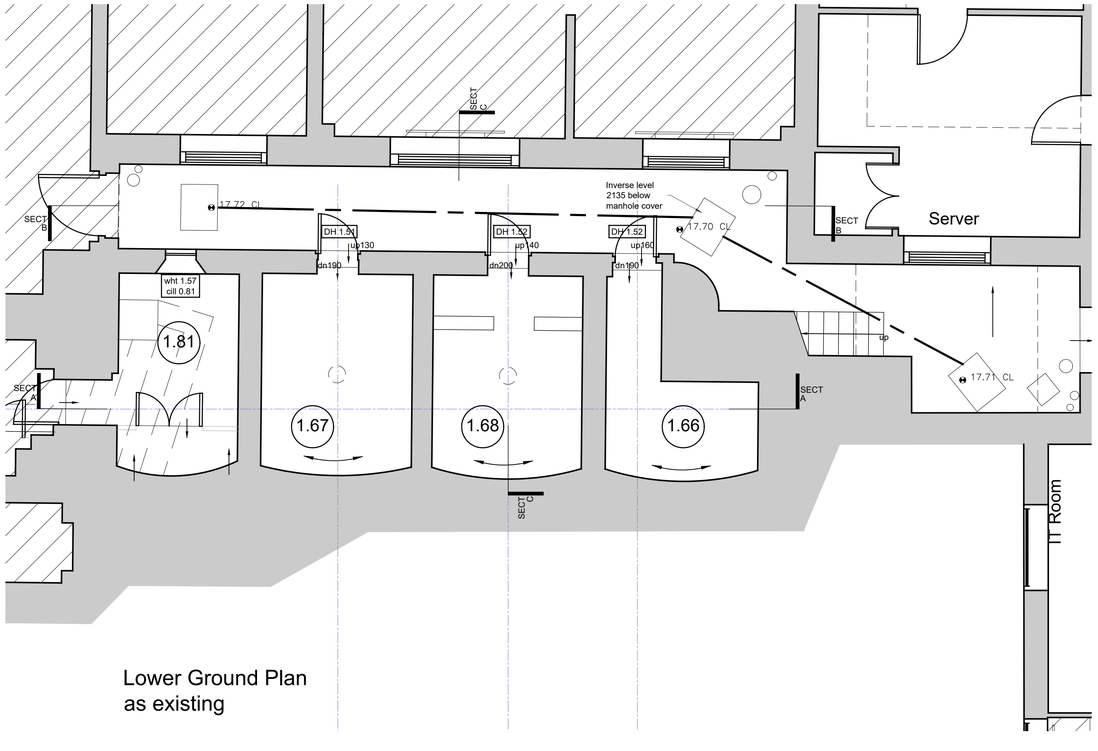
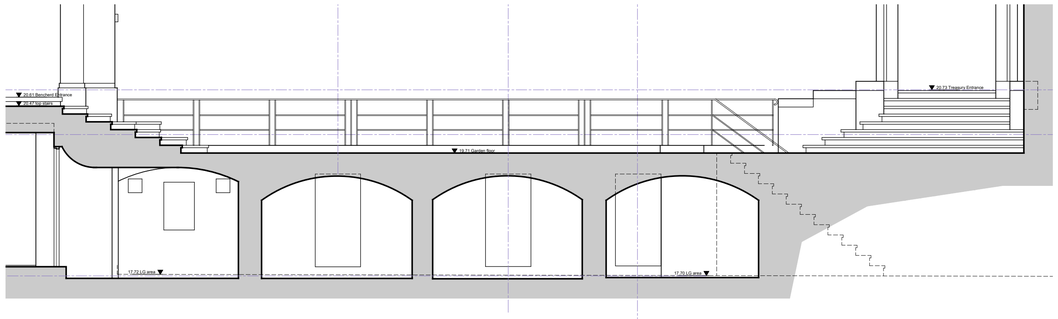


Lower Ground Plan
as existing



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Rev	Date	Revision	By	Chk
E	17.01.20	ISSUED FOR TENDER	AM	***
F	03.02.20	- Existing tree added	AM	***
		- North and scale bar added		

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Client
The Honourable Society of Gray's Inn

Project Name
Law School
Holker Library

Drawing
Below Ground Vaults
South Square, as Existing

Scale
1:50 @A1 1:100@A3

Drawn by
ANM 11 Dec 2019
Checked by
RJY 11 Dec 2019

Project No.	Drawing No	Revision
HK 2252	01.047	F

A1

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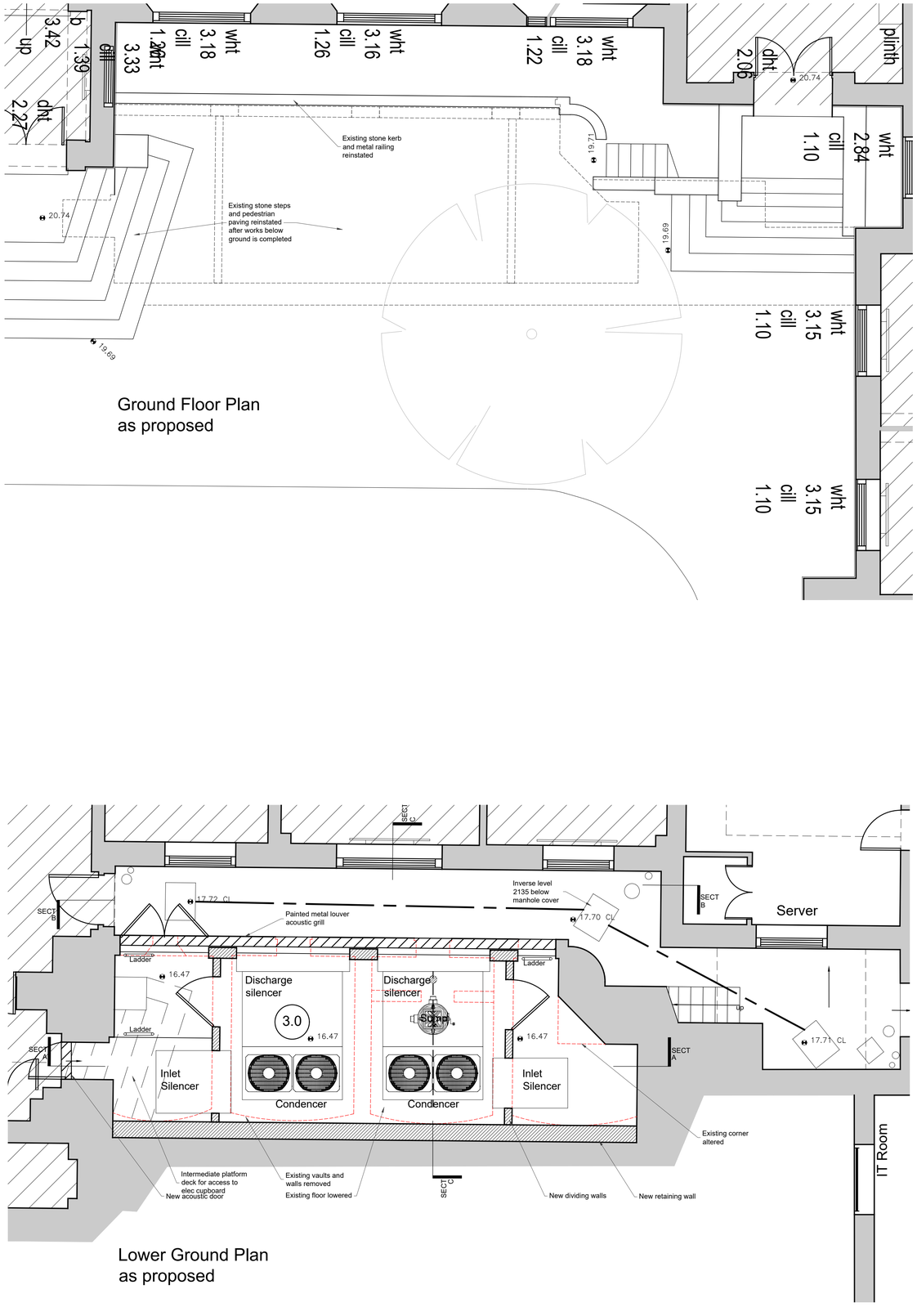
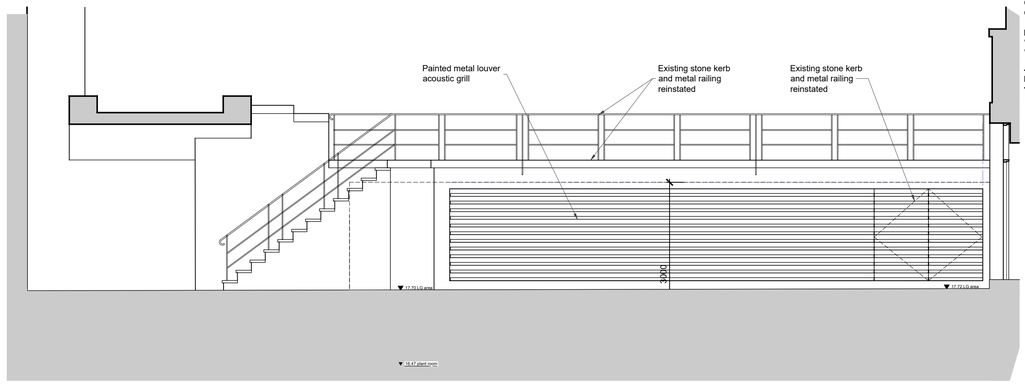
F	03.02.20	- Existing tree added	AM	***
		- North and scale bar added		



Ground Floor Plan
as proposed



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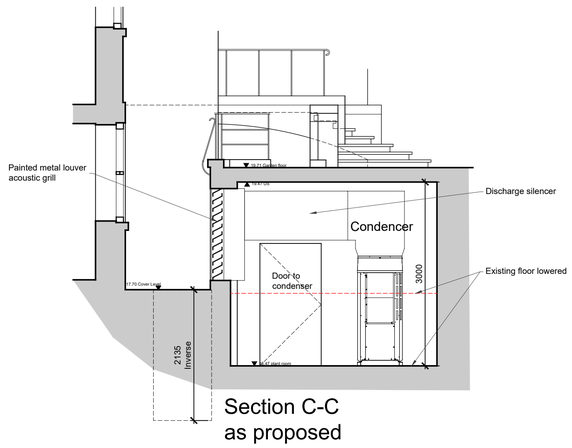

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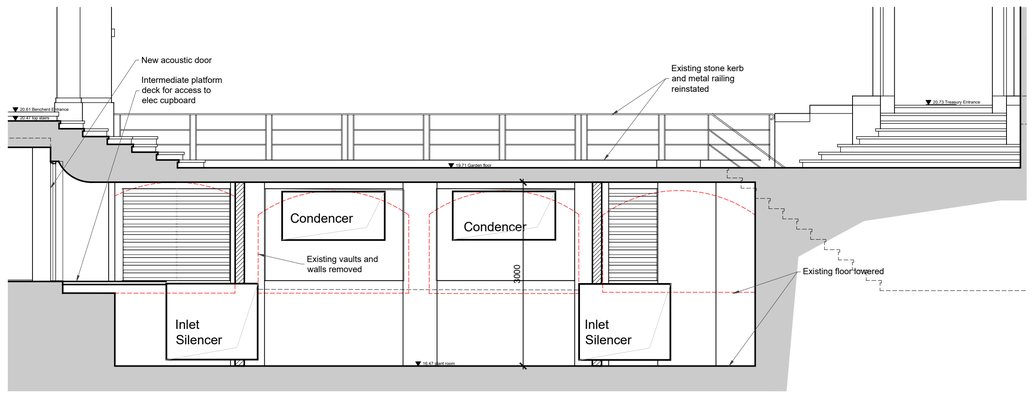
Lower Ground Plan
as proposed



Section A-A
as proposed

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Project Name
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Holker Library

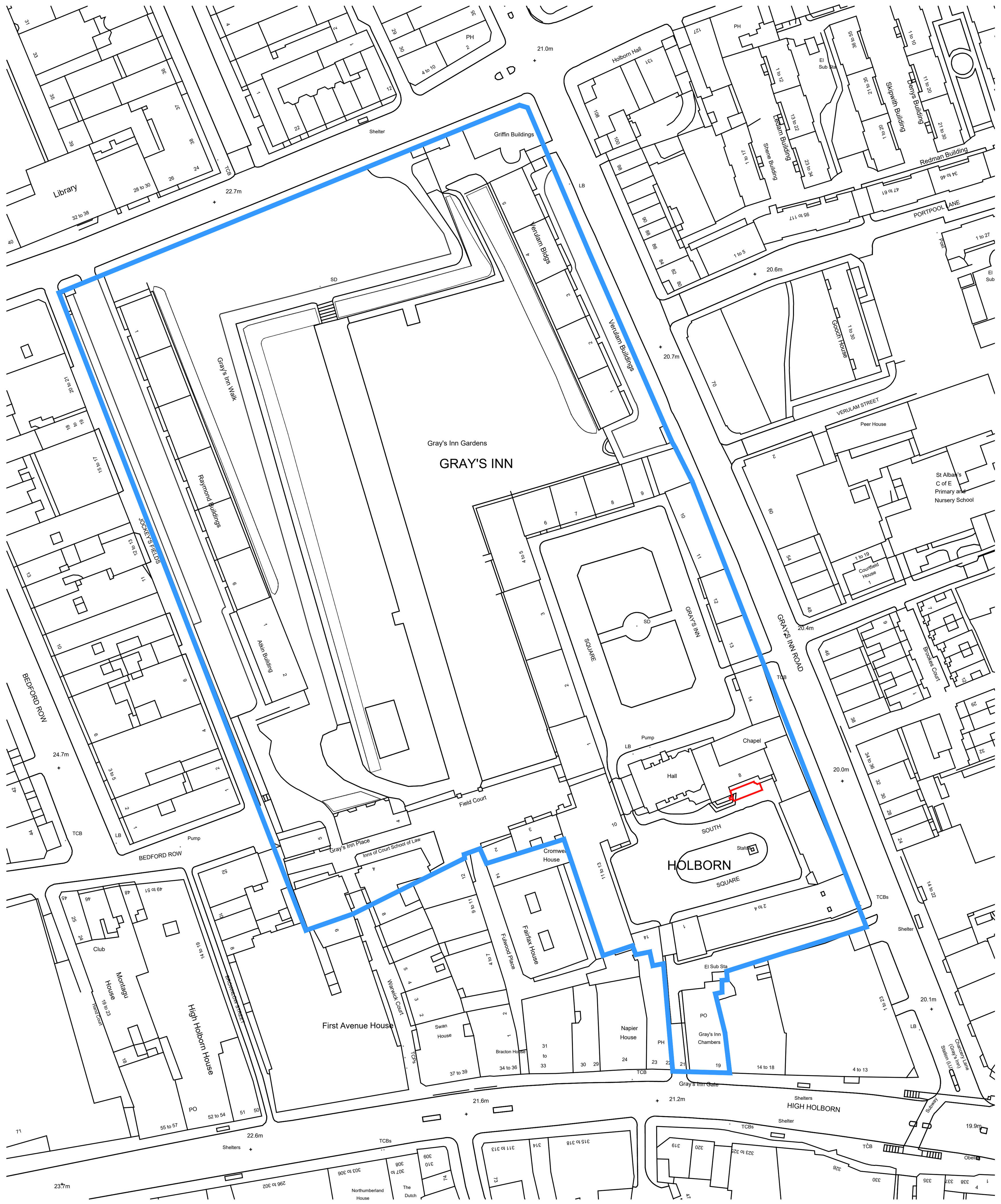
Drawing
Below Ground Vaults
South Square, as Proposed

Scale
1:50 @A1 1:100@A3

Drawn by
ANM 18 Dec 2019

Checked by
RJY 18 Dec 2019

Project No.	Drawing No	Revision
HK 2252	01.048	F



Location Plan

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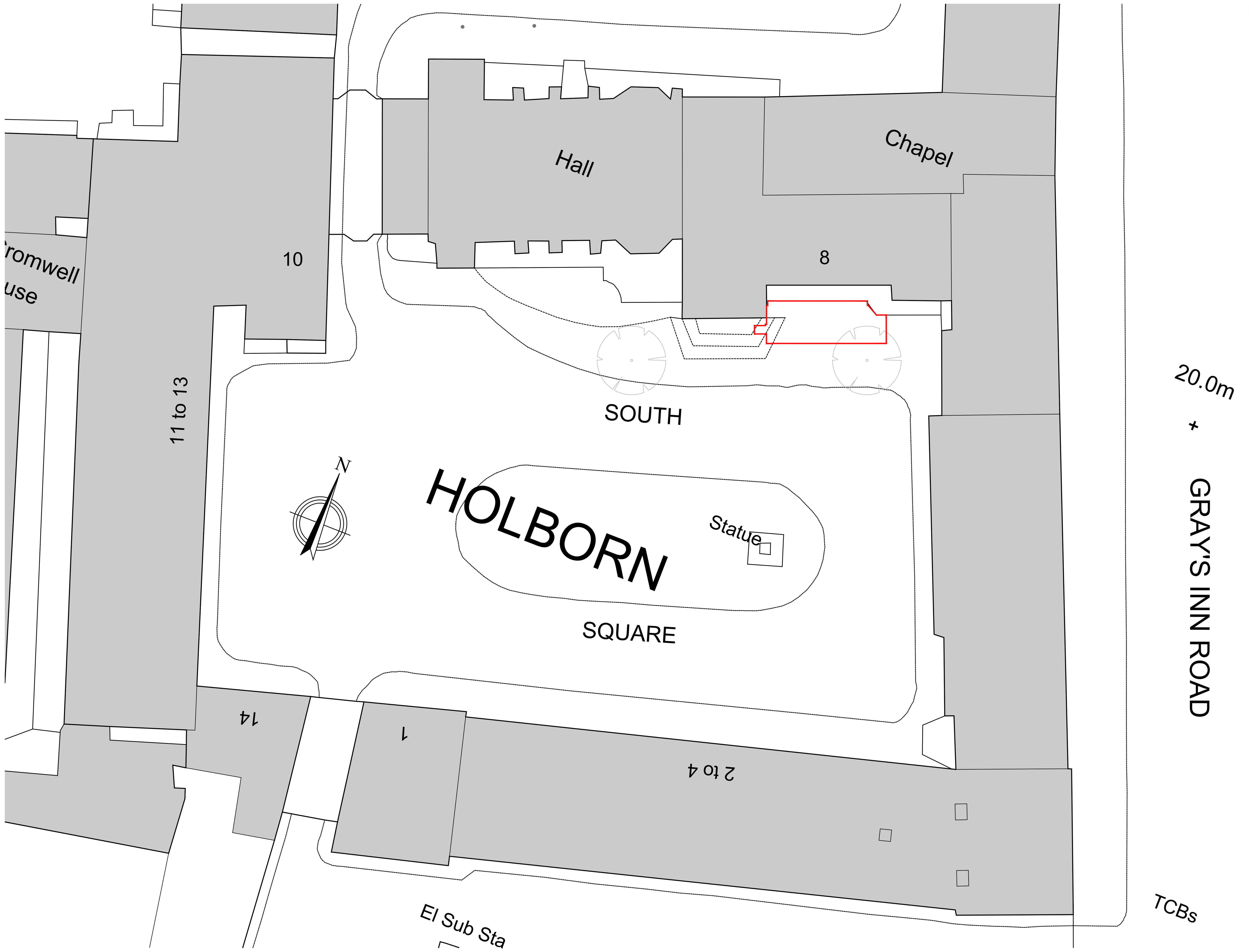

SITE PLAN

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F	03.02.20	Site trees added	AM	***

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Client
The Honourable Society of Gray's Inn

Project Name
Law School
Holker Library

Drawing
Below Ground Vaults, South Sqaure
Site and Location plans

Scale
1:1250 & 1:250 @A1 1:2500 & 1:500 @ A3

Drawn by
ANM 19 Dec 2019
Checked by
RJY 19 Dec 2019

Project No.	Drawing No	Revision
HK 2252	01.049	F

SITE INVESTIGATION & BASEMENT IMPACT ASSESSMENT REPORT

19-21 High Holborn
London WC1

Client: The Honourable Society of Gray's Inn

Engineer: AECOM

J15193

November 2016




GEA Geotechnical & Environmental Associates

Document Control

Project title	19–21 High Holborn, London, WC1V 6BS	**Project ref**	J15193
Report prepared by	Caroline Anderson MEng AUS FGS		
With input from	Martin Cooper BEng CEng MICE FGS		
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	Rupert Evans MSc CEnv CWEM MCIWEM AIEMA		
Report checked and approved for issue by	Steve Branch BSc MSc CGeol FGS FRGS MIEnvSc		

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1	Final	15 September 2015	
2	Final (revised)	26 November 2015	
3	Final (revised)	29 November 2016	

This report has been issued by the GEA office indicated below. Any enquiries regarding the report should be directed to the office indicated or to Steve Branch in our Herts office.

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☐	Nottinghamshire	tel 01509 674888	midlands@gea-ltd.co.uk

CONTENTS

EXECUTIVE SUMMARY

This executive summary contains an overview of the key findings and conclusions. No reliance should be placed on any part of the executive summary until the whole of the report has been read. Other sections of the report may contain information that puts into context the findings that are summarised in the executive summary.

BRIEF

This report describes the findings of a site investigation by Geotechnical and Environmental Associates Limited (GEA) on the instructions of AECOM, on behalf of The Honourable Society of Gray's Inn, with respect to the demolition of the existing four storey extension at the rear of the building and subsequent construction of a new five-storey extension, together with the extension of the existing basement beneath the proposed rear extension. The purpose of the investigation has been to research the history of the site with respect to possible contaminative uses, to determine the ground conditions, to assess the extent of any contamination and to provide information to assist with the design of the basement structure and suitable foundations. The report also includes information required to comply with London Borough of Camden (LBC) Planning Guidance CPG4, relating to the requirement for a Basement Impact Assessment (BIA).

SITE DESCRIPTION

John Rocque's 1746 Map of London and Greenwood's Map of London, dated 1827, show the site to be developed, with the road High Holbourn running east-west, which was later named High Holborn, with an access road shown that ran south to north from High Holbourn to Holbourn Court and Gray's Inn in the north. An Insurance Plan dated 1922 shows that the buildings were in use as offices at that time, while a number of small single storey buildings had been constructed adjacent to the public access road at the rear of the building. The map dated 1953 annotates the former chambers buildings immediately to the north as 'ruins', which were later reconstructed by the time of the map dated 1958. The 1966 Insurance Plan shows that the small single storey buildings had been removed and replaced with a small car parking area, while the building was shown to be in use as offices and chambers. The map dated 1975 shows an electricity substation to be present immediately to the northeast of site. By the time of the 1989map , the buildings formerly occupied by the post office and public house in the east had been redeveloped to form a single building and on the 1994 map dated the building is annotated as 'Gray's Inn Chambers'. The site and surrounding area have since remained largely unchanged.

GROUND CONDITIONS

Below a significant thickness of made ground, the Hackney Gravel was encountered over the London Clay Formation, which was proved to the full depth investigated. The made ground comprised brown gravelly sand, very sandy clayey silt and silty sandy gravelly clay with frequent crushed brick, concrete, ash, tile, shell and coal and extended to a maximum depth of 4.00 m (15.85 m OD). Adjacent to the western elevation of the existing building, the Hackney Gravel initially comprised soft to firm brown silty sandy very gravelly clay which extended to a depth of 4.60 m (15.84 m OD). Below this layer, or directly below the made ground elsewhere, the Hackney Gravel comprised medium dense to dense brown and pale brown slightly silty sand and gravel, and extended to a depth of 6.60 m (13.25 m OD). The London Clay initially comprised firm brown clay to a depth of 6.80 m (13.05 m OD), over high strength stiff fissured dark brownish grey silty clay to a depth of 15.50 m (4.35 m OD) over fissured dark brown very silty clay with occasional fine shell fragments, medium selenite crystals and black carbonaceous material to the full depth investigated, of 20.00 m (-0.15 m OD). Claystones were encountered within the London Clay at depths of 14.30 m (5.55 m OD), 15.50 m (4.35 m OD) and 18.20 m (1.65 m OD). Groundwater was measured at a shallowest depth of 5.00 m (14.85 m OD). The results of the contamination testing indicated elevated concentrations of lead only. Concentrations of pH were found to be significantly elevated within a single sample of made ground.

RECOMMENDATIONS

The proposed 4.4 m deep basement extension is likely to have a formation level within the medium dense to dense brown and pale brown slightly silty sand and gravel of the Hackney Gravel, although the founding level is close to the base of the soft to firm silty sandy very gravelly clay initial horizons of the Hackney Gravel and the basement foundations should extend through this stratum in order to avoid potentially excessive settlements. Groundwater is unlikely to be encountered within the proposed basement extension although monitoring of the standpipes should be continued to confirm this view. End users will be effectively isolated from direct contact with the identified contaminants by the building and areas of external hardstanding, in addition to which the contamination will be removed as part of the basement excavation. Furthermore, it is concluded that the proposed development is unlikely to result in any specific land or slope stability issues, groundwater or surface water issues and will not therefore have any adverse effect on any nearby sites.

Part 1: INVESTIGATION REPORT

This section of the report details the objectives of the investigation, the work that has been carried out to meet these objectives and the results of the investigation. Interpretation of the findings is presented in Part 2.

1.0 INTRODUCTION

Geotechnical and Environmental Associates Limited (GEA) has been commissioned by AECOM, on behalf of The Honourable Society of Gray's Inn, to carry out a desk study and ground investigation at 19-21 High Holborn, London, WC1V 6BS. This report also forms part of a Basement Impact Assessment (BIA), which has been carried out in accordance with guidelines from the London Borough of Camden in support of a planning application.

1.1 Proposed Development

Consideration is being given to the demolition of a four-storey extension at the rear of the existing building and subsequent construction of a new five-storey extension. The existing roof slab will be demolished and replaced with a new lightweight deck. The existing basement beneath the main building will be extended below the new five-storey extension, with no proposed increase in depth to the existing basement. The building will be used for commercial purposes only and the proposed development will not incorporate any areas of soft landscaping.

This report is specific to the proposed development and the advice herein should be reviewed once the development proposals have been finalised.

1.2 Purpose of Work

The principal technical objectives of the work carried out were as follows:

- to check the history of the site with respect to previous contaminative uses;
- to determine the ground conditions and their engineering properties;
- to identify the configuration of existing foundations;
- to assess the possible impact of the proposed development on the local hydrogeology and surrounding structures;
- to provide advice with respect to the design of suitable foundations and retaining walls;
- to provide an assessment of the risk of UXO beneath the site;
- to provide an indication of the degree of soil contamination present; and
- to assess the risk that any such contamination may pose to the proposed development, its users or the wider environment.

1.3 Scope of Work

In order to meet the above objectives, a desk study was carried out, followed by a ground investigation. The desk study comprised:

- a review of readily available geological and hydrogeological maps;
- a review of historical Ordnance Survey (OS) maps and environmental searches sourced from the Envirocheck database;
- review of a detailed UXO risk assessment commissioned by GEA and carried out by 1st Line Defence (ref 2542JF00 dated 20/07/15); and
- a walkover survey of the site carried out in conjunction with the fieldwork.

In the light of the desk study, an intrusive ground investigation was carried out which comprised, in summary, the following activities:

- a single cable percussion borehole advanced to a depth of 20.0 m;
- standard penetration tests (SPTs) at regular intervals to provide quantitative data on the strength of the soils;
- a single window sampler borehole, advanced by means of an open-drive (Terrier) rig to a depth of 5.00 m;
- the installation of a gas and groundwater monitoring standpipe in each of the boreholes, and subsequent monitoring visits on three occasions;
- a series of eight trial pits excavated by hand to expose the existing footings;
- laboratory testing of selected soil samples for geotechnical purposes and for the presence of contamination; and
- provision of a report presenting and interpreting the above data, together with our advice and recommendations with respect to the proposed development.

The report includes a contaminated land assessment which has been undertaken in accordance with the methodology presented in Contaminated Land Report (CLR) 11[1] and involves identifying, making decisions on, and taking appropriate action to deal with, land contamination in a way that is consistent with government policies and legislation within the United Kingdom. The risk assessment is thus divided into three stages comprising Preliminary Risk Assessment, Generic Quantitative Risk Assessment, and Site-Specific Risk Assessment.

1.3.1 Basement Impact Assessment

The work carried out also includes a Hydrological and Hydrogeological Assessment and Land Stability Assessment (also referred to as Slope Stability Assessment), all of which form part of the BIA procedure specified in the London Borough of Camden (LBC) Planning Guidance CPG4[2] and their Guidance for Subterranean Development[3] prepared by Arup ('the Arup

1 *Model Procedures for the Management of Land Contamination* issued jointly by the Environment Agency and the Department for Environment, Food and Rural Affairs (DEFRA) Sept 2004
2 London Borough of Camden Planning Guidance CPG4 *Basements and lightwells* July 2015
3 Ove Arup & Partners (2010) *Camden geological, hydrogeological and hydrological study. Guidance for Subterranean Development.* For London Borough of Camden November 2010

Report'). The aim of the work is to provide information on surface water, groundwater and land stability and in particular to assess whether the development will affect neighbouring properties or groundwater movements and whether any identified impacts can be appropriately mitigated by the design of the development.

1.3.2 Qualifications

The land stability element of the Basement Impact Assessment (BIA) has been carried out by Martin Cooper, a BEng in Civil Engineering, a chartered engineer (CEng), member of the Institution of Civil Engineers (MICE), and Fellow of the Geological Society (FGS) who has over 20 years' specialist experience in ground engineering. The subterranean (groundwater) flow assessment has been carried out by John Evans, MSc in Hydrogeology, Chartered Geologist (CGeol) and Fellow of the Geological Society of London (FGS). The surface water and flooding assessment has been carried out by Rupert Evans, a hydrologist with more than ten years consultancy experience in flood risk assessment, surface water drainage schemes and hydrology / hydraulic modelling. Rupert Evans is a Chartered Environmentalist, Chartered Water and Environmental Manager and a Member of CIWEM.

The assessments have been made in conjunction with Steve Branch, a BSc in Engineering Geology and Geotechnics, MSc in Geotechnical Engineering, a Chartered Geologist (CGeol) and Fellow of the Geological Society (FGS) with over 25 years' experience in geotechnical engineering and engineering geology.

All assessors meet the qualification requirements of the Council guidance.

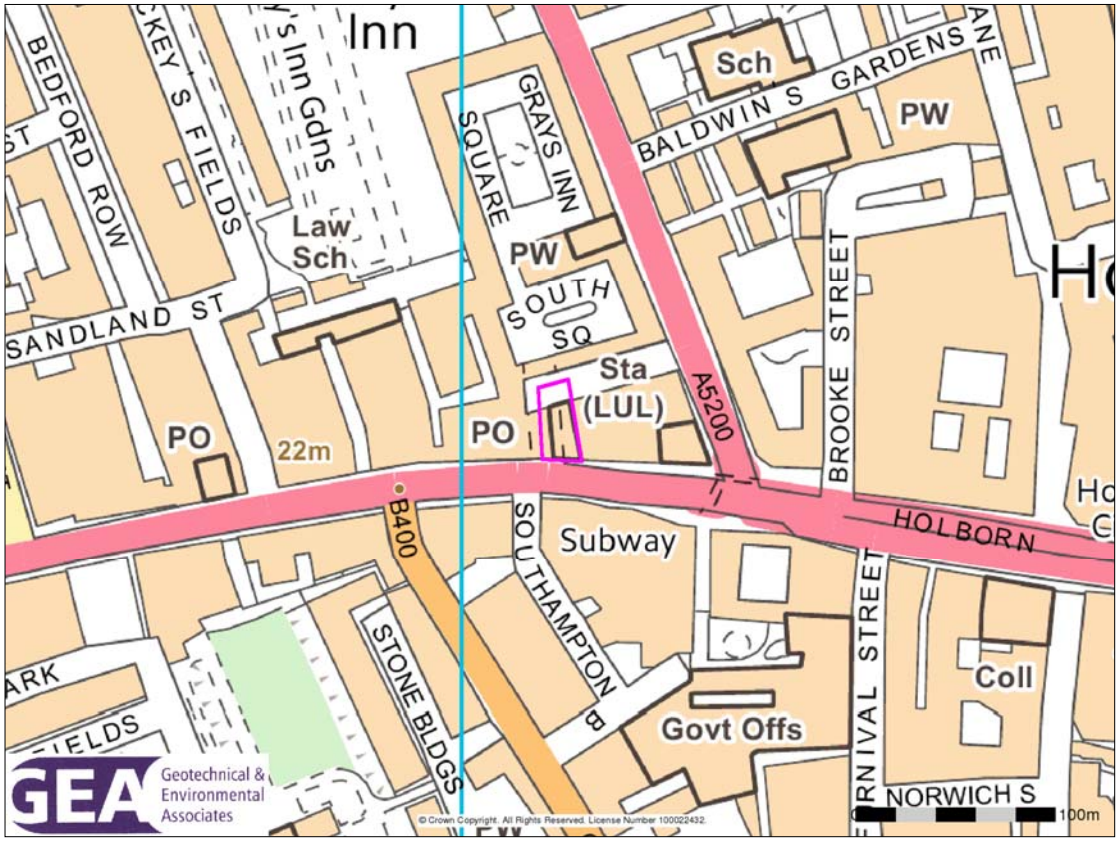
1.4 Limitations

The conclusions and recommendations made in this report are limited to those that can be made on the basis of the investigation. The results of the work should be viewed in the context of the range of data sources consulted, the number of locations where the ground was sampled and the number of soil, gas or groundwater samples tested; no liability can be accepted for information in other data sources or conditions not revealed by the sampling or testing. Any comments made on the basis of information obtained from the client or other third parties are given in good faith on the assumption that the information is accurate; no independent validation of such information has been made by GEA.

2.0 THE SITE

2.1 Site Description

The site is located approximately 85 m west of Chancery Lane London Underground station and 520 m east of Holborn London Underground station. The site fronts onto High Holborn to the south and is bounded to the west by No 22 High Holborn, the four storey Cittie of Yorke public house, to the east by a six storey commercial building and to the north by a private access road leading to Gray's Inn Square to the north. The site may additionally be located by National Grid Reference 531051, 181641 and is shown on the map overleaf.



The site is irregular in shape and measures roughly 30 m north-south by 20 m east-west. The site is occupied by a seven-storey commercial building, which occupies roughly three-quarters of the site in the southeast and at the time of the walkover was occupied at ground level by a stationers. A private access road runs south-north from High Holborn along the west of the site and joins with another private access road orientated east-west from Gray's Inn Road to the east. Above the private access road in the west is five-storey building that is suspended from the public house and commercial building on either side; the ground level of the suspended building is occupied by an archway to allow access to the private road. There is an electricity substation immediately to the northeast of the site at the rear of the commercial building and accessed from the northern private access road. The site is sensibly level with an approximate ground level of 20.0 m OD, with no discernible fall in level and is devoid of vegetation.

During the site walkover it was noted that there is a single level basement that extends beneath the seven-storey commercial building. The adjacent Cittie of Yorke public house was found to have a single level basement and rudimentary measurements taken during the fieldwork suggests the basement does not extend beneath the road in the west.

The Central Line of London Underground runs directly under High Holborn which borders the site to the south.

2.2 Site History

The site history has been researched by reference to historical Ordnance Survey (OS) maps sourced from the Envirocheck database.

John Rocque's 1746 Map of London and Greenwood's Map of London, dated 1827, show the site to be developed with the road High Holbourn, running east-west, which was later named High Holborn, with an access road shown that ran south to north from High Holbourn to

Holbourn Court and Gray's Inn in the north. The Charles Booth map, dated 1898, indicates the site was developed with middle-class housing. The next map, dated 1951, shows the site was unchanged although by 1875 the Gray's Inn was annotated at the location of the present-day archway above the access road, and the building in the south was annotated as a Post Office. Also at that time the buildings to the north were annotated as 'chambers' and the 'South Square' of 'Holborn Court'. The map dated 1896 shows the building to the east of the post office was in use as a public house. An Insurance Plan dated 1922 shows that the buildings were in use as offices at that time, while a number of small single storey buildings had been constructed adjacent to the public access road at the rear of the building.

The map dated 1953 annotates the public house, central building and archway were numbered 19 to 21 inclusive, while the former chambers buildings immediately to the north as 'ruins', which were later reconstructed by the time of the map dated 1958. The 1966 Insurance Plan shows that the small single storey buildings at the rear of the main building had been removed and replaced with a small car parking area, while the building was shown to be in use as offices and chambers. The map dated 1975 shows an electricity substation to be present immediately to the northeast of site. By the time of the 1989 map, the buildings formerly occupied by the post office and public house in the east had been redeveloped to form a single building and on the 1994 map the building is annotated as 'Gray's Inn Chambers'. The site and surrounding area have since remained largely unchanged.

2.3 Other Information

A search of public registers and databases has been made via the Envirocheck database and relevant extracts from the search are appended. Full results of the search can be provided if required.

The search has revealed no records of any landfills, waste treatment, management or disposal sites within 250 m of the site. There have also been no pollution incidents to controlled waters within 250 m of the site that present a concern to the quality of water below the site.

There are seven contemporary trade directory entries listed within 50 m of the site - a laboratory, an inactive printers and gas suppliers, an active commercial cleaning company and an inactive dry cleaners. Other nearby business uses include an office equipment, servicing and maintenance company and a hardware store.

There are no fuel station entries listed within 500 m of the site.

The search indicated that the site is located in an area where less than 1% of homes are affected by radon emissions; which is the lowest classification given by the Health Protection Agency (HPA) and therefore no radon protective measures will be necessary.

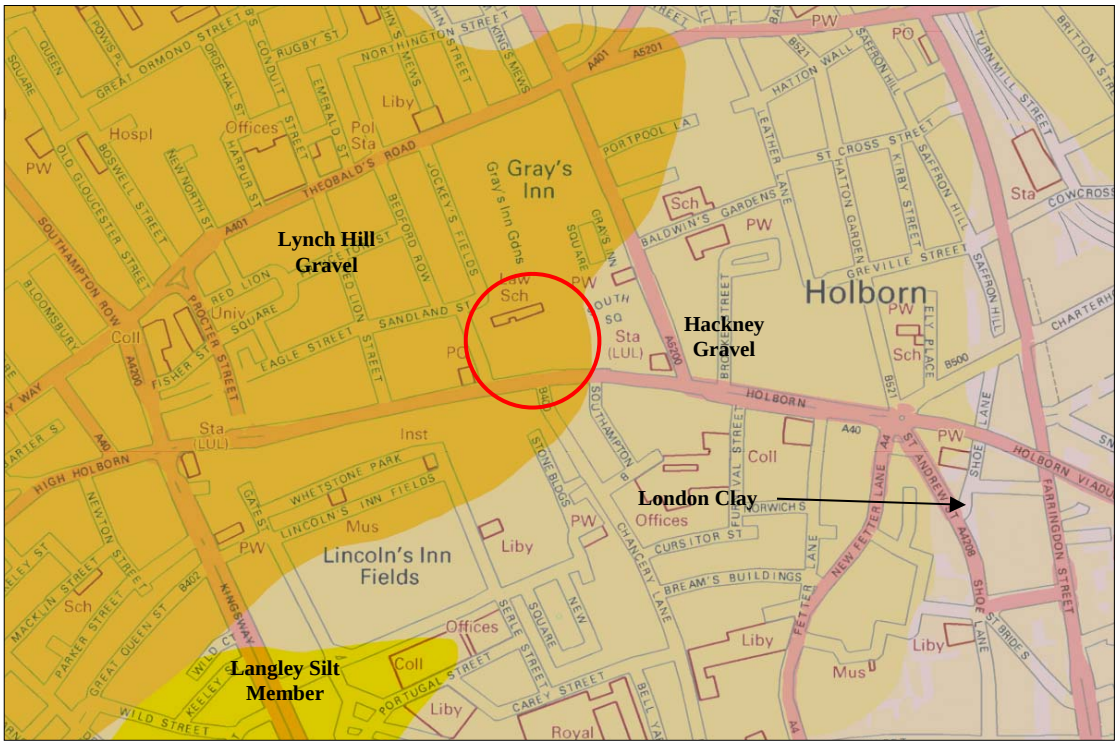
The site is not located within a Nitrate Vulnerable Zone or any other area of sensitive land use.

The Central Line of the London Underground runs beneath High Holborn, immediately to the south of the site. London Underground were consulted with regard to the safe location of the proposed boreholes as part of this investigation and will require on-going consultation and assessment throughout the development in order to ensure that the proposed basement will not impact upon their infrastructure. Additionally, a number of former post office tunnels that now belong to British Telecom are known to be located close to the site and a dialogue should be opened prior to the commencement of construction works.

2.4 Geology

The British Geological Survey (BGS) map of the area (Sheet 256) indicates the site to be directly underlain by the Hackney Gravel over the London Clay, although the map also shows that the site is close to the boundary with the Lynch Hill Gravel in the northwest.

A digital map sourced from FIND maps is included below, indicating the location of the site with respect to the geological boundaries.



Plan: Geological Map

According to the BGS memoir the Lynch Hill and Hackney Gravels predominantly comprise sand and gravel, with localised lenses of clay and silt and is characteristically free-draining. The London Clay Formation is homogenous, slightly calcareous silty clay to very silty clay, with some beds of clayey silt grading to silty fine grained sand.

GEA has previously carried out a ground investigation approximately 90 m to the northeast of the site on Gray's Inn Road. Beneath the existing basement a moderate thickness of made ground was encountered over the Hackney Gravel, which was in turn underlain by the London Clay and finally the Lambeth Group, which was proved to the full depth of the investigation, of 25.70 m (-11.20 m OD).

The Hackney Gravel comprised an initial horizon of medium dense brown very clayey very gravelly fine and medium sand to a level of 3.75 m (15.05 m OD), over medium dense and dense brown slightly clayey very sandy gravel, locally very gravelly sand to depths of between 7.70 m (11.10 m OD) and 3.20 m (11.30 m OD).

The London Clay comprised an initial weathered horizon comprised of firm medium strength brown clay with occasional mica to levels of between 10.00 m (8.80 m OD) and 3.60 m (10.90 m OD). The underlying unweathered London Clay comprised very thickly interbedded

very stiff very high strength dark grey slightly sandy clay with pale brown sand lenses and foraminifera, and very stiff very high strength fissured dark grey clay, to levels of between 17.20 m (-2.70 m OD) and 23.90 m (-5.10 m OD).

The Lambeth Group comprised very stiff very high strength and hard extremely high strength fissured yellowish brown, red and bluish grey mottled clay to the maximum depth investigated. In a single borehole only, very dense light grey and light brown silty fine and medium sand possibly interbedded with brown slightly sandy clayey silt was encountered to the maximum depth investigated of 25.70 m (-11.20 m OD).

An historical BGS borehole carried out roughly 150 m west of the site encountered gravels to a depth of 2.1 m over London Clay to a depth of 23.4 m. Below this the Lambeth Group was encountered to a depth of around 44 m.

2.5 Hydrology and Hydrogeology

The Hackney Gravel and Lynch Hill Gravel are classified as Secondary 'A' Aquifers, referring to permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. The underlying London Clay is classified as 'Unproductive Strata', as defined by the Environment Agency as rock or drift deposits with low permeability that have negligible significance for water supply or river base flow.

The nearest surface water feature is located 414 m to the southeast of the site although the nature of the feature is not known.

Reference to the Lost Rivers of London[4] indicates that a tributary of the River Fleet flowed in an easterly direction, approximately 330 m to the northwest of the site. The direction of groundwater flow beneath the site is likely to be in a southerly direction, downslope towards the River Thames.

The site is not at risk of flooding from rivers or sea, as defined by the Environment Agency, nor is it indicated at being at risk from surface water flooding. The site is not located within a Groundwater Source Protection Zone as defined by the EA.

Any surface water runoff that infiltrates the shallow made ground and Hackney or Lynch Hill Gravels above the London Clay is likely to flow southwards along the surface of the London Clay towards the River Thames which is located roughly 800 m to the south.

The permeability of the Hackney Gravel is expected to range between about 1×10^{-6} m/s and 1×10^{-4} m/s, whereas in contrast, any groundwater flow within the London Clay will be at a very slow rate, due to its negligible permeability. Published data for the permeability of the London Clay indicates the horizontal permeability to generally range between 1×10^{-10} m/s and 1×10^{-8} m/s, with an even lower vertical permeability. The London Clay cannot therefore support groundwater flow and as such do not support a "water table" or continuous piezometric surface. Boreholes constructed within clays do fill with water due to the often high water content of shallow clays; however, this is not reflective of groundwater flow in a porous and permeable saturated strata.

Subsequent monitoring at the site along Gray's Inn Road measured groundwater at levels of between 14.64 m OD and 15.27 m OD in the Hackney Gravel. Deeper groundwater has been encountered at levels of between 10.80 m OD and 14.83 m OD in the London Clay and at levels of between 9.29 m OD and 9.55 m OD in the Lambeth Group.

[4] Nicholas Barton (2000) *London's Lost Rivers.* Historical Publications Ltd

2.6 Preliminary Risk Assessment

Part IIA of the Environmental Protection Act 1990, which was inserted into that Act by Section 57 of the Environment Act 1995, provides the main regulatory regime for the identification and remediation of contaminated land.

The determination of contaminated sites is based on a "suitable for use" approach which involves managing the risks posed by contaminated land by making risk-based decisions. This risk assessment is carried out on the basis of a source-pathway-receptor approach.

2.6.1 Source

The desk study has indicated that the site has had a long history of residential and retail development, with the existing property occupying the site since 1989. The site is therefore not considered to have had a contaminative history and no specific possible sources of contamination have been identified on the site, or within the immediate surrounding area, which comprises residential streets and shops.

2.6.2 Receptor

The future end users of the commercial building will represent high sensitivity receptors. The site is underlain by a Secondary 'A' Aquifer and therefore groundwater is considered to be a relatively sensitive receptor. Similarly, perched water may also exist in the made ground or in the vicinity of existing foundations. Buried services are likely to come into contact with any contaminants present within the soils through which they pass and site workers are likely to come into contact with any contaminants present during demolition and construction works.

2.6.3 Pathway

As the site is to remain, for the majority, covered by the footprint of the existing building there will be limited potential contaminant exposure pathways as the building will effectively form a barrier between any contaminants within the near-surface soils and end-users or infiltration of surface water. Furthermore it is understood that areas of soft landscaping will not form part of the proposed development.

Buried services will be exposed to any contaminants present within the soil through direct contact and site workers will come into contact with the soils during construction works. There is thus considered to be very low potential for a contaminant pathway to be present between any potential contaminant source and a target for the particular contaminant.

2.6.4 Preliminary Risk Appraisal

On the basis of the above it is considered that there is a low risk of there being a significant contaminant linkage at this site, which would result in a requirement for major remediation work. Furthermore as there is no evidence of filled ground within the vicinity, there is not considered to be a significant potential for hazardous soil gas to be present on or migrating towards the site; there should thus be no need to consider soil gas exclusion systems.

3.0 SCREENING

The LBC guidance suggests that any development proposal that includes a subterranean basement should be screened to determine whether or not a full BIA is required.

3.1 Screening Assessment

A number of screening tools are included in the Arup report and for the purposes of this report reference has been made to Appendices E1, E2 and E3 which include a series of questions within screening flowcharts for surface flow and flooding, subterranean (groundwater) flow and land stability.

The flowchart questions and responses to these questions are tabulated overleaf.

3.1.1 Subterranean (groundwater) Screening Assessment

Question	Response for Nos 19 to 21 High Holborn
1a. Is the site located directly above an aquifer?	*Yes. The site is located above a Secondary 'A' Aquifer as designated by the EA.*
1b. Will the proposed basement extend beneath the water table surface?	*Possibly. Groundwater is anticipated to be present within the Hackney Gravel at a level of approximately 15.3 m OD, whilst the deepest excavations are understood to extend below the site to a depth of 4.4 m (15.6 m OD)*
2. Is the site within 100 m of a watercourse, well (used/ disused) or potential spring line?	No. The site is located 330 m to the southeast of the former River Fleet and 800 m to the north of the River Thames.
3. Is the site within the catchment of the pond chains on Hampstead Heath?	No.
4. Will the proposed basement development result in a change in the proportion of hard surfaced / paved areas?	No, the area of the proposed basement extension is already surfaced with cobbles and concrete
5. As part of the site drainage, will more surface water (e.g. rainfall and run-off) than at present be discharged to the ground (e.g. via soakaways and/or SUDS)?	No. Site drainage will continue to be directed to public sewer, as per the existing situation.
6. Is the lowest point of the proposed excavation (allowing for any drainage and foundation space under the basement floor) close to or lower than, the mean water level in any local pond or spring line?	No.

The above assessment has identified the following potential issues that need to be assessed:

Q1a The site is located directly above an aquifer.
Q1b The proposed basement could extend beneath the water table.

3.1.2 Stability Screening Assessment

Question	Response for Nos 19 to 21 High Holborn
1. Does the existing site include slopes, natural or manmade, greater than 7°?	No.
2. Will the proposed re-profiling of landscaping at the site change slopes at the property boundary to more than 7°?	No.
3. Does the development neighbour land, including railway cuttings and the like, with a slope greater than 7°?	No. Figure 16 of the Arup report confirms that the site is not located within an area with slope greater than 7°.

Question	Response for Nos 19 to 21 High Holborn
4. Is the site within a wider hillside setting in which the general slope is greater than 7°?	No. Not according to the slope angle map (figure 16) in the Arup report.
5. Is the London Clay the shallowest strata at the site?	No.
6. Will any trees be felled as part of the proposed development and / or are any works proposed within any tree protection zones where trees are to be retained?	No.
7. Is there a history of seasonal shrink-swell subsidence in the local area and / or evidence of such effects at the site?	No. The site is expected to be underlain by the Hackney Gravel.
8. Is the site within 100 m of a watercourse or potential spring line?	No. The site is located 330 m to the southeast of the former River Fleet and 800 m to the north of the River Thames.
9. Is the site within an area of previously worked ground?	No.
10a. Is the site within an aquifer?	*Yes. The site is located above a Secondary 'A' Aquifer as designated by the EA.*
10b. Will the proposed basement extend beneath the water table such that dewatering may be required during construction?	*Possibly. Groundwater is anticipated to be present within the Hackney Gravel at a level of approximately 15.3 m OD, whilst the deepest excavations are understood to extend below the site to a depth of 4.4 m (15.6 m OD)*
11. Is the site within 50 m of Hampstead Heath ponds?	No.
12. Is the site within 5 m of a highway or pedestrian right of way?	*Yes. The site fronts onto High Holborn to the south and footpaths cross the site from south to north and east to west in the north.*
13. Will the proposed basement significantly increase the differential depth of foundations relative to neighbouring properties?	*Yes, the basement will be extended to around 1.7 m below existing basement level.*
14. Is the site over (or within the exclusion zone of) any tunnels, eg railway lines?	Yes, the Central Line LUL tunnel is known to run along High Holborn immediately to the south of the site. There are also post office tunnels in the vicinity of the site.

The above assessment has identified the following potential issues that need to be assessed:

Q10a The site is located directly above an aquifer.
Q10b The proposed basement could extend beneath the water table.
Q12 The site is within 5 m of a public highway.
Q13 The proposed basement is likely to significantly increase the differential depth of foundations relative to the neighbouring properties.
Q14 The site is within the exclusion zone of tunnels.

3.1.3 Surface Flow and Flooding Screening Assessment

Question	Response for Nos 19 to 21 High Holborn
1. Is the site within the catchment of the pond chains on Hampstead Heath?	No. Figure 14 of the Camden geological, hydrogeological and hydrological study – Guidance for subterranean development dated 2010, confirms that the site is not located within this catchment area.
2. As part of the proposed site drainage, will surface water flows (e.g. volume of rainfall and peak run-off) be materially changed from the existing route?	No. There will not be an increase in impermeable area across the ground surface above the basement, so the surface water flow regime will be unchanged. There will be no surface expression of the basement development, so the surface water flow regime will be unchanged. The basement will entirely be beneath the footprint of the proposed building, therefore the 1m distance between the roof of the basement and ground surface as recommended by Chapter 5 of the Arup report does not apply across these areas.
3. Will the proposed basement development result in a change in the proportion of hard surfaced / paved areas?	No. There will not be an increase in impermeable area across the ground surface above the basement. There will be no surface expression of the basement development.
4. Will the proposed basement development result in changes to the profile of the inflows (instantaneous and long term) of surface water being received by adjacent properties or downstream watercourses?	No. There will not be an increase in impermeable area across the ground surface above the basement, so the surface water flow regime will be unchanged. There will be no surface expression of the basement development, so the surface water flow regime will be unchanged. The basement will entirely be beneath the footprint of the proposed building, therefore the 1m distance between the roof of the basement and ground surface as recommended by Chapter 5 of the Arup report does not apply across these areas.
5. Will the proposed basement result in changes to the quality of surface water being received by adjacent properties or downstream watercourses?	No. The proposed basement is very unlikely to result in any changes to the quality of surface water being received by adjacent properties or downstream watercourses as the surface water drainage regime will be unchanged.
6. Is the site in an area identified to have surface water flood risk according to either the Local Flood Risk Management Strategy or the Strategic Flood Risk Assessment or is it at risk of flooding, for example because the proposed basement is below the static water level of nearby surface water feature?	No. The Camden Flood Risk Management Strategy dated 2013, together with Figures 3i, 4e, 5a and 5b of the SFRA dated 2014, and Environment Agency online flood maps show that the site has a very low flooding risk from surface water, sewers, reservoirs (and other artificial sources), groundwater and fluvial/tidal watercourses. In accordance with paragraph 5.11 of the CPG a positive pumped device will be installed in the basement in order to further protect the site from sewer flooding. The site is located within the Critical Drainage Area number GROUP3-003, but is not in a Local Flood Risk Zone, as identified in the Camden SWMP and Updated SFRA Figure 6/Rev 2.

The above assessment has identified no potential issues that need to be assessed.

4.0 SCOPING AND SITE INVESTIGATION

The purpose of scoping is to assess in more detail the factors to be investigated in the impact assessment. Potential impacts are assessed for each of the identified potential impact factors.

4.1 Potential Impacts

The following potential impacts have been identified by the screening process

Potential Impact	Consequence
The site is located above a Secondary 'A' Aquifer as designated by the EA.	The basement may extend into the underlying aquifer and thus affect the groundwater flow regime.
The proposed basement could extend beneath the water table	
The proposed basement is likely to significantly increase the differential depth of foundations relative to the neighbouring properties.	If not designed and constructed appropriately, the excavation of a basement may result in structural damage to neighbouring buildings and structures.
The site is within the exclusion zone of tunnels.	Excavation of the basement may result in damage to the tunnel.
Site within 5 m of a highway or pedestrian right of way.	Excavation of a basement may result in structural damage to the road or footway.

These potential impacts have been investigated through the site investigation, as detailed below.

4.2 Exploratory Work

The scope of work was determined to a large extent by the limited access to the site and the presence of the nearby London Underground tunnel which operated a buffer zone for works, restricting the work that could be carried out.

In order to meet the objectives described in Section 1.2 as far as possible within these restrictions, a single cable percussion borehole was drilled at the rear of the property using a standard cable percussion rig to a depth of 20.0 m. Standard Penetration Tests (SPTs) were carried out in the borehole and disturbed and undisturbed samples were recovered for subsequent laboratory examination and testing. In addition, a single borehole was drilled adjacent to the private access road leading from High Holborn to a depth of 5.0 m using an open-drive 'Terrier' rig.

Eight trial pits were excavated by hand to reveal foundation details of internal and external walls.

The borehole and trial pit records and results of the laboratory analyses are appended, together with a site plan indicating the exploratory positions. The Ordnance Datum (OD) levels shown on the borehole and trial pit records has been taken from drawing (ref HH-AEC-XX-00-DR-SE-00001 P01, dated May 2015) provided by the consulting engineers.

4.3 Sampling Strategy

The scope of the works was specified by the consulting engineers, with input from GEA. The trial pit locations were specified by the consulting engineers, whilst the borehole locations were agreed with London Underground and set out on site by GEA whilst avoiding areas of known services.

Gas and groundwater monitoring standpipes were installed in the boreholes and have been monitored on three occasions to date.

Six samples of the made ground was subjected to analysis for a range of common industrial contaminants and contamination indicative parameters. For this investigation the analytical suite for the soil included a range of metals, speciation of total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAH), total cyanide and monohydric phenols. The

soil samples was selected to provide a general view of the chemical conditions of the soils that are likely to be involved in a human exposure or groundwater pathway and to provide advice in respect of re-use or for waste disposal classification.

The contamination analyses were carried out at an MCERTs accredited laboratory with the majority of the testing suite accredited to MCERTS standards. Details of the MCERTs accreditation and test methods are included in the Appendix together with the analytical results.

A number of samples recovered from the boreholes were submitted to a geotechnical laboratory for a programme of testing that included moisture content and Atterberg limit tests, undrained triaxial compression tests, soluble sulphate and pH level analysis.

5.0 GROUND CONDITIONS

The investigation has generally confirmed the expected ground conditions in that, beneath a significant thickness of made ground, the Hackney Gravel was encountered over the London Clay Formation, which was proved to the full depth investigated, of 20.00 m (-0.15 m OD).

5.1 Made Ground

Beneath a surface covering of cobbles and concrete to a depth of 200 mm, the made ground comprised brown gravelly sand and very sandy clayey silt with pockets of yellow-brown and pale grey clay, coal, concrete and crushed brick to depths of between 0.80 m (19.05 m OD) and 2.00 m (18.44 m OD), below which, the made ground comprised dark brown silty sandy gravelly clay with frequent crushed brick, concrete, ash, tile, shell fragments and coal to depths of between 3.40 m (17.04 m OD) and 4.00 m (15.85 m OD).

No visual or olfactory evidence of contamination was noted in the made ground; however six samples of the made ground have been subject to contamination testing as a precautionary measure and the results are presented in Section 5.5.

5.2 Hackney Gravel

Adjacent to the western elevation of the existing building, the Hackney Gravel initially comprised soft to firm brown silty sandy very gravelly clay with pockets of dark greyish brown clay, fine to coarse subangular gravel and occasional roots which extended to a depth of 4.60 m (15.84 m OD). Below this layer, or directly below the made ground elsewhere, and in Borehole No 1, the Hackney Gravel comprised medium dense to dense brown and pale brown slightly silty sand and gravel, gravel is fine to coarse subangular to rounded and was encountered to a depth of 6.60 m (13.25 m OD) in Borehole No 1 and to the full depth of Borehole No 2, of 5.00 m (15.44 m OD), where the borehole was terminated due to the density of the gravels.

No visual or olfactory evidence of contamination was observed within these soils.

5.3 London Clay

The London Clay initially comprised an upper weathered horizon of firm brown clay to a depth of 6.80 m (13.05 m OD). Below this, high strength stiff fissured dark brownish grey silty clay with occasional pockets of sand extended to a depth of 15.50 m (4.35 m OD). The

London Clay then comprised fissured dark brown very silty clay with occasional fine shell fragments, medium selenite crystals and black carbonaceous material and was encountered to the full depth investigated, of 20.00 m (-0.15 m OD).

Claystones were encountered within this stratum at depths of 14.3 m (5.55 m OD), 15.50 m (4.35 m OD) and 18.20 m (1.65 m OD). The results of laboratory testing indicate the clay to be of high volume change potential.

These soils were observed to be free of any evidence of soil contamination.

5.4 Groundwater

Groundwater was encountered as strikes during drilling in Borehole No 1 at depths of 5.50 m and 14.30 m, rising to 5.00 m (14.85 m OD) and 14.00 m (5.85 m OD) respectively. Groundwater was not encountered during drilling within Borehole No 2 and was not encountered within the trial pits.

Groundwater has subsequently been monitored within Borehole Nos 1 and 2 and the results are summarised in the table below.

Date	Borehole No	Depth to water (m) [Level (m OD)]
25/07/15 (Fieldwork)	1	5.00 [14.85]
	2	DRY
07/08/15	1	5.04 [14.81]
	2	No reading due to no standpipe access
24/08/15	1	5.05 [14.80]
	2	DRY
14/09/15	1	5.02 [14.83]
	2	DRY

5.5 Soil Contamination

The table below sets out the values measured within six samples of made ground analysed; all concentrations are in mg/kg unless otherwise stated.

Determinant	Maximum concentration recorded (mg/kg)	Minimum concentration recorded (mg/kg)	Number of samples below detection limit	Normalised upper bound US_{95}
Arsenic	33	13	None	23
Cadmium	0.13	0.1	5	0.11
Chromium	29	18	None	27
Copper	450	17	None	258
Mercury	3.9	0.14	None	2.7
Nickel	35	16	None	28
Lead	**27000**	56	None	**14045**
Selenium	0.2	0.2	All	0.2

Determinant	Maximum concentration recorded (mg/kg)	Minimum concentration recorded (mg/kg)	Number of samples below detection limit	Normalised upper bound US_{95}
Zinc	890	43	None	493
Total Cyanide	0.5	0.5	All	0.5
Total Phenols	0.3	0.3	All	0.3
Sulphide	0.93	0.5	5	0.71
Total PAH	25	2	1	23
Benzo(a)pyrene	2.5	0.1	1	2.1
Naphthalene	0.21	0.1	4	0.15
TPH	330	10	3	182
Total organic carbon %	8.1	0.29	None	4.63
pH	12.6	8.8	-	-

Note: The use of the normalised upper bound for 95th percentile confidence aims to remove some of the uncertainty associated with calculation of an arithmetic sample mean of a relatively small number of samples. The US_{95} value is the upper bound of the range within which it can be stated with 95% confidence that the true mean concentration of the data set will fall.
Figure in **bold** indicates concentration in excess of risk-based soil guideline values, as discussed in Part 2 of this report

The results of the contamination testing indicate elevated concentrations of lead only.

The pH was found to be significantly elevated within a sample of made ground from Trial Pit No 17 at a depth of 0.50 m.

5.5.1 Generic Quantitative Risk Assessment

The use of a risk-based approach has been adopted to provide an initial screening of the test results to assess the need for subsequent site-specific risk assessments. To this end the table below indicates those contaminants of concern that have values in excess of a generic human health risk based guideline values which are either that of the CLEA[5] Soil Guideline Value where available, or is a Generic Screening Value calculated using the CLEA UK Version 1.06[6] software assuming a commercial end use, or is based on the DEFRA Category 4 Screening values[7]. The key generic assumptions for this end use are as follows:

- that groundwater will not be a critical risk receptor;
- that the critical receptor for human health will be working female adults aged 16 to 65 years old;
- that young children will not have prolonged exposure to the site;
- that the exposure duration will be a working lifetime of 49 years;
- that the critical exposure pathways will be direct soil and indoor dust ingestion, skin contact with soils and dust, and inhalation of dust and vapours; and
- that the building type equates to a three storey office.

5 *Updated Technical Background to the CLEA Model (Science Report SC050021/SR3) Jan 2009* and Soil Guideline Value reports for specific contaminants; all DEFRA and Environment Agency.
6 Contaminated Land Exposure Assessment (CL|EA) Software Version 1.06 Environment Agency 2009
7 CL:AIRE (2013) *Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination* Final Project Report SP1010 and DEFRA (2014) *Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination* Policy Companion Document SP1010

It is considered that these assumptions are acceptable for this generic assessment of this site, albeit extremely conservative as the development will result in the removal of the made ground through construction of the proposed basement extension. The tables of generic screening values derived by GEA and an explanation of how each value has been derived are included in the Appendix.

Where contaminant concentrations are measured at concentrations below the generic screening value it is considered that they pose an acceptable level of risk and thus further consideration of these contaminant concentrations is not required. However, where concentrations are measured in excess of these generic screening values there is considered to be a potential that they could pose an unacceptable risk and thus further action will be required which could include;

- additional testing to zone the extent of the contaminated material and thus reduce the uncertainty with regard to its potential risk;
- site specific risk assessment to refine the assessment criteria and allow an assessment to be made as to whether the concentration present would pose an unacceptable risk at this site; or
- soil remediation or risk management to mitigate the risk posed by the contaminant to a degree that it poses an acceptable risk.

The results of the contamination testing have revealed elevated concentrations of lead within two samples of made ground tested from Trial Pit Nos 18 and 20 at depths of 0.4 m and 0.8 m respectively. All of the other contaminants were found to be below their respective generic guideline value and of generally low concentrations. This assessment is based upon the potential for risk to human health, which at this site is considered to be the critical risk receptor. The significance of the contamination results is considered further in Part 2 of the report.

5.6 Soil Gas

Three gas monitoring visits have been carried out to date and have indicated low concentrations of carbon dioxide, no methane and no flow in Borehole Nos 1 and 2.

In determining the significance of soil gas concentrations both the gas concentrations and borehole flow rates are used to define a characteristic situation for a site based on the limiting borehole gas volume flow, renamed as the Gas Screening Value (GSV) for methane and carbon dioxide. In this case the following GSVs have been determined, in accordance with guidance provided by CIRIA[8] and the current British Standards[9].

Gas	Max concentration vol.	Ave flow rate l/hr	GSV
Methane	< 0.01	< 0.01	0.000001
Carbon dioxide	0.3	< 0.01	0.00003

On the basis of the above the site is therefore defined as Characteristic Situation 1 – 'Very Low Risk'. On the NHBC "traffic light" system[10] the site may be considered to be Green.

8 Wilson, S, Oliver, S, Mallett, H, Hutchings, H and Card, G (2007) *Assessing risks posed by hazardous ground gases to buildings* CIRIA Report C665
9 British Standard BS8485 (2015) *Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings*
10 Boyle, R and Witherington, P (2006) *Guidance on evaluation on development proposals on sites where methane and carbon*

5.7 Existing Foundations

The findings of the trial pits are summarised in the table below. Sketches and photographs of each pit are included in the Appendix.

Trial Pit No	Structure	Foundation detail	Bearing Stratum
16A	Close to fire escape at rear of building	Footing not proved	N/A
16B		Hard surface encountered to 2.3 m below ground level and extending laterally from wall beyond the adjacent curb line.	N/A
17	Rear of building	Section A-A': Not proved Section B-B': Mass concrete strip Top 0.25 m bgl Base varies 0.40 m bgl to 0.60 m bgl Lateral projection 100 mm	N/A MADE GROUND (brownish grey very silty very gravelly sand with tile, brick, concrete and coal fragments)
18	Corner of building at rear	Concrete footing Top 0.10 m bgl Base 0.65 m bgl Lateral projection 180 mm	MADE GROUND (dark brown very silty gravelly sand with frequent brick, slate fragments and occasional metal pieces)
19	Western elevation of building	Concrete structure encountered to 0.92 m, lateral projection and underside not proved	N/A
20	Internal; former toilet area	Section A-A': Hard surface encountered at 1.70 m below ground level, lateral projection not proved. Section B-B': Hard surfaces encountered at 1.50 m and 1.70 m bgl respectively, lateral projection not proved.	N/A
22	Adjacent to Cittie of Yorke Public House	Concrete structure encountered at 0.96 m depth, lateral projection not proved.	N/A
23		Concrete structure encountered at 0.85 m depth, lateral projection not proved.	

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

Consideration is being given to the demolition of the four-storey extension at the rear of the existing building and subsequent construction of a new five-storey extension. The existing roof slab will be demolished and replaced with a new lightweight deck. The existing basement beneath the main building will be extended below the new five storey extension, with no proposed increase in depth to the existing basement. The building will be used for commercial purposes only and the proposed development will not incorporate any areas of soft landscaping.

The basement extension at the rear is proposed to be 4.4 m deep below existing ground level, which is roughly 1.7 m deeper than the existing basement.

Anticipated loads have not been provided but they are expected to be moderate to high.

7.0 GROUND MODEL

The desk study has revealed that the site and surrounding area have not had a potentially contaminative history, and on the basis of the fieldwork, the ground conditions at this site can be characterised as follows:

- Below a significant thickness of made ground, the Hackney Gravel was encountered over the London Clay Formation, which was proved to the full depth investigated, of 20.00 m (-0.15 m OD);
- beneath a surface covering of cobbles and concrete to a depth of 200 mm, the made ground comprises brown gravelly sand, very sandy clayey silt and silty sandy gravelly clay with frequent crushed brick, concrete, ash, tile, shell fragments and coal to depths of between 3.40 m (17.04 m OD) and 4.00 m (15.85 m OD);
- the Hackney Gravel initially comprises soft to firm brown silty sandy very gravelly clay with pockets of dark greyish brown clay, fine to coarse subangular gravel and occasional roots and extends to a depth of 4.60 m (15.84 m OD) to the west of the existing building only;
- below this, the Hackney Gravel comprises medium dense to dense brown and pale brown slightly silty sand and gravel, gravel is fine to coarse subangular to rounded and is present to a depth of 6.60 m (13.25 m OD);
- the London Clay initially comprises an upper weathered horizon of firm brown clay to a depth of 6.80 m (13.05 m OD);
- below this, high strength stiff fissured dark brownish grey silty clay with occasional pockets of sand extends to a depth of 15.50 m (4.35 m OD) over fissured dark brown very silty clay with occasional fine shell fragments, medium selenite crystals and

black carbonaceous material to the full depth investigated, of 20.00 m (-0.15 m OD);

- claystones were encountered within the London Clay at depths of 14.3 m (5.55 m OD), 15.50 m (4.35 m OD) and 18.20 m (1.65 m OD);
- the results of laboratory testing indicate the clay to be of high volume change potential;
- groundwater was measured at a shallowest depth of 5.00 m (14.85 m OD);
- the results of the contamination testing indicate elevated concentrations of lead only;
- concentrations of pH were found to be significantly elevated within a sample of made ground from Trial Pit No 17 at a depth of 0.50 m; and
- the results of the gas monitoring carried out to date indicate the site is defined as Characteristic Situation 1 – 'Very Low Risk' and Green under the NHBC "traffic light" system.

8.0 ADVICE AND RECOMMENDATIONS

The proposed 4.4 m deep basement extension is likely to have a formation level within the medium dense to dense brown and pale brown slightly silty sand and gravel of the Hackney Gravel, although it will be close to the base of the soft to firm silty sandy very gravelly clay initial horizons of the Hackney Gravel and the basement foundations should extend through this stratum in order to avoid potentially excessive settlements.

Excavations for the proposed basement structure will require temporary support to maintain stability of the excavation and surrounding structures at all times.

Groundwater is unlikely to be encountered within the proposed basement extension although monitoring of the standpipes should be continued to confirm this view.

8.1 Basement Construction

The formation level for the basement is likely to be within the sands and gravels of the Hackney Gravel at a depth of approximately 4.4 m. On the basis of the groundwater observations to date, groundwater is unlikely to be encountered from within the proposed basement. Localised perched water may be encountered within the made ground, although these inflows are unlikely to be prolonged and should be adequately dealt with using sump pumping, the rate of inflow is unknown. As with any basement project it would be prudent to undertake trial excavations to a depth as close to the proposed basements as possible in order to determine the likely inflow rate of any groundwater.

There are a number of methods by which the sides of the basement excavation could be supported in the temporary and permanent conditions. The choice of wall may be governed to a large extent by whether it is to be incorporated into the permanent works and have a load bearing function, and the extent to which groundwater inflows need to be prevented.

It is understood that a bored pile wall is the preferred solution to form the basement retaining walls and at this stage it is anticipated that a contiguous wall may be suitable with grouting between piles to control groundwater inflows. A bored pile wall would also provide more support in the temporary situation, which would be favourable given the proximity to the

London Underground Tunnel.
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 and 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 retaining walls will need to be designed to support the loads from these foundations unless they are underpinned.

8.1.1 Retaining Walls

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

Stratum	Bulk Density (kg/m^3)	Effective Cohesion (c' – kN/m^2)	Effective Friction Angle (Φ' – degrees)
Made ground	1700	Zero	27
Hackney Gravel	1800	Zero	32
London Clay	2000	Zero	23

Groundwater is unlikely to be encountered within the excavation, although monitoring of the standpipes should be continued in order to establish equilibrium levels. At this stage, it is recommended that for the design of the retaining walls, that groundwater level should be assumed to be ¾ of the retained height, unless the risk of groundwater and surface water collecting behind the retaining walls can be suitably mitigated through the use of the use of a fully effective drainage system. The advice in BS8102:2009[11] should be followed in the design of the basement retaining walls and with regard to waterproofing requirements.

8.1.2 Basement Heave

The excavation of the new basement extension to a depth of about 4.4 m will result in an approximate unloading of $90kN/m^2$, leading to elastic heave and long term swelling of the London Clay.

The effects of the longer term swelling movement within the London Clay will be mitigated to some extent by the applied structural loads. An analysis of these movements, including a building damage assessment, is to be undertaken by GEA and will be issued as an addendum report.

8.2 Basement Raft Foundation

Depending on the loads and whether they can be relatively uniformly distributed, it may be feasible to adopt a basement raft foundation for the proposed development. However, further consideration will need to be given to possible movements if this foundation solution is to be considered.

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

8.3 Spread Foundations

If the existing basement is to be retained, a structural check should be made on the capacity of the existing slab, although it should be possible to increase the loading on the existing shallow foundations by 10 % without any significant increase in settlement.

The basement will extend to a depth of 4.4 m and new foundations extending through the initial clay layer of the Hackney Gravel and bearing in the medium dense sands and gravels may be designed to apply a net allowable bearing pressure of 200 kN/m^2. This value incorporates an adequate factor of safety against bearing capacity failure and should ensure that settlement remains within normal tolerable limits.

Although the foundations will probably be at a reasonable distance from the Central Line tunnel and out of the buffer zone, London Underground are likely to require an estimate of the anticipated loads and potential movements in order to demonstrate that their infrastructure will not be affected by the proposed development.

8.4 Piled Foundations

For the ground conditions at this site some form of bored pile is likely to be the most appropriate type. A conventional rotary augered pile may be appropriate, with temporary casing installed to maintain stability and prevent groundwater inflows, or alternatively the use of bored piles installed using continuous flight auger (cfa) techniques, which would not require the provision of casing, would also be appropriate.

The following table of ultimate coefficients may be used for the preliminary design of bored piles, based on the SPT & Cohesion / level graph in the appendix.

Stratum	Depth m	kN / m^2
Ultimate Skin Friction		
Basement Excavation	GL to 4.5	Ignore
Hackney Gravel	4.5 to 5.0	34
Hackney Gravel (Saturated)	5.0 to 7.0	38
London Clay (α=0.5)	7.0 to 18.0	Increasing linearly from 37 to 75
Ultimate End Bearing		
London Clay	15.0 to 18.0	Increasing linearly from 1170 to 1350

In the absence of pile tests, guidance from the London District Surveyors Association (LDSA)[12] suggests that a factor of safety of 2.6 should be applied to the above coefficients in the computation of safe theoretical working loads.

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

On the basis of the above coefficients the following pile capacities have been estimated; the example load for a 25 m long pile is for guidance only.

Pile Diameter (mm)	Pile Length (m)	Safe Working Load (kN)
300	10	100
	15	210
	20	355
	25	530
450	10	170
	15	345
	20	565
	25	830
600	10	250
	15	490
	20	790
	25	1,160

The above examples are not intended to constitute any form of recommendation with regard to pile size or type, but merely serve to illustrate the use of the above coefficients. Specialist piling contractors should be consulted with regard to the design of an appropriate piling scheme and their attention should be drawn to potential groundwater inflows within the made ground and Hackney Gravel, silt partings within the London Clay and proximity to the underlying Lambeth Group.

8.5 Basement Floor Slab

For the proposed single level basement on the north-western part of the site, it should be possible to adopt a ground bearing slab, due to the covering thickness of granular soils that will remain beneath the proposed basement which should act to mitigate any potential have of the underlying London Clay, although this should be reviewed once the levels and loads are known.

8.6 Shallow Excavations

On the basis of the borehole findings and trial pits, it is considered that shallow excavations for foundations and services that extend through the made ground should remain generally stable in the short term, although some instability may occur. However, should deeper excavations be 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.

The investigation has indicated that shallow groundwater inflows are unlikely to be encountered. Perched water inflows may, however, be encountered, particularly within the vicinity of existing foundations, although such inflows should readily be dealt with through sump pumping.

8.7 Effect of Sulphates

Chemical analyses carried out on selected samples; including three samples of made ground and three samples of the natural soils have revealed generally low concentrations of soluble sulphate and near-neutral pH in accordance with Class DS-2 of Table C2 of BRE Special Digest 1 Part C (2005). The measured pH value of the samples shows that an ACEC class of AC-2 would be appropriate for the site. This assumes a mobile water conditions at the site.

The guidelines contained in the above digest should be followed in the design of foundation concrete.

8.8 Site Specific Risk Assessment

The desk study has indicated that the site has not had a contaminative history, having been occupied by the existing building throughout its developed history. With the exception of the existing access roads and potential localised fuel spillages, no sources of contamination have been identified. The results of the contamination testing have however identified an elevated concentration of lead within a single sample of made ground. No elevated concentrations of the other contaminants were identified.
The exact source of the contamination is unknown, but the made ground was noted as containing variable amounts of extraneous material. The potential contamination is therefore considered likely to be relatively immobile and unlikely to be in a soluble form, such that it does not therefore present a significant risk of leaching and migration within any perched groundwater.

The notably alkaline level identified within made ground from Trial Pit No 17 is likely to be as a result of the significant amount of concrete encountered at this location.

End users will be effectively isolated from direct contact with the identified contaminants by the building and areas of external hardstanding, in addition to which the contamination will be removed as part of the basement excavation, which will extend over part of the footprint of the site, while the remaining area will continued to be used as public vehicular and pedestrian access routes. A requirement for remediation is not therefore envisaged. However, if during ground works any visual or olfactory evidence of contamination is identified it is recommended that further investigation be carried out and that the risk assessment is reviewed.

Site workers should be made aware of the 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[13] and CIRIA[14] and the requirements of the Local Authority Environmental Health Officer.

8.9 Waste Disposal

Any spoil arising from excavations or landscaping works, which is not to be re-used in accordance with the CL:AIRE guidance[15], will need to be disposed of to a licensed tip. 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 going to landfill is subject to landfill tax at either the standard rate of

13 HSE (1992) HS(G)66 *Protection of workers and the general public during the development of contaminated land* HMSO
14 CIRIA (1996) *A guide for safe working on contaminated sites* Report 132, Construction Industry Research and Information Association
15 CL:AIRE (2011) *The Definition of Waste: Development Industry Code of Practice* Version 2, March 2011

£82.60 per tonne (about £150 per m^3) or at the lower rate of £2.60 per tonne (roughly £5 per m^3). However, the classification for tax purposes is not the same as that for disposal purposes. Currently all made ground and topsoil is taxable at the 'standard' rate and only naturally occurring rocks and soils which are accurately described as such in terms of the 2011 Order[16] would qualify for the 'lower rate' of landfill tax.

Based upon on the technical guidance provided by the Environment Agency[17] it is considered likely that the made ground from this site, as represented by the six chemical analyses carried out, would be classified as a HAZARDOUS waste under the waste code 17 05 04 (soils and stones not containing dangerous substances) and would be taxable at the standard rate. The hazardous rating is due to the single elevated concentration of lead and notably alkaline levels within two samples of made ground. It is likely that the natural soils, if separated out, could be classified as an INERT waste also under the waste code 17 05 04. This material would be taxable at the lower rate, if accurately described as naturally occurring sand and gravel in terms of the 2011 Order on the waste transfer note. As this site has not had a contaminative

history there should be no requirement for WAC leaching analyses to confirm that this material is suitable for landfilling, although this would require confirmation from the receiving site.

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[18] 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 insitu prior to excavation.

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

The local waste regulation department of the Environment Agency 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.

9.0 BASEMENT IMPACT ASSESSMENT

The screening identified a number of potential impacts. The desk study and ground investigation information has been used below to review the potential impacts, to assess the likelihood of them occurring and the scope for reasonable engineering mitigation.

The table below summarises the previously identified potential impacts and the additional information that is now available from the site investigation in consideration of each impact.

16 *Landfill Tax (Qualifying Material) Order 2011*
17 Environment Agency (2013) *Hazardous Waste: Interpretation of the definition and classification of hazardous waste. Technical Guidance* WM2 Third Edition, August 2013
18 Regulatory Position Statement (2007) *Treating non-hazardous waste for landfill - Enforcing the new requirement* Environment Agency 23 Oct 2007

Potential Impact	Site Investigation Conclusions
The site is located above a Secondary 'A' Aquifer as designated by the EA.	Groundwater has been measured at a level of approximately 20.0 m OD. The proposed basement extension is likely to be 4.4 m deep (15.6 m OD). The groundwater has been monitored at a shallowest depth of 5.00 m (14.85 m OD), such that it is unlike to extend into the water table, although groundwater monitoring should be continued to confirm this view.
The proposed basement could extend beneath the water table	
The proposed basement is likely to significantly increase the differential depth of foundations relative to the neighbouring properties.	If not designed and constructed appropriately, the excavation of a basement may result in structural damage to neighbouring buildings and structures. A ground movement analysis, including building damage assessment, will be submitted separately to this report.
The site is within the exclusion zone of tunnels.	The investigation has not indicated any specific problems, such as weak or unstable ground, voids, high water table, that would make working within 5 m of public infrastructure particularly problematic at this site, although best practice in design and construction will ensure the stability of the highway.
Site within 5 m of a highway or pedestrian right of way.	

9.1 BIA Conclusion

A Basement Impact Assessment has been carried out following the information and guidance published by the London Borough of Camden. Information from a Site Investigation has been used to assess potential impacts identified by the screening process.

It is concluded that the proposed development is unlikely to result in any specific land or slope stability issues, groundwater or surface water issues and will not therefore have any adverse effect on any nearby sites.

10.0 OUTSTANDING RISKS AND ISSUES

This section of the report aims to highlight areas where further work is required as a result of limitations on the scope of this investigation, or where issues have been identified by this investigation that warrant further consideration. The scope of risks and issues discussed in this section is by no means exhaustive, but covers the main areas where additional work is considered to be required.

The ground is a heterogeneous natural material and variations will inevitably arise between the locations at which it is investigated. This report provides an assessment of the ground conditions based on the discrete points at which the ground was sampled, but the ground conditions should be subject to review as the work proceeds to ensure that any variations from the Ground Model are properly assessed by a suitably qualified person.

Further gas and groundwater monitoring should be carried out to confirm that groundwater will not be encountered during basement excavation or ideally trial excavations are undertaken, to depths as close to the full basement depth.

London Underground should be consulted to ensure that the proposed development does not affect any of their infrastructure and are likely to require an estimate of the anticipated loads and potential movements, which is typically required in any case to comply with the requirements of CPG4.

If during ground works any visual or olfactory evidence of contamination is identified it is

recommended that further investigation be carried out and that the risk assessment is reviewed.

These areas of doubt should be drawn to the attention of prospective contractors and further investigation will be required or sufficient contingency should be provided to cover the outstanding risk.

APPENDIX

Borehole Records

Trial Pit Records

Geotechnical Laboratory Test Results

SPT & Cohesion / Depth Graph

Chemical Analyses (Soil)

Generic Risk Based Screening Values

Envirocheck Report Summary

Historical Maps

Site Plan

GEA Geotechnical & Environmental Associates	Widbury Barn Widbury Hill Ware SG12 7QE	**Site** 19-21 High Holborn, London, WC1V 6BS	**Borehole Number** **BH1**

Boring Method	**Casing Diameter**		**Ground Level (mOD)**	**Client**	**Job Number**
	Diameter	Depth Base			
Cable Percussion	150	7.00	19.85	The Honourable Society of Gray's Inn	J15193
	Location		**Dates** 25/07/2015	**Engineer**	**Sheet** Sheet 1 of 2

Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					19.65	(0.20) 0.20	CONCRETE (cobbles over concrete)		
0.30	D1						MADE GROUND (brown gravelly sand with concrete and brick backfill)		
0.50	B2					(0.60)			
					19.05	0.80	MADE GROUND (dark brown silty sandy clay with frequent crushed brick, concrete and coal)		
1.20	B3								
1.20 - 1.65	SPT (C)N=14			N=14 (4,4/5,3,2,4)					
1.75	D4								
2.00	B5								
2.00 - 2.45	SPT (C)N=17			N=17 (2,2/3,6,5,3)					
						(3.20)			
2.75	D6								
3.00	B7								
3.00 - 3.45	SPT (C)N=13			N=13 (2,2/3,3,3,4)					
3.75	D8								
4.00	B9				15.85	4.00			
4.00 - 4.45	SPT (C)N=23			N=23 (5,6/6,6,5,6)			Medium dense brown slightly silty SAND and GRAVEL. Gravel fine, medium, coarse sub angular to rounded		
4.75	D10								
5.00	B11								
5.00 - 5.45	SPT (C)N=26			N=26 (10,7/6,5,7,8)		(2.60)			
6.50	B12								
6.50 - 6.95	SPT (C)N=14			N=14 (6,4/3,3,4,4)	13.25	6.60 (0.20)	Firm brown CLAY		
					13.05	6.80	High strength fissured stiff dark brownish grey silty CLAY with occasional pockets of sand and claystones at 14.3 m to 14.9 m		
7.50	D13								
8.00 - 8.45	U14								
9.00	D15								
9.50	D16								
9.50 - 9.95	SPT (S)N=17			N=17 (5,4/4,4,4,5)					

Continued on Next Page

Remarks

1 hr dayworks clearing area and removing spoil
Groundwater encountered at depths of 5.50 m and 14.30 m
1 hr chiselling time due to presence of claystones
Gas and groundwater monitoring standpipe installed to 7.00 m depth

Scale (approx)	**Logged By**
1:50	CA/GT

GEA Geotechnical & Environmental Associates	Widbury Barn Widbury Hill Ware SG12 7QE	**Site** 19-21 High Holborn, London, WC1V 6BS	**Borehole Number** **BH1**

Boring Method	**Casing Diameter**		**Ground Level (mOD)**	**Client**	**Job Number**
	Diameter	Depth Base			
Cable Percussion	150	7.00	19.85	The Honourable Society of Gray's Inn	J15193
	Location		**Dates**	**Engineer**	**Sheet**
			25/07/2015		Sheet 2 of 2

Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
10.50	D17								
11.00 - 11.45	U18								
12.00	D19								
12.50	D20								
12.50 - 12.95	SPT (S)N=19			N=19 (4,4/5,4,5,5)		(8.70)			
13.50	D21								
14.00 - 14.45	U22								
15.00	D23								
15.50	D24				4.35	15.50	Stiff to very stiff fissured dark brown very silty CLAY with occasional fine shell fragments, medium selenite crystals, black carbonaceous material and claystones at 15.5 m and 18.2 m depth		
15.50 - 15.95	SPT (C)N=45			N=45 (8,10/11,12,15,7)					
16.50	D25								
17.00	D26								
17.00 - 17.45	SPT (S)N=27			N=27 (5,6/6,7,7,7)					
18.00	D27					(4.50)			
18.50	D28								
18.50 - 18.95	SPT (S)N=39			N=39 (6,7/8,10,10,11)					
19.25	D29								
19.55	D30								
19.55 - 20.00	SPT (S)N=31			N=31 (5,6/7,7,8,9)					
					-0.15	20.00	Complete at 20.000m		

Remarks

1 hr dayworks clearing area and removing spoil
Groundwater encountered at depths of 5.50 m and 14.30 m
1 hr chiselling time due to presence of claystones
Gas and groundwater monitoring standpipe installed to 7.00 m depth

Scale (approx)	**Logged By**
1:50	CA/GT

GEA Geotechnical & Environmental Associates Widbury Barn Widbury Hill Ware SG12 7QE			**Site** 19-21 High Holborn, London, WC1V 6BS	**Borehole Number** **BH2**
Boring Method Opendrive Sampler	**Casing Diameter** Diameter:	Depth Base:	**Ground Level (mOD)** 20.44	**Client** The Honourable Society of Gray's Inn	**Job Number** J15193
	Location		**Dates** 26/07/2015	**Engineer**	**Sheet** Sheet 1 of 1

Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
						(2.00)	MADE GROUND (45 mm thick paving slabs over brown very sandy clayey silt with pockets of yellow-brown and pale grey clay, frequent brick and fragments of concrete and coal)		
2.00 - 2.45	SPT (S)			N=0 (0,0/0,0,0,0)	18.44	2.00	MADE GROUND (dark brown silty sandy slightly gravelly clay with pockets of ash, brick, tile and shell fragments)		
						(1.40)			
3.00 - 3.45	SPT (S)N=1			N=1 (0,0/0,1,0,0)					
					17.04	3.40	Soft to firm brown silty sandy very gravelly CLAY with pockets of dark greyish brown clay, fine to coarse subangular gravel and occasional roots		
4.00 - 4.45	SPT (S)N=9			N=9 (1,2/3,3,2,1)		(1.20)			
					15.84	4.60	Very dense pale brown very sandy silty fine to coarse subangular to rounded GRAVEL		
						(0.40)			
5.00 - 5.05	SPT (S)			0 (53 for 50mm/0 for 0mm)	15.44	5.00	Complete at 5.00m		

Remarks

Borehole refused at 5.00 m depth due to density of gravels
Gas and groundwater monitoring standpipe installed to 5.00 m depth
Groundwater not encountered during drilling

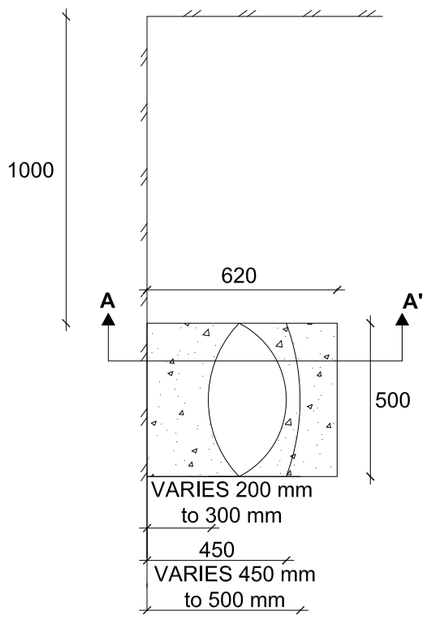
Scale (approx)	**Logged By**
1:50	CA

GEA Geotechnical & Environmental Associates	Widbury Barn Widbury Hill Ware Herts SG12 7QE	**Site** 19-21 High Holborn, London, WC1V 6BS		
Excavation Method Manual	**Dimensions** 620 x 500 x 950 mm	**Ground Level (m OD)** 19.79	**Client** The Honourable Society of Gray's Inn	**Job Number** J15193
	Location Adjacent to fire exit	**Date** 24th to 27th July 2015	**Engineer** AECOM	**Sheet Number** 1 of 1

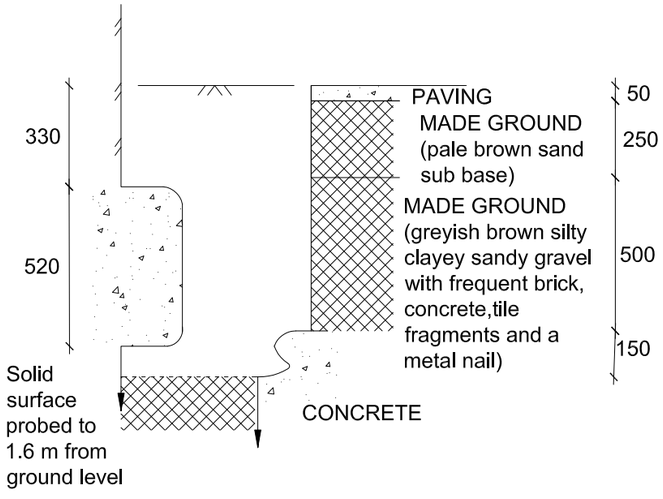
Trial Pit Number

TP16A

Plan



Section A-A'



Photographs:

Notes:
Groundwater not encountered
Trial pit terminated due to concrete obstructions

Scale
1 : 20

Logged By
CA