Document:	**Ground Investigation Report**
Project:	**The British Museum (East Road Building)**
Reference No:	**GL25617Rev2**
Date:	**November 2023**
Prepared for:	**Steadberry Restoration Limited**

harrisongeotechnical
ENGINEERING

A division of Harrison Group Environmental Limited

HARRISON GROUP ENVIRONMENTAL LIMITED

Document: **Ground Investigation Report**

Project: **The British Museum (East Road Building)**

Reference No: **GL25617 Rev2**

Date: **November 2023**

Prepared For: **Steadberry Restoration Limited**

REPORT STATUS

Revision	Comments	Prepared By	Approved By	Issued By	Audited By
0	First Issue	INITIALS JBL DATE 22/03/23	INITIALS JK DATE 31/03/23	INITIALS JBL DATE 22/03/23	INITIALS JK DATE 31/03/23
1	Second Issue	INITIALS JBL DATE 31/03/23	INITIALS JK DATE 31/03/23	INITIALS JBL DATE 31/03/23	INITIALS JK DATE 31/03/23
2	Third Issue	INITIALS JBL DATE 15/11/23	INITIALS JK DATE 16/11/23	INITIALS JBL DATE 15/11/23	INITIALS JK DATE 16/11/23
		INITIALS DATE	INITIALS DATE	INITIALS DATE	INITIALS DATE

CONTENTS

FOREWORD

General Conditions Relating to Site Investigation

This investigation has been devised to generally comply with the relevant principles and requirements of B.S.10175:2011+A2:2017 'Investigation of potentially contaminated sites - Code of practice', 'Land contamination: technical guidance' collection (Environment Agency, 2016), 'Land contamination: risk management' (Environment Agency, 2019) and BS EN 1997 (Eurocode 7). The recommendations made and opinions expressed in this report are based on the information obtained from the sources described using a methodology intended to provide reasonable consistency and robustness.

The opinions expressed in this report are based on the ground conditions revealed by the site works, together with an assessment of the site and of laboratory test results. Whilst opinions may be expressed relating to sub-soil conditions in parts of the site not investigated, for example between exploratory positions, these are only for guidance and no liability can be accepted for their accuracy.

Boring and sampling procedures are undertaken in accordance with B.S.5930:2015+A1:2020 'Code of Practice for Ground Investigations'. Likewise, in-situ and laboratory testing comply with B.S.1377:1990 'Methods of Tests for Soils for Civil Engineering Purposes' and B.S.22475:2011, unless stated otherwise in the text. Chemical Testing has been undertaken by a UKAS accredited laboratory.

The groundwater conditions entered on the boring records are those observed at the time of investigation. The normal rate of boring usually does not permit the recording of an equilibrium water level for any one water strike. Moreover, groundwater levels are subject to seasonal variation or changes in local drainage conditions.

Some items of the investigation have been provided by third parties and whilst Harrison Group have no reason to doubt the accuracy, the items relied on have not been verified. No responsibility can be accepted for errors within third party items presented in this report.

This report is produced in accordance with the scope of Harrison Group's appointment and is subject to the terms of appointment. Harrison Group accepts no liability for any use of this document other than by its client and only for the purposes, for which it was designed and produced. No responsibility can be accepted for any consequences of this information being passed to a third party who may act upon its contents/recommendations.

Any advice, opinions, or recommendations within this document should be read and relied upon only in the context of the document as a whole. The contents of this document are not to be construed as providing legal, business or tax advice or opinion.

EXECUTIVE SUMMARY

Location	The site is located within the grounds of the British Museum in central London. The site can be accessed from Montague Place, London, WC1B 3DG centred at approximate National Grid Reference (NGR) 530053, 181723.
Previous & Current Site Use	The site under consideration is located in the northeast corner of the British Museum grounds. The site covers an area of approximately 0.03ha and can be identified by National Grid Reference 530076, 181803. Examination of the supplied topographical survey shows elevation of the site as approximately 24.5 metres above Ordnance Datum (maOD). The site was bounded to the southwest by a service road and the main Grade I listed buildings of the British Museum, and to the north and east by large townhouses and associated gardens and basements along Montague Street. At the time of our assessment the site was occupied by the main structure of the East Road Building, which was roughly rectangular in shape and of brick construction. The structure was a single storey in height but was also raised approximately 1.5m above the surrounding ground level supported by a retaining wall and associated walkway ramp. The building had a flat roof with skylights and was primarily used for storage, office, welfare and workshop space. From the mapping available, the site is shown to have been part of the gardens of the terraced townhouses lining Montague Street, from the late 19th century until the 1960s. The British Museum expanded their site boundary at this time to incorporate much of these gardens, including the proposed site. The current East Road Building was shown to have been present on-site from the 1960s and has remained unchanged to the present day.
Proposed Site Use	The proposed development is detailed on ABA drawings ref: BMERB-AB-XX-00-DR-S-0009-P01 to BMERB-AB-XX-XX-DR-S-0015-P01. It is proposed to construct a new two-storey service building, including a single storey basement as part of the SWEC development at the British Museum, with the existing East Road Building demolished to facilitate the redevelopment. The basement development is modest in size such that it does not extend beyond the footprint of the building and is no deeper than one full story below ground level (approximately 3m in depth). We also understand that there will be no soft landscaped areas in the final proposed design. Due to the nature of the development detailed, this report and associated geoenvironmental assessment has assumed a proposed commercial end use for geoenvironmental assessment.
Background Information	HGE have undertaken a Stage 1 Tier 1 Preliminary Risk Assessment (Desk Study Report) for the subject site, ref: GL25617 dated February 2023. Although the findings of the desk study report have been considered within this report it is recommended the Desk Study should be read in conjunction with this report which is presented in Appendix C. This report concluded that an intrusive geo-environmental and geotechnical ground investigation should be undertaken at the site in accordance with relevant guidance. The purpose of the work associated with this interpretative report was to undertake a ground investigation, focusing on a geotechnical assessment and a geoenvironmental Tier 2 generic quantitative risk assessment for the site and the proposed development. The subject site and proposed development is referred to as The British Museum (East Road Building). It is understood that the subject site area will be completely covered by the proposed structures footprint.
Ground Conditions and Geology	Soil containing anthropogenic material (made ground) was encountered to a maximum depth of 3.70mbgl (TPB). Within the boreholes, the maximum depth of the made ground was recorded at 1.95mbgl (BHB). In positions where the extent of made ground was proven, the level at which natural deposits were encountered ranged from 22.31 - 23.08mAOD. Within the boreholes, the disturbed soil comprised granular horizons over more cohesive strata with anthropogenic material such as brick, concrete, possible clinker, asphalt, animal bone and tile fragments. Within the trial pits, more granular fill was typically encountered, with similar anthropogenic material encountered, with the addition of occasional metal, slate, ceramic, glass, lead, possible ACM, and oyster shell fragments. The underlying natural superficial soils consisted of both cohesive and granular horizons. The cohesive deposits were described as firm brown slightly sandy slightly gravelly CLAY, with gravel comprising subangular to subrounded, fine to coarse flint. This stratum was encountered between 1.90m and 2.80mbgl. These soils are representative of the Lynch Hill Gravel Member. The shallow granular soils were described as medium dense to very dense brown fine to coarse SAND and subangular to subrounded, fine to coarse flint GRAVEL. This stratum was encountered between 2.60m and 6.20mbgl. This material is also representative of the Lynch Hill Gravel Member. Cohesive bedrock deposits were found to underlie the superficial deposits, comprising of stiff, grey CLAY, with occasional lenses of fine grey sand, and occasional fine selenite. Within BHB a thin band of medium strong claystone was encountered between 6.40 and 6.60mbgl. This cohesive stratum is typical of and is considered representative of the London Clay Formation. Olfactory and visual evidence of potential contamination was limited to granular and cohesive fill containing gravel of concrete, brick, asphalt, tile, animal bone fragments, possible clinker, metal, slate, ceramic, oyster shell, clay pipe fragments, glass, lead and ACM fragments.

	Depth to groundwater was recorded to range between 3.41m to 5.50m (21.39 to 19.26maOD) within the exploratory holes during drilling and subsequent monitoring of the wells installed. Long-term (6 month) groundwater monitoring was carried out the results of which correlated well with the dipped depths reported above.
Foundations, Floor Slabs	We would not advise placing any significantly loaded structures within the made ground deposits or near surface cohesive deposits due to their variable nature, limited thickness and generally poor geotechnical properties. The shallow granular soils were described as medium dense to very dense brown fine to coarse sand and subangular to subrounded, fine to coarse flint gravel. In the boreholes this stratum was encountered between 2.60m and 6.20mbgl. While beyond the depth where we would recommend new traditional foundations it is nevertheless a good founding medium and could be utilised to support the construction of the basement box. Bearing capacity of the subsoils will increase with depth and pad foundations placed at around 3.00mbgl founded within these dense granular deposits could be associated with allowable bearing capacity of 225kN/m^2 for a nominal 1m wide pad foundation. In accordance with the proposed plans provided by ABA, preliminary pile capacity calculations have been undertaken in accordance with BS EN 1997-1:2004 +A1:2013 (Eurocode 7), Design Approach 1, Combinations 1 and 2 for the use of continuous flight auger (CFA) piles. The assessment has been undertaken using the software package GEO5 2021 Pile (Fine Software). The soil profile has been modelled using boreholes BHB, which provides coverage of ground conditions to sufficient depth beneath the site. Using a pile diameter of 450mm (as scoped by ABA) and an embedment depth of 8.00m within the stiff London Clay Formation, an allowable load in the order of 200kN can be allowed for each individual pile, with loadings taken by a combination of skin and end bearing resistance. For a 450mm diameter pile constructed to 10.00m, a maximum allowable load in the order of 275kN is achievable. Groundwater should not be encountered in shallow excavations, although surface water/rainfall may pond in excavations. Effective groundwater control is a prerequisite constraint on the construction process. Although groundwater levels are currently below the expected excavation level they may rise. A groundwater monitoring programme is currently being carried out. We expect that the proposed piled wall will also assist in managing the rate of groundwater entering the excavations during construction. This approach should mean only minor local pumping will be necessary during construction rather than more significant dewatering techniques,
Concrete Design	Shallow soils down to 6mbgl (Made Ground and Lynch Hill Gravel Member) indicate that a design sulphate class of DS-1 and an ACEC class of AC-1s. If concrete is anticipated to encounter the underlying London Clay Formation a design sulphate class of DCS-5 and an ACEC class of AC4s could be required depending on the applications.
Geoenvironmental Contamination Summary and Recommendations	Due to the nature of the development detailed, this report and associated geoenvironmental assessment has assumed a proposed commercial end use for geoenvironmental assessment. No elevated contamination concentrations were identified above any of the relevant commercial end use criteria within the 6 No. soil samples analysed. The levels of soil contaminants recorded in the soils are not considered to represent a significant risk to human health end users associated with the proposed development, given that the proposed end us is for commercial end use with no soft landscaping. However, consideration should be given to the fact the ground investigation was limited to positions outside of the existing and proposed building footprint, and that potential sources and extent of soil contamination across the site may not have been fully assessed. Considering the results and that the proposed structures footprint will cover the whole site area, further investigation or remedial action is not considered to be warranted at this stage. The proposed development will break all potential pollutant linkages to human health end users with the exception of inhalation of soil gas/vapours. However, should indications of additional contamination be discovered during development, this should be further assessed, and appropriate action taken, as necessary. The potential risk to construction workers should be mitigated through a contractor's risk assessment prior to development. If any obviously contaminated soil is encountered the advice of a suitably qualified person should be sought regarding the appropriate course of action. The result of the asbestos analysis indicates that there were no asbestos fibres detected in any of the soil samples tested, however, asbestos was identified within a bulk asbestos sample taken from TPE at 1.40mbgl. Based on the anthropogenic impacts observed as well as the potential contaminant sources identified in the HGE Stage 1 Tier 1 Preliminary Risk Assessment (Desk Study), there is potential that some ACM could be locally present within made ground across the area. Should further areas of made ground containing potential asbestos-containing materials (ACMs), or other forms of contamination be discovered during development, this should be further assessed.

	An asbestos survey is recommended prior to demolition of any structures. Any subsequent removal to be undertaken by controlled methods by appropriately qualified operators. Groundwater from the superficial Lynch Hill Gravel Member (Secondary A Aquifer) has been analysed from the cable percussive borehole. Only copper was recorded slightly exceeding a relevant criteria (exceeded its initial EQS criteria of 1ug/l with 1.6ug/l but did not exceed relevant drinking water criteria). It is considered the concentration of copper is at a level which would be unlikely to be significantly detrimental to the identified controlled waters and likely at background concentrations for the surrounding area. The appropriate ground gas protection measures for the proposed buildings on the site are based on the GSV and building type. Based on the worst case GSVs for CO_2 and CH_4 in accordance with BS8485:2015, the site falls within CS1 'Very low hazard potential'. Based on the limited gas monitoring undertaken, a viable source of ground gases has not been found and an assessment of the levels recorded during monitoring suggests that remedial action is not required. However, data should be provided to contractors involved in development to allow them to undertake their own specific risk assessments. Volatile Organic Compounds (VOCs) were recorded during the ground gas monitoring rounds at concentrations of <10ppm, recorded at a maximum of 0.6ppm and as such do not give cause for concern. Carbon monoxide and hydrogen sulphide were recorded to have maximum concentrations of 55ppm and 6ppm. No residential screening thresholds are published for carbon monoxide or hydrogen sulphide. However, the levels recorded do exceed the stringent long-term exposure limits (30ppm and 5ppm respectively published in table 1 of HSE EH40/2005 'workplace exposure limits'). Given that no significant potential source was identified, and that much of the made ground is expected to be removed during construction works, this is not considered to pose a risk to the proposed development. It should however be taken into consideration by the designer. The potential risk to construction workers should be mitigated through a contractor's risk assessment prior to development. If any obviously contaminated soil is encountered the advice of a suitably qualified person should be sought with regard to the appropriate course of action. The basic requirement for development standards in the UK is that land should be 'suitable for use' or 'fit for purpose'. It is important to consider the limited nature of the sampling for this investigation, and the possibility of higher concentrations of contaminants and differing ground conditions existing between sample positions. However, providing the recommendations are adhered to, we believe that the site can be suitable for the intended use. We recommend that this report is submitted to Regulators as part of the planning process. It is recommended that correspondence with the regulators is undertaken before any additional ground investigation and associated assessments are undertaken.

GROUND INVESTIGATION REPORT
FOR
THE BRITISH MUSEUM (EAST ROAD BUILDING)

1 TERMS OF REFERENCE & INTRODUCTION

1.1 Introduction

The work covered by this report was undertaken on behalf of Steadberry Restoration Ltd (Client), in accordance with Harrison Geotechnical Engineering (HGE) quotation GL25617 - The British Museum - Rev 2 dated December 2022. The work was undertaken in accordance with the relevant specification Ref. *1910-41-S01-A - Proposed Site Investigations* issued by Alan Baxter Ltd (ABA) who acted as the engineer.

HGE have undertaken a Stage 1 Tier 1 Preliminary Risk Assessment (Desk Study Report) for the subject site, ref: GL25617 dated February 2023. Although the findings of the desk study report have been considered within this report it is recommended the Desk Study should be read in conjunction with this report and is presented in Appendix C.

The purpose of the work associated with this interpretative report was to undertake a ground investigation, focusing on a geotechnical assessment and a geoenvironmental Tier 2 generic quantitative risk assessment for the site and the proposed development. The subject site and proposed development is referred to as The British Museum (East Road Building). It is understood that the subject site area will be completely covered by the proposed structure's footprint.

The site is located within the grounds of the British Museum in central London. The site can be accessed from Montague Place, London, WC1B 3DG centred at approximate National Grid Reference (NGR) 530053, 181723. The site boundary is indicated on drawing GL25617-DR001 presented in the appendix.

We understand it is proposed to construct a new two-storey service building, including a single storey basement as part of the SWEC development at the British Museum, as set out in the plans provided by ABA. The basement development is modest in size such that it does not extend beyond the footprint of the building and is no deeper than one full story below ground level (approximately 3m in depth). We also understand that there will be no soft landscaped areas in the final proposed design.

At the time of our assessment the site was occupied by the main structure of the East Road Building, which was roughly rectangular in shape and of brick construction. The structure was a single storey in height but was also raised approximately 1.5m above the surrounding ground level supported by a retaining wall and associated walkway ramp. The building had a flat roof with skylights and was primarily used for storage, office, welfare and workshop space.

Due to the nature of the development detailed, this report and associated geoenvironmental assessment has assumed that the end use will comprise of commercial end use. It is understood that no soft landscaping will be associated with the proposed development.

A Topographical Survey for the subject site was provided by ABA, Ref: VF02_Base Model.

2 BACKGROUND INFORMATION

2.1 Site Description

The site under consideration is located in the northeast corner of the British Museum grounds. The site covers an area of approximately 0.03ha and can be identified by National Grid Reference 530076, 181803. Examination of the supplied topographical survey shows elevation of the site as approximately 24.5 metres above Ordnance Datum (maOD).

The site was bounded to the southwest by a service road and the main Grade I listed buildings of the British Museum, and to the north and east by large townhouses and associated gardens and basements along Montague Street.

At the time of our assessment the site was occupied by the main structure of the East Road Building, which was roughly rectangular in shape and of brick construction. The structure was a single storey in height but was also raised approximately 1.5m above the surrounding ground level supported by a retaining wall and associated walkway ramp. The building had a flat roof with skylights and was primarily used for storage, office, welfare and workshop space.

A site walkover was undertaken on 31st January 2023 and the findings are presented in the HGE Stage 1 Tier 1 Preliminary Risk Assessment (Desk Study Report) appended in Appendix C.

2.2 HGE Phase 1 Desk Study Report GL25617

HGE have undertaken a Stage 1 Tier 1 Preliminary Risk Assessment (Desk Study Report) for the subject site, ref: GL25617 dated February 2023. Although the findings of the desk study report have been considered within this report it is recommended the Desk Study should be read in conjunction with this report and is presented in Appendix C.

A summary of the findings in the report and the conclusions are detailed below:

The geology underlying the site is detailed to comprise superficial Lynch Hill Gravel Member overlying London Clay Formation.

The site area is detailed as having a Secondary A aquifer designation (Lynch Hill Gravel Member). The underlying solid geology (London Clay Formation) is identified as unproductive. The site does not lie within a source protection zone.

No surface water features are recorded within 250m of the site. It should be noted that the River Thames is located approximately 1.2km to the southeast of the site.

A negligible risk of flooding from either rivers or the sea was identified on site. However, a moderate risk is considered from groundwater flooding.

The site is located within a SSSI Impact Risk Zone and a conservation zone.

The closest active groundwater abstraction is located some 209m west of the site associated with a heat pump at the London School of Hygiene and Tropical Medicine.

The closest historical tank was located 313m northwest of the site, an obsolete petrol station was recorded 297m west of the site and the closest historical garage was recorded 247m northwest of the site. No historical tanks were located within 250m of the site.

4 No. electrical substations were recorded within 250m of the site. The closest was situated 15m northwest of the site.

No historical industrial land uses were recorded within 250m of the site. The closest was a hospital located 259m northeast of the site.

21 No. recent industrial land uses are recorded within 250m of the site. Examples of these include electronic stores, electrical substations, publishers, house clearance companies, vehicle hire, recording studios, machinery, and photographic stores.

When considering the possibility of encountering UXO a Medium Risk was returned for any proposed drilling, sampling, bulk excavations or piling in any post war Un-worked Ground.

The site is known to have been heavily influenced by human activity to as far back as the Roman period, and especially from c. 1643 onwards, when the large scale earthworks of the ‘Lines of Communication’ were undertaken in very close proximity to the site during the Civil War. Various incarnations of Montagu House and the British Museum followed, with the surrounding farmland yielding to urbanization by the turn of the 19th century until Montagu House was surrounded on all sides by high-status residential townhouses and their gardens.

From the mapping available, the site is shown to have been part of the gardens of the terraced townhouses lining Montague Street, from the late 19th century until the 1960s. The British Museum expanded their site boundary at this time to incorporate much of these gardens, including the proposed site. The current East Road Building was shown to have been present on-site from the 1960s and has remained unchanged to the present day.

The potential for uncontrolled backfill and relict structures have been identified as potential geotechnical hazards.

The potential presence of a considerable thickness of dense granular Lynch Hill Gravel Member and the anticipated loads associated with the proposed structures are likely to make shallow foundations (including rafts) a suitable foundation solution. However, given the proposed designs include a single storey basement, it is likely that a piled foundation solution may be required.

Consideration of the sulphate content of the soils should be given with respect to the grade of concrete suitable for use at this location. The density and permeability of shallow soils should be assessed in order to consider pavement and drainage design. The likely granular nature of the superficial deposits covering the site, suggest that conventional soakaways maybe suitable in the absence of significant made ground deposits. Although groundwater levels will need to be confirmed.

Examination of available historic map data shows since the late 19th century the site was occupied by gardens, boundary walls and garden outbuildings. Unless they and all existing underground structures are thoroughly ‘grubbed out’, demolition of the existing buildings may lead to the presence of relict substructures. There is also the possibility for underground services to cross the site.

Of the identified potential contamination sources, made ground associated with the historic nature of the site, and possible asbestos (buried and within existing buildings) are believed to be the most significant sources of potential contamination and will be considered further in the assessment process.

Potential contaminants identified based on the current and previous use could include but not inclusive to metals/metalloids and their compounds, inorganic compounds, total petroleum hydrocarbons (TPH), polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAH). An asbestos fibre screen should be included as part of the recommended suite to rule out its’ presence within the near surface soils where physical contact is anticipated with future site users.

A UXO study suggested a Medium Risk for any proposed drilling, sampling, bulk excavations or piling in any post war un-worked ground.

An initial assessment of the risk posed by each pollutant linkage was carried out and is presented in the table below. Refer to the full report presented in Appendix C for a complete Conceptual Site Model (CSM) and Phase 1 risk assessment.

As part of the Desk Study a Groundwater Screening Assessment was undertaken to feed into a Basement Impact Assessment (BIA) to be carried out by others. It was concluded that the development will not result in any specific issues relating to hydrogeology and hydrology of the site and that it is assumed that suitable and appropriate construction methods will be adopted to ensure that there will not be any negative impacts on the groundwater, slope stability or effects on adjacent properties or public highways.

Hazard Identification				Hazard Assessment			
Link No.	**Source/ Hazard**	**Pathway**	**Receptor**	**Probability**	**Consequence**	**Hazard Ranking**	**Hazard Assessment:** - **Action required (AR)** - **Site Investigation (GI)** - **No Action (NA)**
1	Hazardous vapours / soil gas from made ground, volatile hydrocarbons/free product or migrating to site from backfill material	Ingress into excavations, structures and confined spaces, and subsequent inhalation.	People on the site during development construction.	Low Likelihood	Minor	Very Low Risk	**GI** - Ground gas monitoring/assessment with ground worker risk assessment required.
2		Ingress into structures and confined spaces, and subsequent inhalation.	People using the site post development construction.	Low Likelihood	Mild to Medium	Moderate / Low Risk	
3	Contaminated soil from previous and present contamination sources both on and off site	Ingestion of soil through direct contact, eating with dirty hands and dust inhalation.	People on the site during development construction.	Low Likelihood	Minor	Low Risk	**GI** - Possibility of contamination across the site. Requires quantification through investigation and chemical testing followed by ground worker risk assessment.
4			People using the site post development construction. Human end users and neighbours post development construction.	Low Likelihood	Minor	Low Risk	**GI** - Possibility of contamination across the site. Requires quantification through investigation and chemical testing followed by ground worker risk assessment.
5							
6		Leaching.	Groundwater – Secondary A aquifer superficial deposits. Surface Waters - The River Thames Off-site human receptors and infrastructure.	Low Likelihood	Mild to Medium	Moderate / Low Risk	**GI -** Possibility of contamination across the site which could be affecting groundwater and surface waters. Groundwater chemical analysis and leachate soil analysis should be undertaken as part of intrusive investigation with subsequent assessment. There could be a requirement for DQRA depending on the conditions encountered and the results of the proposed chemical analysis.
7		Infiltration					
8		Via service pipes.	People using site after development completion.	Low Likelihood	Medium	Moderate / Low Risk	**GI** - Chemical testing and assessment of risk required only if significantly deleterious conditions encountered during invasive investigation works and/or in proposed landscape and garden areas. This excludes private gardens which is considered under link 2.

9		Plant uptake.	Local flora and fauna.	Low Likelihood	Minor	Very Low Risk	NA - Chemical testing and assessment of risk required only if significantly deleterious conditions encountered during invasive investigation works.
10		Direct Contact	Building structures	Low Likelihood	Minor	Very Low Risk	**GI** - Chemical testing and assessment of risk required only if significantly deleterious conditions encountered during invasive investigation works and/or in proposed structure areas.
11	Potential asbestos containing materials within Made Ground soils	Inhalation of dust.	Humans on and in the vicinity of the site during demolition/ development construction.	Low Likelihood	Severe	Moderate Risk	**GI -** Possibility of asbestos in existing Made Ground and so it is recommended that the potential for ACMs is assessed through an appropriate survey, with removal and disposal undertaken in accordance with the 'Duty of Care' and applicable legislation.

Table 2.2: HGE Phase 1 Desk Study Initial Hazard Identification and Hazard Assessment (Table of Pollutant Links)

3 INTRUSIVE INVESTIGATION

3.1 Introduction

The intrusive investigation was designed to target the ground conditions at the site concentrating on the proposed building footprint. This was undertaken by 2 No. cable percussive boreholes, 5 No. foundation inspection pits and following ground gas and groundwater monitoring of the borehole installations.

The sampling strategy and locations were designed and provided by ABA, considering local site constraints including reference to topography of the site, the geology encountered and the development proposals.

During and immediately following completion of the fieldwork, soil samples were transported to Harrison Group's Laboratory in Norwich via in house transportation where, upon arrival, they were logged into our sample management system. Following receipt of the geotechnical schedules, certain geotechnical samples were subsequently dispatched to laboratory subcontractors via courier.

3.2 Fieldwork, Monitoring and In-Situ Testing Program

Details of the site investigation methods employed have been presented on the appended data sheet and a summary of the fieldwork has been presented below with the exploratory locations indicated on appended drawing GL25617-DR003 presented in Appendix B. All fieldwork records are provided within Appendix D.

3.2.1 Service Clearance and Surveying

Exploratory locations were surveyed whilst undertaking a utility clearance survey on 9th January 2023 to establish co-ordinates and levels. The service clearance was conducted by a specialist subcontractor, Safe Dig Surveys Ltd. In addition to examining plans, covers were lifted, and services traced using variety of electromagnetic means. Where possible ground probing radar was also utilised with known services marked up on the ground.

Any changes to proposed exploratory positions, as a result of the above, were discussed and confirmed with ABA via email and telephone. In areas where poor GPS signal was encountered, co-ordinates and levels have been extrapolated from previously undertaken topographical surveys provided.

The location is presented on the exploratory location plan GL25617-DR003 presented in Appendix B. Co-ordinates and levels are detailed, both below, and on the relevant logs presented in Appendix D.

3.2.2 Hand Excavated Foundation Inspection Pits

Five hand excavated foundation inspection pits, TPA to TPE were excavated to a maximum depth of 3.80mbgl, to expose and identify any potential obstructions within the near surface soils. These included existing foundations, relic structures, roots and services. The trial pits were excavated by hand to depth.

In some cases, where proving the base of a foundation was not possible due to excavating restrictions, a pilot hole was drilled through the top of the exposed foundation to estimate foundation thickness. These details are included on the trial pit drawings in Appendix D.

Following the completion of each location, the trial pits were reinstated, matching like for like the original surface where practically possible.

Photographs have been provided electronically as an attachment to this report showing the pre-excavation condition of the trial pit locations, features encountered during excavation and the final reinstatement condition.

The trial pits are summarised below in Table 3.2.2.

Trial Pit No.	Easting	Northing	Surface Level (mAOD)	Depth (mbgl)	Detail
TPA	530060.80	181810.51	25.18	1.25	To establish foundation profiles of the existing service bridge.
TPB	530069.97	181816.59	26.01	3.80	To establish foundation profiles and depths of the existing East Road building, garden wall and neighbouring residential basement.

Trial Pit No.	Easting	Northing	Surface Level (mAOD)	Depth (mbgl)	Detail
TPC	530084.58	181802.22	26.08	3.10	To establish foundation profiles and depths of the existing East Road building and neighbouring residential basement.
TPD	530088.83	181796.77	25.82	3.20	To establish foundation profiles and depths of the existing East Road building and neighbouring residential basement.
TPE	530068.78	181817.13	25.93	2.30	To establish foundation profiles and depths of the existing East Road building and garden wall.

Table 3.2.2: Summary of Hand Excavated Foundation Inspection Pits

A detailed description of all the strata encountered, position and types of samples taken, tests performed; along with any groundwater observations made at the time of excavation are included on the trial pit logs presented in Appendix D.

3.2.3 Cable Percussive Boreholes

Two cable percussive boreholes, recorded as BHA and BHB, were drilled between 16th and 20th January 2023 to a maximum depth of 15.00m to sample, test, and log the sub-soils underlying the site. Upon completion the boreholes were installed with a monitoring well as detailed in section 3.2.3. A summary of the borehole is provided below in Table 3.2-3.

Location ID	Easting	Northing	Ground Level (maOD)	Depth (m)	Installed	Purpose	Termination Reason	Fieldwork Date(s)
BHA	530063.81	181808.10	24.83	15.00	Y	General site coverage	Target depth achieved	19/01/2023 – 20/01/2023
BHB	530076.89	181791.35	24.81	15.00	Y	General site coverage	Target depth achieved	16/01/2023 – 18/01/2023

Table 3.2.3 Summary of Cable Percussive Boreholes

In accordance with the requirements of the Detailed Unexploded Ordnance Risk Assessment, (presented in Appendix C), during the intrusive works both exploratory locations were cleared for unexploded Ordnance by an EOD Engineer.

A detailed description of the strata encountered, position and types of samples and in-situ tests taken, along with any groundwater observations made at the time of drilling are included on the borehole logs presented in Appendix D. Rig certificates are presented in Appendix D.

3.2.4 Monitoring Wells

2 No. cable percussive boreholes were installed with standpipes for monitoring the ground gas and groundwater within the soils encountered. Table 3.2.4 summarises the details of these installations.

Monitoring Point ID	Diameter of Installation (mm)	Base Depth of Installation (m)	Response Zone (m depth)		Target Strata
			Top	Base	
BHA	50	7.00	1.00	7.00	Made Ground / Lynch Hill Gravel Member
BHB	50	8.00	1.00	8.00	Made Ground / Lynch Hill Gravel Member

Table 3.2.4 Summary of Monitoring Installations

Detailed descriptions of the installation and their corresponding backfill materials are included on the relevant exploratory hole log presented in Appendix D.

3.2.5 Ground Gas & Ground Water Monitoring

Three rounds of monitoring have currently been undertaken on the borehole installations on the following dates:

- Round 1 - 7th February 2023
- Round 2 - 22nd February 2023 (groundwater sampling)
- Round 3 - 7th March 2023

The gas monitoring utilised a GA5000 infrared gas analyser to record concentrations of gases including methane, carbon dioxide, oxygen and the related pressure and flow. Volatile Organic Compounds (VOCs) were monitored utilising a PID meter. The results are presented on the gas monitoring result sheets contained in Appendix D.

Groundwater levels and any free phase NAPL (DNAPL and LNAPL) were also monitored on the above dates utilising a dual phase interface meter.

Groundwater samples from the installations were collected as part of the monitoring round on 22nd February 2023. The groundwater results are presented in Appendix D.

3.3 Fieldwork Observations

3.3.1 Ground Conditions

Soil containing anthropogenic material (*made ground*) was encountered to a maximum depth of 3.70mbgl (TPB). Within the boreholes, the maximum depth of the made ground was recorded at 1.95mbgl (BHB). In positions where the extent of made ground was proven, the level at which natural deposits were encountered ranged from 22.31 – 23.08mAOD. Within the boreholes, the disturbed soil comprised granular horizons over more cohesive strata with anthropogenic material such as brick, concrete, possible clinker, asphalt, animal bone and tile fragments. Within the trial pits, more granular fill was typically encountered, with similar anthropogenic material encountered, with the addition of occasional metal, slate, ceramic, glass, lead, possible ACM, and oyster shell fragments.

The underlying natural superficial soils consisted of both cohesive and granular horizons.

The cohesive deposits were described as firm brown slightly sandy slightly gravelly CLAY, with gravel comprising subangular to subrounded, fine to coarse flint. This stratum was encountered between 1.90m and 2.80mbgl. These soils are representative of the *Lynch Hill Gravel Member.*

The shallow granular soils were described as medium dense to very dense brown fine to coarse SAND and subangular to subrounded, fine to coarse flint GRAVEL. This stratum was encountered between 2.60m and 6.20mbgl. This material is also representative of the *Lynch Hill Gravel Member.*

Cohesive bedrock deposits were found to underlie the superficial deposits, comprising of stiff, grey CLAY, with occasional lenses of fine grey sand, and occasional fine selenite. Within BHB a thin band of medium strong CLAYSTONE was encountered between 6.40 and 6.60mbgl. This cohesive stratum was proven to the base of the boreholes (15mbgl) is typical of and is considered representative of the *London Clay Formation.*

3.3.2 Groundwater

Depth to groundwater was recorded to range between 3.41m and 5.50m (21.39 to 19.26maOD) within the exploratory holes during drilling and subsequent monitoring of the wells installed, the results are presented in Appendix D and summarised in Table 3.3.2 overleaf.

Exploratory Hole Location	Groundwater depth during drilling (mbgl)	Response Zone Depth (m)	Groundwater Depth (m) / Level (maOD) encountered during monitoring		
			Round 1 (07/02/2023)	Round 2 (22/02/2023)	Round 3 (07/03/2023)
BHA	5.50	1.00 – 7.00	3.61 / 20.97	3.55 / 21.03	3.62 / 20.96
BHB	5.40	1.00 – 8.00	3.41 / 21.39	3.43 / 21.37	3.45 / 21.35

Table 3.3.2 Summary of Groundwater Levels During Drilling/Excavation & Monitoring

The desk study modelled the groundwater flow and reported that in the wider area the groundwater is shown dipping very slightly to the west, albeit with a gradient magnitude of <0.01, although this is largely influenced by a single historic borehole (TQ28SE778) which may represent an outlier.

In the area of the East Road Building the groundwater is shown as largely level / dipping very gently to the north.

A down the hole data logger (Diver) was placed beneath the water table in each of the boreholes to allow for semi continuous groundwater level monitoring over a period of six months. This data, corrected for barometric variations, is presented below as Figure 3.3.2

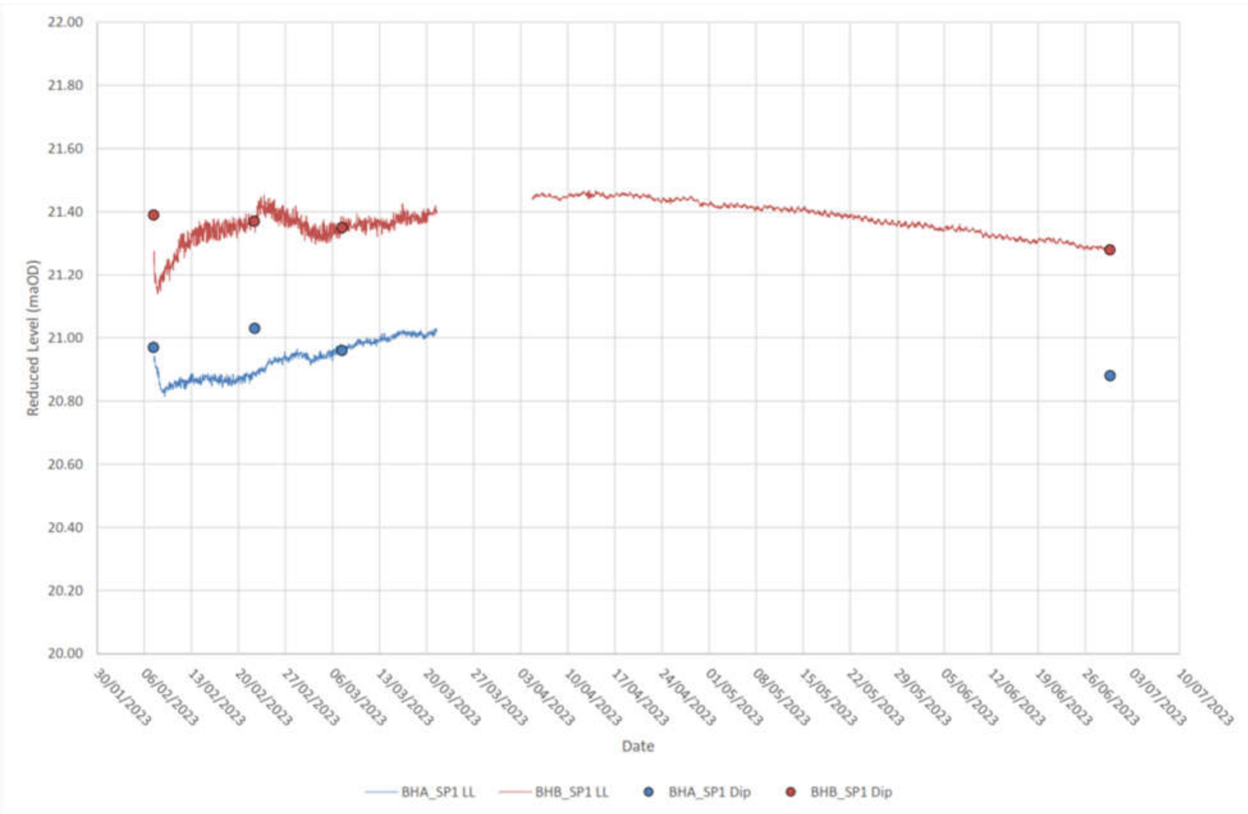

Figure 3.3.2: Summary of dip levels and long term monitoring.

The above figure shows the natural variation in groundwater levels over time with small variations most likely related to rainwater events. It also exhibits a relatively good correlation between this constant monitoring and the dip levels recorded taken during the initial monitoring rounds.

3.3.3 Ground Gas

The gas monitoring regime comprised 3 No. rounds carried out over a one month period following completion of the fieldwork, the results of which are presented in Appendix D and summarised in Table 3.3.3 overleaf.

Monitoring Point ID	Barometric Pressure (mB)	Gas Concentration Ranges						Max Flow Rate (l/hr)
		CH_4 (%)	CO_2 (%)	O_2 (%)	CO (ppm)	H_2S (ppm)	Peak PID (ppm)	
BHA	999 - 1037	<0.1 - 0.1	0.1 - 0.5	20.4 - 21.7	<1 - 6	<1	<0.1 - 0.3	0.0
BHB	999 - 1038	<0.1 - 0.2	0.1 - 0.2	2.0 - 22.1	<1 - 55	<1	<0.1 - 0.6	0.1

Table 3.3.3 Summary of Ground Gas Concentrations and Flow Rates

3.3.4 Contamination Observations

Olfactory and visual evidence of potential contamination was limited to the granular and cohesive fill, as detailed below:-

- BHA contained brick, concrete, asphalt, tile, and animal bone fragments.
- BHB contained brick, asphalt, possible clinker, and animal bone fragments.
- TPA contained brick, concrete, asphalt, and animal bone fragments.
- TPB contained brick and concrete.
- TPC contained brick, concrete, metal, slate, animal bone, ceramic, oyster shell, tile, and clay pipe fragments.
- TPD contained brick, concrete, ceramic, glass, and ceramic fragments.
  TPE contained brick, concrete, glass, oyster shell, slate, possible ACM, lead, and animal bone fragments.

3.4 In-Situ Testing

In-situ testing was undertaken for geotechnical purposes and is summarised in Table 3.4 below with subsequent sections providing details regarding the tests results.

Test Type and Reference (BS 1377: 1990 unless stated)	Stratum	Number of Results	Results (Range)	Comments / Limitations
Standard Penetration Test (BS EN ISO 22476-3:2005)	Made Ground (Cohesive)	2	N = 7 - 8 N_{60} = 9 - 10	Indicative of firm cohesive soils.
	Lynch Hill Gravel Member (Cohesive)	2	N = 50 N_{60} = 63	Indicative of very dense granular soils.
	Lynch Hill Gravel Member (Granular)	4	N = 26 - 50 N_{60} = 28 - 53	Indicative of medium dense to very dense granular soils.
	London Clay Formation	8	N = 13 - 28 N_{60} = 16 - 35	Indicative of firm to stiff cohesive soils.

Table 3.4 Summary of In-Situ Geotechnical Testing

3.4.1 Standard Penetration Testing

The N values reported directly from the blow counts of the equipment in the field standard penetration tests are presented on the appended borehole records. To adjust the field test results for potential energy loss to and by the drive rods, these have been converted to standardised N_{60} values by using the following equation provided in BS EN ISO 22476-3:2005+A1:2011.

$$N_{60} = \frac{E_r}{60} N\boldsymbol{\lambda}$$

where:

N = N values from field tests.

E_r = Energy ratio of the hammers (76% (SI08) and 57% (SI07) for the cable percussive hammers and 70% (DART312) for the dynamic sampling rig hammer utilised on this site).

$\boldsymbol{\lambda}$ = Correction value for the rod length below the anvil (where in granular soils).

Figure 3.4.1 below provides the relationship between depth and N_{60}.

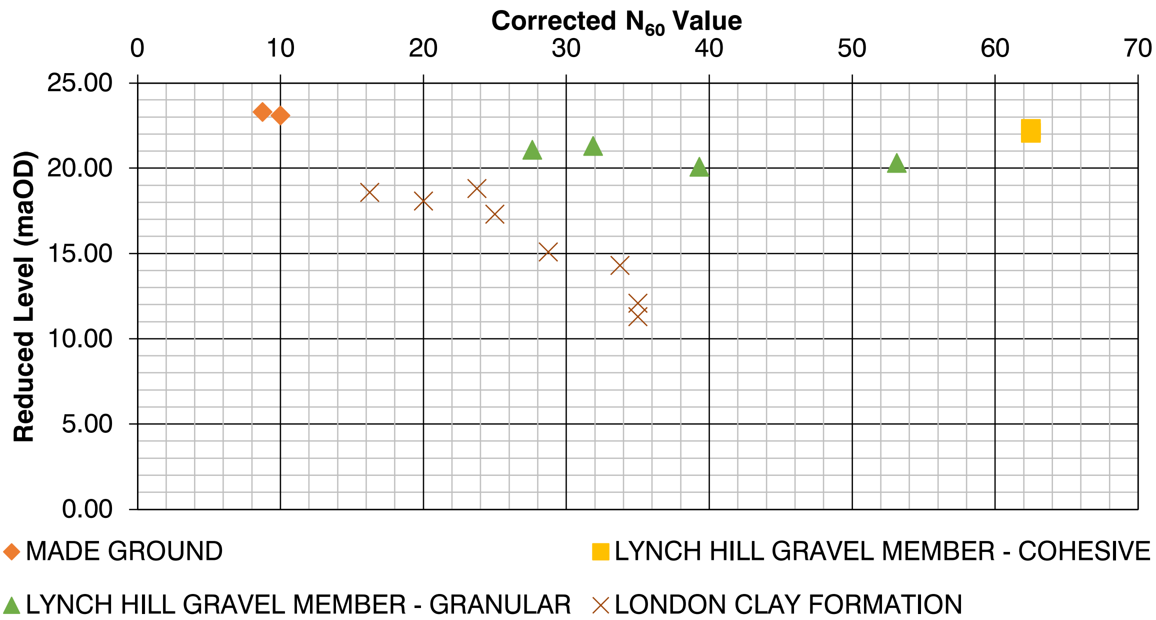

Figure 3.4.1 Corrected N_{60} Values vs. Depth

The above graph shows that all of the SPT N_{60} values were above 20. Using these values, the majority of the Lynch Hill Gravel Member can be interpreted as being medium dense or better.

The SPT results, in conjunction with engineer's descriptions can be also used as a guide to estimate the strength of cohesive material. The figure above indicates that most of the tests conducted in the cohesive London Clay material trended with a higher resistance, which can be interpreted as a stiff increasing in strength with depth.

Adjustment can also be made to N-values to consider the effect of the overburden pressure in granular material, as described in BS EN ISO 22476-3:2005+A1:2011. This correction has not been applied to the data for this project.

3.5 Geotechnical Laboratory Testing

The following laboratory tests have been scheduled by Harrison Geotechnical Engineering and conducted on samples obtained from the exploratory holes. Unless otherwise stated the tests were performed in accordance with BS1377 Methods of Test for Soils for Civil Engineering Purposes. The laboratory test results presented in the appendix and are summarised in Table 3.5 below.

Test Type and Reference (BS 1377: 1990 unless stated)	Strata	Depth (m)	Number of Results	Results (Range)	Comments / Limitations
Water Content (BS EN ISO 17892-1:2014)	Made Ground	0.80 - 1.95	3	15 - 22%	-
	Lynch Hill Gravel Member	2.00 - 2.50	4	11 - 23%	
	London Clay Formation	7.25 - 9.95	4	25 - 33%	
Atterberg Limits (Part 2)	Made Ground	0.80	1	PL 22% LL 37% PI 15 Modified PI 8	British Standard classification – Moderate plasticity (CI).
	Lynch Hill Gravel Member	2.00	2	PL 18 - 19% LL 47 - 50% PI 28 - 32 Modified PI 28 - 32	British Standard classification – Moderate plasticity (CI).

Test Type and Reference (BS 1377: 1990 unless stated)	Strata	Depth (m)	Number of Results	Results (Range)	Comments / Limitations
	London Clay Formation	7.25 - 9.95	4	PL 24 - 27% LL 71 - 77% PI 46 - 51 Modified PI 46 - 51	British Standard classification – Very High plasticity (CV).
Particle Size Distribution - Wet Sieving (Part 2, clause 9.2) & Sedimentation by pipette (Part 2, clause 9.4)	Lynch Hill Gravel Member	3.50 - 4.50	4	Cobbles 0.0% Gravel 47.9 - 75.8% Sand 24.0 - 51.9% Fines 0.2 - 1.0%	The recovery of an adequate mass of coarse grained soils for particle distribution analysis can be difficult in boreholes. In obtaining such samples from cable tool boreholes it should also be noted that some loss of fine material generally occurs due to the nature of the sampling process. For health and safety precautions unable to undertake test if suspected asbestos or gross contamination is identified on sample preparation.
Single Stage 100mm UU Triaxial Compression Test (Part 7, clause 8)	London Clay Formation	8.50 - 14.95	6	115 - 234 kPa	The London Clay Formation samples tested were representative of stiff (high strength) to very stiff (very high strength) cohesive soils.
Soil pH – Geochemical Testing (BRE SD1 2005)	Made Ground	0.50 - 1.00	3	7.9 – 11.3	-
	Lynch Hill Gravel Member	2.00 – 6.00	7	7.6 – 9.3	
	London Clay Formation	6.60 - 15.00	8	8.1 – 9.1	
Water Soluble Sulphate Content 2:1 Aqueous Extract (BRE SD1 2005)	Made Ground	0.50 - 1.00	3	20 – 72.4mg/l	-
	Lynch Hill Gravel Member	2.00 – 6.00	7	2.7 – 59.1mg/l	
	London Clay Formation	6.60 - 15.00	8	176 - 450mg/l	
Acid soluble sulphate content (Total BS1377 HCl extract)	London Clay Formation	6.60 - 15.00	8	0.041 – 0.081%	-
Sulphur (Total) (L038-PL - I2 in house)	London Clay Formation	6.60 - 15.00	8	0.341 – 0.831%	-

Table 3.5 Summary of Geotechnical Laboratory Test Results

3.6 Chemical Laboratory Testing

6 No. samples of the near surface made ground (depth ranging 0.50m to 1.40m) were submitted to a UKAS/MCERTS accredited laboratory for a general suite of analytes as detailed in Table below.

2 No. groundwater samples were collected from monitoring round 2 at a depth of 4.00mbgl from the monitoring wells installed. It was submitted to a UKAS/MCERTS accredited laboratory for a suite of analytes (Suite HW1.1) as detailed in Table 3.6 overleaf.

Analysis Type	Number of Tests
SOILS	
Suite HS1.0: (As, B, Cd, Cr (total & VI), Cu, Ni, Pb, Hg, Se, Zn, V, Be, pH, TOC, TPH CWG, PAH USEPA 16, phenols (total), asbestos screen (with ID where found)).	6
Full WAC Suite (inert solid suite, LoI, pH, ANC and single stage leachate).	1
Asbestos Identification	1
GROUNDWATER	
Suite HW1.1: As, B, Cd, Cr (total and VI), Cu, Pb, Hg, Ni, Se, Zn, cyanide (total and free), sulphate, sulphide, sulphur (free), chloride, NH4 as N, pH, nitrate, nitrite, conductivity, hardness, COD, DOC, DO, PAH (speciated 16), TPH CWG (C10-C40), phenols (speciated)	2

Table 3.6 Summary of Chemical Laboratory Testing

3.7 Comparison with the Ground Model

The soils encountered during the investigation appear to be comparable to that of the ground model and the background research.

Groundwater was encountered between 5.40 and 5.50mbgl during drilling, and between 3.41m and 3.62mbgl during the current monitoring rounds within the Lynch Hill Gravel Member (Secondary A aquifer).

4 GEOTECHNICAL ASSESSMENT

4.1 General

It is understood that the current site, consisting of single storey brick structure is proposed to be replaced by a new two-storey service building, including a single storey basement as part of the SWEC development at the British Museum, as set out in the plans provided by ABA.

The basement development is modest in size such that it does not extend beyond the footprint of the building and is no deeper than one full story below ground level (approximately 3m in depth).

We understand that basement will be formed using a secant piled retaining wall with a reinforced concrete box structure inside the piles. The piles will be bored to reduce the noise and vibration generated, extending through the gravel layer into the London Clay. The basement box will be founded in the dense gravel layer.

The ground conditions were found to comprise made ground to a maximum recorded depth of 3.70m overlying variable cohesive and granular natural Lynch Hill Gravel Member, underlain by London Clay Formation bedrock, which was encountered at a depth of 6.40m and proven to a maximum depth of 15.00m.

Potential geotechnical hazards identified at this location include sulphate bearing soils, uncontrolled backfill, relict structures, high groundwater level, unexploded ordnance, shrink/swell potential, and variable natural soils.

It should be noted that the current work has only investigated the site at discrete locations. Ground conditions may vary between areas of investigation.

4.2 Geotechnical Considerations

For the proposed development, the primary geotechnical considerations will be the strength and compressibility of the founding soils and following on from this the foundation requirements of the proposed structures. This section of the report presents comments on the ground conditions in relation to design and construction of the geotechnical elements of the proposed structures.

Recommended characteristic values of parameters for geotechnical design as determined from consideration of the results of geotechnical testing conducted on samples of the soils recovered during the ground investigation, and consideration of published data and correlations with index properties, are discussed below and are summarised in Table 4.2 below.

Stratum	Bulk Unit Weight, ɣ' (kN/m³)	Undrained Shear Strength, c_u (kPa)	Effective Cohesion, c' (kPa)	Angle of Internal Friction, ø' (degrees)	Elastic Modulus, E' (MPa)
Made Ground	18.0	-	0	33	20
Lynch Hill Gravel Member - Cohesive	19.0	75	8	29	~0.5
Lynch Hill Gravel Member - Granular	21.0	-	0	41.5	70
London Clay Formation	20.5	125	5	15	40

Table 4.2 Summary of Geotechnical Properties

4.3 Foundation Recommendations

4.3.1 Traditional Foundations

We would not advise placing any significantly loaded structures within the made ground deposits or near surface cohesive deposits due to their variable nature, limited thickness and generally poor geotechnical properties.

The shallow granular soils were described as medium dense to very dense brown fine to coarse sand and subangular to subrounded, fine to coarse flint gravel. In the boreholes this stratum was encountered between 2.60m and 6.20mbgl. While beyond the depth where we would recommend new traditional foundations it is nevertheless a good founding medium and could be utilised to support the construction of the basement box.

Bearing capacity of the subsoils will increase with depth and pad foundations placed at around 3.00mbgl founded within these dense granular deposits could be associated with allowable bearing capacity of 225kN/m^2 for a nominal 1m wide pad foundation.

The actual settlement of foundations will be dependent upon their size and configuration but would generally not be expected to exceed 25mm at the recommended maximum allowable bearing capacity.

It is recommended that all excavations are inspected by suitably experienced personnel before construction of the foundations. If any soft/loose material is identified, foundations be increased in depth to found upon competent soils. Should unsuitable material be encountered at founding depths, and deepening the foundations is not considered a viable option, alternative foundations options or ground improvement should be considered.

Where possible and in order to reduce any possible differential settlement, new foundations should be placed within the same geological horizon.

The above has been modelled for a new independent foundation and does not consider any potential affects (loadings or settlements) on existing adjacent foundations/structures and potential basements.

Groundwater should not be encountered in shallow excavations, although surface water/rainfall may pond in excavations. The strength of the sub-soils will be moisture dependent both on drying and wetting and excavations should not be left open for any longer than required for construction and wet weather working should be avoided where possible.

4.3.2 Piled Foundations

In accordance with the proposed plans provided by ABA, preliminary pile capacity calculations have been undertaken in accordance with BS EN 1997-1:2004 +A1:2013 (Eurocode 7), Design Approach 1, Combinations 1 and 2 for the use of continuous flight auger (CFA) piles. The assessment has been undertaken using the software package GEO5 2021 Pile (Fine Software).

The soil profile has been modelled using boreholes BHB, which provides coverage of ground conditions to sufficient depth beneath the site.

Using a pile diameter of 450mm (as scoped by ABA) and an embedment depth of 8.00m within the stiff London Clay Formation, a maximum allowable load in the order of 200kN can be allowed for each individual pile, with loadings taken by a combination of skin and end bearing resistance. For a 450mm diameter pile constructed to 10.00m, an allowable load in the order of 275kN is achievable.

Different configurations of depth and pile diameter may give larger allowable bearing capacities for each pile if required. However, it should be noted that due allowance should be given for pile interaction which may result in a reduced overall capacity where individual pile spacing is less than three times the pile diameter.

Given that the site is currently active and that there are very sensitive structures in close vicinity of the site that may be adversely affected during piling operations, it is considered that a driven pile option is not appropriate for this site.

On this site, if continuous flight auger techniques were to be used, instability of the pile bore in the Made Ground and Lynch Hill Gravel Member may be experienced. Similarly, if the use of conventional rotary auger techniques is required, it is likely that temporary casing will be needed to the base of the superficial deposits, to support the pile bore and to exclude groundwater.

The axial load capacity of the piles may be determined from the characteristic values recommended in Table 4.2-1 using the static design procedures and the partial and model factors given in the BS EN 1997-1:2004+A1:2013. In these procedures the axial capacity of the pile is taken to be the sum of the adhesion on the pile shaft and the end bearing resistance on the pile base.

Given the nature of the granular soils underlying the site, it is expected that any excess groundwater pressure will dissipate rapidly and, hence, it is recommended that the resistance on the pile shaft in this stratum, together with the underlying Made Ground, is determined using effective stress strength parameters. On this basis, the resistance on the pile shaft is related to the effective overburden pressure using an earth pressure coefficient and an angle of friction between the pile shaft and the founding soil. The value of earth pressure coefficient depends on the pile construction techniques used and for driven concrete piles may be taken as 1.0 times the at-rest earth pressure coefficient. The angle of friction between the pile shaft and the founding soils depends on the material forming the pile shaft and for cast-in-place concrete piles is typically taken to be equal to the angle of internal friction of the founding soil.

For the Thames Group clays, the adhesion on the pile shaft is related to the undrained shear strength on the founding clay by an adhesion factor. The adhesion factor depends on the degree of softening and stress relief in the clay around the pile during boring and prior to concreting. Given that significant quantities of groundwater may enter the pile bore it is expected that softening of the clay may take place. For such conditions, an adhesion factor of 0.50 is considered appropriate for the London Clay.

4.3.3 Floor Slabs / Heave Assessment

We understand a basement floor slab may form part of the construction. The weight of the proposed building is slightly less than the weight of the soil that will be removed during the excavation. The London Clay will therefore experience a slight load reduction. However, because the excavation remains some way above the London Clay and the amount of unloading is small, heave pressures from the clay are not expected to be significant and will be accommodated by the ground-bearing slab without heave protection being required.

Suitable compaction of the sub-grade should be carried out in any case in order provide a consistent founding layer and minimise potential deflections. It is important that the sub-grade is protected from exposure during construction to limit the potential detrimental effects of wetting or drying of cohesive sub-soils.

4.4 Stability of Excavations

The underlying made ground and natural deposits comprised cohesive and granular deposits. Shallow excavations within underlying cohesive deposits are likely to be generally relatively stable in the short term, although support will likely be required where the excavations extend within granular deposits (made ground and natural), where they are to be left open for any significant period of time, or where man entry is required. No materials should be stockpiled adjacent to open excavations.

The inflow of groundwater into shallow excavations should be expected within the granular deposits and at the base of the made ground units. Groundwater was encountered at circa 5.5mbgl during the intrusive works, subsequent monitoring has identified the standing water levels within the natural granular deposits between 3.41 and 3.62mbgl. Groundwater conditions can vary dependent on the time of year and the amount of rainfall that has occurred and therefore levels may differ from the observations currently recorded. Therefore, sump pumping of groundwater within shallow excavations could potentially be required.

We expect that the proposed piled wall will also assist in managing the rate of groundwater entering the excavations during construction. This approach should mean only minor local pumping will be necessary during construction rather than more significant dewatering techniques, which could impact the surrounding Grade I listed buildings.

Attention is drawn to the provisions of the Health and Safety at Work regulations, which state that any excavations should be inspected by a competent person, particularly where personnel entry is required. Where necessary excavation sides should be fully supported or battered back to a safe angle.

4.5 Foundation Concrete (Aggressive Chemical Environment)

Made Ground

Chemical laboratory testing of the shallow soils down to 6mbgl (Made Ground and Lynch Hill Gravel Member) found soluble sulphates in concentrations of up to 0.072g/l, associated with pH values varying between 7.6 and 7.9.

The results indicate that a design sulphate class of DS-1 and an ACEC class of AC-1s should be used for buried concrete in contact with these materials in accordance with BRE Special Digest 1, "Concrete in aggressive ground".

London Clay Formation

From examination of the London Clay soils it is thought that this horizon would be classified as "greenfield" with "static'' groundwater in cohesive deposits" in accordance with Table C1 of the above mentioned digest.

Chemical testing of eight London Clay Deposit soil samples found soluble sulphates in concentrations between 176 to 450mg/l from the samples tested along with pH values of between 8.1 and 9.1. The samples were tested for the "Pyrite" BRE suite and yielded total potential sulphate values (TPS) of up to 4.46% and therefore oxidisable sulphides of above 0.3% indicating pyrite is present which may oxidise if the ground is disturbed.

It should be noted that the concrete specification varies greatly for the London Clay Formation dependent on whether or not oxidation has occurred due to ground disturbance. Disturbed material would be natural ground that was substantially disturbed; for example, by cutting and filling to terrace a site, or by excavation and backfilling, so that air can enter and oxidise any pyrite contained therein. Simply cutting through ground without opening up the ground beyond the cut face (e.g. piling operations or excavation without backfill) does not generally result in disturbed ground.

Therefore, if it is considered that the deposits will be disturbed, the results suggest a Design Sulphate Class of DS-5 for the London Clay in accordance with BRE Special Digest 1 "Concrete in aggressive ground" and an Aggressive Chemical Environment for Concrete (ACEC) class of AC-4s (assuming static conditions).

The digest described should be consulted prior to scheduling the permanent works as the specification must be applicable to the application.

4.6 Geotechnical Hazard Evaluation

6 No. geotechnical hazards have been carried forward in the assessment and are detailed in Table below. Based on the findings of the intrusive investigation, laboratory testing and monitoring each risk has been evaluated to assess whether a positive risk remains. Where a positive risk is still identified the recommended action(s) have been provided.

Hazard	Requires further consideration?	Comment
Sulphate Bearing Soils	No/**Yes**	Shallow soils down to 6mbgl (Made Ground and Lynch Hill Gravel Member) indicate that a design sulphate class of DS-1 and an ACEC class of AC-1s. If concrete is anticipated to encounter the underlying London Clay Formation a design sulphate class of DCS-5 and an ACEC class of AC4s could be required depending on the applications.
Uncontrolled Backfill	**Yes**	No significant uncontrolled fill and limited made ground has been recorded. However, given the limited coverage during this investigation, the possibility remains for areas of significant uncontrolled backfill and should be monitored during excavation works.

Hazard	Requires further consideration?	Comment
Relict Structures	**Yes**	Assessment of the history of the site area has identified that historical structures have been present in the proposed development area and features were encountered during the trial pitting works on site. Given the limited coverage during this investigation, the possibility remains for further relict structures to be present and should be monitored during excavation works.
Shrink/Swell Potential	**No**	Although the shallow superficial cohesive soils were shown to have medium volume change potential, they were of limited extent, and it is not envisaged that any significant structures will be founded within this horizon.
High Groundwater Level	**Yes**	Effective groundwater control is a prerequisite constraint on the construction process. Although groundwater levels are currently below the expected excavation level it may rise. A groundwater monitoring programme is currently being carried out.
Variable Deposits	**Yes**	Limited exploratory positions, and none in the proposed building footprint were undertaken, therefore the extent of any variable deposits across the site could not be confirmed. Foundation excavations should be deepened where necessary to ensure they found in the dense granular deposits and suitably reinforced were required.

Table 4.6 Geotechnical Hazard Evaluation

It is considered that the development of the site will not be limited based on the geotechnical findings of the investigation, assuming the recommendations from this report are followed and approved construction methods are adhered to.

5 CONTAMINATION ASSESSMENT

5.1 General

The risks posed to the potential sensitive receptors associated with the site are assessed at this stage. An initial assessment of the risk posed by each pollutant linkage was carried out and is presented in the HGE Stage 1 Tier 1 Preliminary Risk Assessment (Desk Study Report), summarised in Table 2.2 in Section 2.2. Refer to the full report presented in Appendix C for a complete Conceptual Site Model (CSM) and preliminary risk assessment.

Specific assessment of the short-term exposure to ground workers was not part of the scope of this investigation. Therefore, regarding these pollutant links (links 1, 3 and 11 of Table 2.2), soil chemical analysis and ground gas/vapour data should be made available for contractor's own risk assessment.

The risk to future site users from ground gases (link 2) is assessed by considering ground gas and vapour data recorded from monitoring and from the volatile concentrations recorded in the analysed soils and groundwater analysis.

The risks associated with long-term human exposure to soil (link 4) can be addressed by comparing the laboratory test results with soil generic assessment criteria (GAC) derived using the CLEA model. This specifically applies to dermal exposure and inhalation of contaminated dust but can be used as a preliminary indication to consider the effects on controlled water (link 6,7), drinking water supply pipes (link 8), natural flora and fauna (link 9) and building structures (link 10) from soil contamination on the site. Screening values have been published for standard land uses, including commercial and residential (with and without gardens) and the CLEA software initially allows for GAC to be amended for site specific exposure scenarios. The potential for asbestos to be present in soil (links 11) will also be considered by reviewing laboratory test results in accordance with CAR:SOILTM (CL:AIRE, 2016) guidance for the application of the Control of Asbestos Regulations (2012) Interpretation for Managing and Working with Asbestos in Soil and Construction and Demolition Materials.

The risk to controlled water (link 6,7) has been assessed by considering soil concentrations initially and considered further by comparing concentrations detected in groundwater to environmental quality standards (EQS) and drinking water standards (DWS) researched in Defra (2015) directions to English and Welsh authorities to improve water quality in respect of the EU Water Framework Directive (WFD).

We understand it is proposed to construct a new two-storey service building, including a single storey basement as part of the SWEC development at the British Museum, as set out in the plans provided by

ABA. The basement development is modest in size such that it does not extend beyond the footprint of the building and is no deeper than one full story below ground level (approximately 3m in depth). We also understand that there will be no soft landscaped areas in the final proposed design.

5.2 Soil Assessment

6 No. samples of the near surface made ground were submitted to a UKAS/MCERTS accredited laboratory for a general suite of analytes as detailed in section 3.6.

For an initial screening of soil chemical test results with regard to long-term human health risks, the results have been compared to GAC. Land Quality Management Limited and the Chartered Institute for Environmental Health published ‘Suitable 4 Use Levels’ (S4UL) as GAC for a range of substances, for a range of generic land uses. DEFRA published category four screening levels (C4SL) for six contaminants in March 2014 to assist practitioners in assessing land contamination under part IIA of the Environmental Protection Act 1990. These have also been identified as suitable for use within the planning system, although it should be noted that they assume a higher level of acceptable risk than S4UL and earlier published GAC. Rather than universally adopting a higher level of risk, the S4UL are applied initially, with C4SL considered where the maximum concentrations exceed the S4UL.

For each land use category, a single value is provided for metals, with three values specified for organic contaminants based on the proportion of soil organic matter (%SOM) or the total organic carbon (%TOC) content of the soil. Unless otherwise stated, the GAC (S4UL and C4SL) for the most conservative SOM (1%) has been used for the assessment.

Records of the soil chemical testing have been appended to this report and are summarised in the following tables.

Based on the proposed end use of the proposed development the soil analysis results have been screened against ‘Commercial’ end use criteria.

Compared to Commercial end use criteria

Determinant	Maximum recorded concentration (mg/kg)	LQM/CIEH S4UL 2014 and C4SL* for commercial (mg/kg)	Maximum Exceeds Screening Value?	Samples Exceeding (Fieldwork ID Sample ID Depth)	Exceedance Values (Relative to Sample IDs)
Arsenic	20	640	No	-	-
Beryllium	1.3	12	No	-	-
Boron	2.7	240000	No	-	-
Cadmium	< 0.2	190	No	-	-
Chromium	23	8600	No	-	-
Chromium - Hexavalent	< 1.8	33	No	-	-
Copper	110	68000	No	-	-
Lead	1100	2300	No	-	-
Mercury	2.9	58	No	-	-
Nickel	25	980	No	-	-
Selenium	< 1	12000	No	-	-
Vanadium	59	9000	No	-	-
Zinc	150	730000	No	-	-
Acenaphthene	0.13	84000	No	-	-
Acenaphthylene	0.47	83000	No	-	-
Anthracene	0.67	520000	No	-	-
Benzo(a)anthracene	1.7	170	No	-	-

Determinant	Maximum recorded concentration (mg/kg)	LQM/CIEH S4UL 2014 and C4SL* for commercial (mg/kg)	Maximum Exceeds Screening Value?	Samples Exceeding (Fieldwork ID Sample ID Depth)	Exceedance Values (Relative to Sample IDs)
Benzo(a)pyrene	4.6	35	No	-	-
Benzo(b)fluoranthene	3.6	44	No	-	-
Benzo(ghi)perylene	3.3	3900	No	-	-
Benzo(k)fluoranthene	2.1	1200	No	-	-
Chrysene	1.7	350	No	-	-
Coronene	< 0.05	-		-	-
Di-benzo(a,h)anthracene	0.6	3.5	No	-	-
Fluoranthene	2.6	23000	No	-	-
Fluorene	0.16	63000	No	-	-
Indeno(1,2,3-cd)pyrene	3	500	No	-	-
Naphthalene	0.16	190	No	-	-
Phenanthrene	1.1	22000	No	-	-
Pyrene	2.6	54000	No	-	-
Speciated Total EPA-16 PAHs	27.7	-		-	-
Total PCBs	< 0.007	-		-	-
Total Phenols - Monohydric	< 1	-		-	-
Aliphatic >C5 - C6	< 0.001	3200	No	-	-
Aliphatic >C6 - C8	< 0.001	7800	No	-	-
Aliphatic >C8 - C10	< 0.001	2000	No	-	-
Aliphatic >C10 - C12	< 1	9700	No	-	-
Aliphatic >C12 - C16	5.4	59000	No	-	-
Aliphatic >C16 - C21	< 8	1600000	No	-	-
Aliphatic >C21 - C35	27	1600000	No	-	-
Aliphatic (C5 - C35)	40	-		-	-
Aromatic >C5 - C7	< 0.001	26000	No	-	-
Aromatic >C7 - C8	< 0.001	56000	No	-	-
Aromatic >C8 - C10	< 0.001	3500	No	-	-
Aromatic >C10 - C12	< 1	16000	No	-	-
Aromatic >C12 - C16	< 2	36000	No	-	-
Aromatic >C16 - C21	12	28000	No	-	-
Aromatic >C21 - C35	75	28000	No	-	-
Aromatic (C5 - C35)	87	-		-	-
Benzene	< 0.005	27	No	-	-
Ethylbenzene	< 0.005	56000	No	-	-
MTBE (Methyl Tertiary Butyl Ether)	< 0.005	-		-	-

Determinant	Maximum recorded concentration (mg/kg)	LQM/CIEH S4UL 2014 and C4SL* for commercial (mg/kg)	Maximum Exceeds Screening Value?	Samples Exceeding (Fieldwork ID Sample ID Depth)	Exceedance Values (Relative to Sample IDs)
o-Xylene	< 0.005	6600	No	-	-
p & m-Xylene	< 0.005	5900	No	-	-
Toluene	< 0.005	56000	No	-	-
pH	7.2 - 9.6	-		-	-
Total Organic Carbon (TOC)	2.4%	-		-	-
Asbestos in Soil	Chrysotile-Hard/Cement Type Material	-	Yes	TPE_ES3_1.40	N/A

Table 5.2a Exceedances compared to Commercial end use criteria.

No elevated concentrations were identified above any of the commercial end use criteria within the 6 No. soil samples analysed, with the exception of a positive asbestos ID in TPE.

It should be noted that when the sample results were compared against the most stringent land use criteria 'Residential with Homegrown Produce', 5 No. determinants exceeded. These are as detailed in the table below, Table 5.2b.

<u>Compared to Residential with Homegrown Produce end use criteria</u>

Determinant	Maximum recorded concentration (mg/kg)	LQM/CIEH S4UL 2014 and C4SL* for residential with homegrown produce (mg/kg)	Maximum Exceeds Screening Value?	Samples Exceeding (Fieldwork ID Sample ID Depth)	Exceedance Values (Relative to Sample IDs)
Lead	1100	200	Yes	BHA_ES2_0.80 TPC_ES1_0.50 TPE_ES2_0.80 TPE_ES4_1.70	300 370 640 1100
Mercury	2.9	1.2	Yes	TPC_ES1_0.50 TPE_ES2_0.80 TPE_ES4_1.70	2.9 2 1.6
Benzo(a)pyrene	4.6	2.2	Yes	BHB_ES2_0.50 BHB_ES2_0.50	4.6 4.5
Benzo(b)fluoranthene	3.6	2.6	Yes	BHB_ES2_0.50 BHB_ES2_0.50	3.6 3.5
Di-benzo(a,h)anthracene	0.6	0.24	Yes	BHB_ES2_0.50 BHB_ES2_0.50	0.6 0.54

Table 5.2b Exceedances compared to Residential with homegrown produce end use criteria.

Based on the above, the levels of soil contaminants recorded in the soils are not considered to represent a significant risk to human health end users associated with the proposed development, given that the proposed end us is for commercial end use with no soft landscaping.

However, consideration should be given to the fact the ground investigation was limited to positions outside of the existing and proposed building footprint, and that potential sources and extent of soil contamination across the site may not have been fully assessed.

Considering the results and that the proposed structures footprint will cover the whole site area, further investigation or remedial action is not considered to be warranted at this stage. The proposed development will break all potential pollutant linkages to human health end users with the exception of inhalation of soil gas/vapours. However, should indications of additional contamination be discovered during development, this should be further assessed, and appropriate action taken, as necessary.

The potential risk to construction workers should be mitigated through a contractor's risk assessment prior to development. If any obviously contaminated soil is encountered the advice of a suitably qualified person should be sought regarding the appropriate course of action.

The result of the asbestos analysis indicates that there were no asbestos fibres detected in any of the soil samples tested, however, asbestos was identified within a bulk asbestos sample taken from TPE at 1.40mbgl. Based on the anthropogenic impacts observed as well as the potential contaminant sources identified in the HGE Stage 1 Tier 1 Preliminary Risk Assessment (Desk Study), there is potential that some ACM could be locally present within made ground across the area.

Should further areas of made ground containing potential asbestos-containing materials (ACMs), or other forms of contamination be discovered during development, this should be further assessed.

5.3 Water Supply Pipework

UKWIR has published the 'Guidance for the selection of water supply pipes to be used in brownfield sites (10/WM/03/21)' to advise developers of contaminants in soil which have the potential to leach through drinking water supply pipework and includes a list of threshold concentrations specific to several commonly used types of pipework.

It should be noted that the scope of testing presented in this report is limited to assessing contaminated land based on the previous site use and does not include analysis of all the parameters specified in the UKWIR guidance.

This investigation includes a preliminary assessment of the risk to drinking water supply pipes that would be installed as part of any proposed development. Shallow soil samples of made ground soils have been analysed for a range of potential contaminants, including organic substances listed by UKWIR 'Guidance for the selection of water supply pipes to be used in Brownfield sites'. The details of the compounds currently analysed, and results obtained are detailed in section 5.2 'Soil Assessment'.

The currently recorded TPH concentrations within the soils do not exceed UKWIR TPH criteria. At this stage VOC and SVOC testing has not been undertaken.

Depending on the design, location and depth of the proposed potable water supply pipes, and the extent of any proposed remediation mitigation measures, it may be plausible to adopt standard potable water supply pipes based on the limited analysis to date.

It is recommended that this report is provided to the appointed water company to advise on appropriate materials to be used for construction of potable water supplies.

5.4 Phytotoxic Contamination

It is understood that no soft landscaping will be associated with the proposed redevelopment with the subject site completely covered by the footprint of the proposed building structure. However, should areas of soft landscaping be considered we would recommend BS3882:2015 testing for topsoil to be utilized.

5.5 Groundwater Assessment

The site is not recorded to lie within a source protection zone. The superficial soils (Lynch Hill Gravel Member) are defined as a Secondary A aquifer with the underlying solid geology (London Clay Formation) defined as an unproductive aquifer.

The closest active groundwater abstraction is located some 209m west of the site associated with a heat pump at the London School of Hygiene and Tropical Medicine.

No surface water features, or potable water abstractions are recorded within 250m of the site. It should be noted that the River Thames is located approximately 1.2km to the southeast of the site.

A negligible risk of flooding from either rivers or the sea was identified on site. However, a moderate risk is considered from groundwater flooding.

Groundwater was encountered within the superficial deposits during the investigation between 5.40 and 5.50mbgl and subsequently between 3.41mbgl and 3.62mbgl during the three monitoring rounds undertaken. Based upon the groundwater screening assessment undertaken in the HGE report (ref: *GL25617 – British Museum – Desk Study Report (East Road Building)*) the groundwater flow in the wider area is inferred to flow very slightly to the west, albeit with a gradient magnitude of <0.01, although this is largely influenced by a single historic borehole (TQ28SE778) which may represent an outlier. In the area of the East Road Building the groundwater is shown as largely level / dipping very gently to the north.

It should be noted that groundwater flow direction could be locally influenced by the presence of underground structures (e.g., building foundations, basements and utility corridors), the influence of which may vary seasonally.

The risk to controlled waters is addressed by comparing the laboratory test data to adopted screening values. At this stage the risk to controlled water is evaluated from groundwater sampled on completion of the intrusive works. Environment Agency (EA) publication “Groundwater Protection: Principles and Practice (GP3)” describes the method for assessing the risk to controlled waters.

Currently 2 No. groundwater samples have been sampled and analysed for a suite of analytes (Suite HW1.1) as detailed below. The groundwater samples were taken from the superficial deposits (secondary A aquifer) in boreholes BHA and BHB:

- **Suite HW1.1:** As, B, Cd, Cr (total and VI), Cu, Pb, Hg, Ni, Se, Zn, cyanide (total and free), sulphate, sulphide, sulphur (free), chloride, NH4 as N, pH, nitrate, nitrite, conductivity, hardness, COD, DOC, DO, PAH (speciated 16), TPH CWG (C10-C40), phenols (speciated)

The results of the groundwater sample analyses are summarised in Table 5.5.1 below, and are compared against the appropriate groundwater screening values, which are described in the appended Groundwater Screening Values Datasheet (collectively referred to as the ‘applicable standards’). These include the UK Drinking Water Standards, WHO Drinking Water Quality Guidelines (WHO DWQG), Environmental Quality Standards (EQS) annual averages (EQS-AA) and maximum allowable concentrations (EQS-MAC), and the Society of Brownfield Risk Assessment (SoBRA) GACgwvap.

The table below only details determinants from the 2 No. Suite HW1.1 analysis.

Determinant (Hardness band - mgCaCO$_3$/l)	**Max. Recorded (µg/l) – Range provided where exceeding**	**U.K. Drinking Water Standard / [WHO DWQG] (µg/l)**	**EQS-AA (freshwater)/ [EQS-MAC (freshwater)] (µg/l)**	**SoBRA – Commercial (µg/l)**	**Sample Exceeding (Borehole ID_Sample ID)**	**Exceedance Values**
Ammoniacal Nitrogen as N	17	500	-	-		
Chemical Oxygen Demand	11mg/l	-	-	-		
Chloride	48000	250,000	250,000	-		
Cyanide - Free	< 10	50	1 [5]	-		
Cyanide - Total	< 10	50	1 [5]	-		
Dissolved Organic Carbon	3620	-	-	-		
Dissolved Oxygen	11000	-	-	-		
Electrical Conductivity	610uS/cm	2,500	-	-		
Elemental Sulphur	< 20	-	-	-		
Nitrate as N	7130	50,000	-	-		
Nitrite as N	6.9	3,000	-	-		
pH	7.7 - 7.9	6.5 - 9.5	[6 – 9]	-		
Sulphate as SO4	48700	250,000	400,000	-		
Sulphide	< 5	-	-	-		
Total Hardness	296mgCaCO3/l	-	-	-		
Arsenic	1.49	10	50	-		
Boron	44	2,400	2,000	-		

Determinant (Hardness band - $mgCaCO_3/l$)		Max. Recorded (µg/l) – Range provided where exceeding	U.K. Drinking Water Standard / [WHO DWQG] (µg/l)	EQS-AA (freshwater)/ [EQS-MAC (freshwater)] (µg/l)	SoBRA – Commercial (µg/l)	Sample Exceeding (Borehole ID_Sample ID)	Exceedance Values
Cadmium	0.04	3	0.25	-	No		
Calcium		110000	-	[1.5]	-		
Chromium (II)		< 0.2	50 (total)	4.7 [32]	-		
Chromium (VI)		< 5		3.4	-		
Copper		1.6	2,000	1 (bioavailable)	-	BHA_EW1-SP1_4.00 BHB_EW1-SP1_4.00	1.5 1.6
Lead		< 0.2	10	1.2 (bioavailable) [14]	-		
Magnesium		5100	-	-	-		
Mercury		< 0.05	6	[0.07]	95		
Nickel		1	70	4 (bioavailable) [34]	-		
Selenium		< 0.6	40	-	-		
Zinc		1.6	-	10.9 (bioavailable)	-		
Acenaphthene		< 0.01	-	[0.1]	15,000,000		
Acenaphthylene		< 0.01	-	-	20,000,000		
Anthracene		< 0.01	-	0.1 [0.1]	-		
Benzo(a)anthracene		< 0.01	-	-	-		
Benzo(a)pyrene		< 0.01	0.7	0.00017 [0.27]	-		
Benzo(b)fluoranthene		< 0.01	-	[0.017]	-		
Benzo(g,h,i)perylene		< 0.01	-	[0.0082]	-		
Benzo(k)fluoranthene		< 0.01	-	[0.017]	-		
Chrysene		< 0.01	-	-	-		
Dibenz(a,h)anthracene		< 0.01	-	-	-		
Fluoranthene		< 0.01	-	0.0063 [0.12]	-		
Fluorene		< 0.01	-	-	18000000		
Indeno(1,2,3-cd)pyrene		< 0.01	-	-	-		
Naphthalene		< 0.01	-	2 [130]	23000		
Phenanthrene		< 0.01	-	-	-		
Pyrene		< 0.01	-	-	-		
Total EPA-16 PAHs		< 0.16	-	-	-		
Catechol		< 0.5	-	-	-		
Cresols		< 0.5	-	-	-		
Ethylphenol & Dimethylphenol		< 0.5	-	-	-		
Isopropylphenol		< 0.5	-	-	-		
Naphthols		< 0.5	-	-	-		
Phenol		< 0.5	-	7.7 [46]	-		
Resorcinol		< 0.5	-	-	-		

Determinant (Hardness band - mgCaCO$_3$/l)	Max. Recorded (µg/l) – Range provided where exceeding	U.K. Drinking Water Standard / [WHO DWQG] (µg/l)	EQS-AA (freshwater)/ [EQS-MAC (freshwater)] (µg/l)	SoBRA – Commercial (µg/l)	Sample Exceeding (Borehole ID_Sample ID)	Exceedance Values
Total Phenols (HPLC)	< 3.5	-	-	-		
Trimethylphenol	< 0.5	-	-	-		

Table 5.5 Summary of Groundwater Test Results for determinants >MDL

The contaminants listed above which do not exceed the applicable standards are not considered to pose a risk to the sensitive receptors identified and are therefore not considered further.

Implications of the contaminants exceeding threshold values as summarised in Table 5.5-1 above are considered in more detail below.

5.6 Heavy Metals

Copper marginally exceeded its initial EQS criteria of 1ug/l with a maximum recorded value of 1.6ug/l. The concentration does not exceed relevant drinking water criteria (2000ug/l).

It is considered the concentration of copper is at a level which would be unlikely to be significantly detrimental to the identified controlled waters and likely at background concentrations for the surrounding area.

5.7 Ground Gas/Vapour Assessment

3 No. rounds of gas monitoring have currently been undertaken between 7th February and 7th March 2023. All the monitoring rounds to date have been undertaken on a high atmospheric pressure.

C665 2007 recommends that for a site with a low generation potential of source gas, 6 No. monitoring visits should be undertaken for commercial end use over 2 months.

Given the gas concentrations and flows from the first three monitoring rounds, and that other than the 1.95m of made ground no significant source of soil gas generation was identified it is considered that additional gas monitoring is not required.

Currently the maximum recorded carbon dioxide reading was 0.5%. Methane levels were recorded at 0.2%, whilst oxygen levels were recorded down to a minimum of 2.0%.

Flow levels were generally recorded at 0.0 l/hr, however some positive flow (0.1 l/hr) was recorded during monitoring round 1 in BHB.

Carbon monoxide and hydrogen sulphide were recorded to have maximum concentrations of 55ppm and 6ppm. No residential screening thresholds are published for carbon monoxide or hydrogen sulphide. However, the levels recorded do exceed the stringent long-term exposure limits (30ppm and 5ppm respectively published in table 1 of HSE EH40/2005 ‘workplace exposure limits’). Given that no significant potential source was identified, and that much of the made ground is expected to be removed during construction works, this is not considered to pose a risk to the proposed development. It should however be taken into consideration by the designer.

Requirement C2 of Schedule 1 of the Building Regulations 2004 for England & Wales covers the potential for methane and carbon dioxide ingress into buildings. This publication indicates that a risk-based approach to consideration of ground gas hazard potential should be undertaken.

Further reference is made to BS8485:2015+A12919 which provides a mechanism to initially quantify the risk from methane (CH_4) and carbon dioxide (CO_2) by calculating a maximum gas flow rate or gas screening value (GSV) as part of a conservative semi-quantitative approach. The worst case GSV is calculated by multiplying the highest flow rate with the maximum recorded concentration of each gas across the site. We have also calculated the GSV for each borehole based on maximum concentrations and flows from the three monitoring rounds.

Table 5.7 summarises the pertinent ground gas concentrations and flow readings taken during the investigation and presents the GSVs for methane and carbon dioxide.

Zone	Max Reported (%)					Flow (l/h)	Peak PID (ppm)	GSV - CH_4 (l/h)	CS - CH_4	GSV – CO_2 (l/h)	CS - CO_2
	CH_4	CO_2	O_2 (min)	H_2S (ppm)	CO (ppm)	Max					
BHA	0.1	0.5	20.4	<1	6	0.0	0.3	0.0001	CS1	0.0005	CS1
BHB	0.2	0.2	2.0	<1	55	0.1	0.6	0.0002	CS1	0.0002	CS1

Table 5.7 Ground Gas Assessment

Based on the worst case GSVs for CO_2 and CH_4 in accordance with BS8485:2015, the site falls within CS1 'Very low hazard potential'.

Volatile Organic Compounds (VOCs) were recorded during the ground gas monitoring rounds at concentrations of <10ppm, recorded at a maximum of 0.6ppm and as such do not give cause for concern.

The appropriate ground gas protection measures for the proposed buildings on the site are based on the GSV and building type. From the information provided, we understand that the buildings planned at the site can be described as industrial style, with well-ventilated areas. The building will be civil engineer designed and any ground protection measures will be appropriately maintained. This comprises building 'type D' in BS8485:2015.

Table 4 in BS8485:2015 provides a scoring matrix whereby a minimum score should be achieved for certain building types under certain CS situations. For this site, type D buildings in a gas regime of CS1, no gas protection measures should be required.

If during construction, evidence is uncovered which may suggest gas protection measures may be appropriate, reference to BS8485:2015 should be made by the design engineer to select appropriate gas protection measures.

Reference to BRE Report 211 "Radon: guidance on protective measures for new buildings" indicates that the site is located in an area where <1% of homes are above action level. On this basis it is considered that special protection measures are not necessary within the proposed development with regard to natural radon hazards. However, it has been stated that in accordance with building regulation, until a building had been constructed and occupied, it is not possible to accurately assess the severity of a radon problem on a particular site.

5.8 Waste Disposal

All waste related activities must be undertaken in accordance with The Waste (England and Wales) Regulations (2011) and The Landfill (England and Wales) Regulations (2002). Any proposed disposal or reuse of materials must be in accordance with the Waste (England and Wales) Regulations 2011 (as amended). According to the regulations waste soil and construction waste must be classified and assessed prior to disposal. The process is described in the Environment Agency Technical Guidance WM3 (2021), with the following steps identified:

Steps to *classify* the waste

i. Check if the waste needs to be classified (is it a waste).
ii. Identify the code or codes that may apply to the waste, as classified in the List of Waste (LoW).
iii. Identify the assessment needed to select the correct code.

Steps to *assess* the waste

iv. Determine the chemical composition of the waste.
v. Identify if the substances in the waste are 'hazardous substances' or 'persistent organic pollutants.'
vi. Assess the hazardous properties of the waste.
vii. Assign the classification code and describe the classification code.

Once classified, the waste can be removed to the appropriately licensed facilities with some waste requiring pre-treatments prior to disposal. The results contained in this report should be submitted to allow suitable classification for waste disposal purposes by the contractor.

Specific Waste Acceptance Criteria (WAC) testing has been undertaken on one sample. The results of this testing indicate the soils may generally be classified as inert.

If soils are planned to be removed from the site, waste classification should be reviewed, completed and is the responsibility of the contractor generating/holding the waste soil. The waste classification should be determined in accordance with Environment Agency's Technical Guidance (WM3, 2018) and it may be appropriate to do so in conjunction with the intended landfill to receive it. If excavated soils are planned to be retained and reused on site after it may be appropriate to complete a materials management plan (MMP) according to CL:AIRE (2011) The Definition of Waste: Development Industry Code of Practice (DoW CoP), to appropriately reuse material without contravening the waste regulations.

5.9 Contamination Risk Evaluation – Pollutant Linkages

This stage of the risk-based system is intended to establish the requirements for risk management where a positive risk has been identified following the intrusive investigation, laboratory testing and monitoring. Action is recommended where deemed appropriate.

It is necessary to identify unacceptable risk situations where a pollutant link is deemed to be made. To examine the possible options available at this stage, a risk evaluation table has been produced as below. This is based on the previous sections, and three possible outcomes are listed below.

- NA – No action is required with respect to this pollutant linkage, as either the linkage is not made, or the risk may be considered negligible in this case.
- GI – Further investigation and assessment is required to fully assess the risk.
- AR – Action Recommended. An unacceptable level of risk was identified. Therefore, action is required to break the pollutant linkage.

<table>
<tr><th colspan="4">Hazard Identification</th><th rowspan="2">Evaluated Risk</th><th rowspan="2">Action Consideration</th></tr>
<tr><th>Link No.</th><th>Source/ Hazard</th><th>Pathway</th><th>Receptor</th></tr>
<tr><td>1</td><td rowspan="2">Hazardous vapours / soil gas from made ground, volatile hydrocarbons/ free product or migrating to site from backfill material</td><td>Ingress into excavations, structures and confined spaces, and subsequent inhalation.</td><td>People on the site during development construction.</td><td rowspan="2">N/A</td><td rowspan="2">The appropriate ground gas protection measures for the proposed buildings on the site are based on the GSV and building type. Based on the worst case GSVs for CO2 and CH4 in accordance with BS8485:2015, the site falls within CS1 'Very low hazard potential'. Based on the limited gas monitoring undertaken, a viable source of ground gases has not been found and an assessment of the levels recorded during monitoring suggests that remedial action is not required. However, data should be provided to contractors involved in development to allow them to undertake their own specific risk assessments.
Volatile Organic Compounds (VOCs) were recorded during the ground gas monitoring rounds at concentrations of <10ppm, recorded at a maximum of 0.6ppm and as such do not give cause for concern.
Carbon monoxide and hydrogen sulphide were recorded to have maximum concentrations of 55ppm and 6ppm. No residential screening thresholds are published for carbon monoxide or hydrogen sulphide. However, the levels recorded do exceed the stringent long-term exposure limits (30ppm and 5ppm respectively published in table 1 of HSE EH40/2005 'workplace exposure limits'). Given that no significant potential source was identified, and that much of the made ground is expected to be removed during construction works, this is not considered to pose a risk to the proposed development. It should however be taken into consideration by the designer.</td></tr>
<tr><td>2</td><td>Ingress into structures and confined spaces, and subsequent inhalation.</td><td>People using the site post development and construction and residential users off site (to the south east</td></tr>
<tr><td>3</td><td rowspan="5">Contaminated soil and groundwater from previous and present contamination sources both on and off site</td><td rowspan="3">Ingestion of soil through direct contact, eating with dirty hands and dust inhalation.</td><td>People on the site during development construction.</td><td rowspan="3">N/A</td><td rowspan="3">No elevated concentrations were identified above any of the commercial end use criteria within the 6 No. soil samples analysed.
It should be noted that when the sample results were compared against the most stringent land use criteria 'Residential with Homegrown Produce', 5 No. determinants exceeded.
Based on the above, the levels of soil contaminants recorded in the soils are not considered to represent a significant risk to human health end users associated with the proposed development, given that the proposed end us is for commercial end use with no soft landscaping.
However, consideration should be given to the fact the ground investigation was limited to positions outside of the existing and proposed building footprint, and that potential sources and extent of soil contamination across the site may not have been fully assessed.
Considering the results and that the proposed structures footprint will cover the whole site area, further investigation or remedial action is not considered to be warranted at this stage. The proposed development will break all potential pollutant linkages to human health end users with the exception of inhalation of soil gas/vapours. However, should indications of additional contamination be discovered during development, this should be further assessed, and appropriate action taken, as necessary.
The potential risk to construction workers should be mitigated through a contractor's risk assessment prior to development. If any obviously contaminated soil is encountered the advice of a suitably qualified person should be sought regarding the appropriate course of action.</td></tr>
<tr><td>4</td><td rowspan="2">People using the site post development construction.
Human end users (residential and commercial) and neighbours post development construction.</td></tr>
<tr><td>5</td></tr>
<tr><td>6</td><td>Leaching.</td><td rowspan="2">Groundwater –
Secondary A aquifer superficial deposits.
Surface Waters -
The River Thames</td><td rowspan="2">N/A</td><td rowspan="2">The only determinant to exceed commercial criteria was copper, which marginally exceeded its initial EQS AA (freshwater 1ug/l) criteria with a maximum concentration of 1.6ug/l. The concentrations do not exceed relevant drinking water criteria (2000ug/l).
It is considered the concentration of copper is at a level which would be unlikely to be significantly detrimental to the identified controlled waters.</td></tr>
<tr><td>7</td><td>Infiltration</td></tr>
</table>

			Off-site human receptors and infrastructure.		
8		Via service pipes.	People using site after development completion.	N/A	It is recommended that this report is provided to the appointed water company to advise on appropriate materials to be used for construction of potable water supplies.
9		Plant uptake.	Local flora and fauna.	-	It is understood that no soft landscaping will be associated with the proposed redevelopment with the subject site completely covered by the footprint of the proposed building structure. However, should areas of soft landscaping be considered we would recommend BS3882:2015 testing for topsoil to be utilized.
10		Direct Contact	Building structures	-	Please refer to concrete classification in section 4.6.
11	Potential asbestos containing materials within existing structures and Made Ground soils	Inhalation of dust.	Humans on and in the vicinity of the site during demolition/ development construction.	N/A	The result of the asbestos analysis indicates that there were no asbestos fibres detected in any of the soil samples tested, however, asbestos was identified within a bulk asbestos sample taken from TPE at 1.40mbgl. Based on the anthropogenic impacts observed as well as the potential contaminant sources identified in the HGE Stage 1 Tier 1 Preliminary Risk Assessment (Desk Study), there is potential that some ACM could be locally present within made ground across the area. Should further areas of made ground containing potential asbestos-containing materials (ACMs), or other forms of contamination be discovered during development, this should be further assessed. An asbestos survey is recommended prior to demolition of any structures. Any subsequent removal to be undertaken by controlled methods by appropriately qualified operators.

Table 5.9 Pollutant Linkage Risk Evaluation

The proposed development is detailed on ABA drawings ref: BMERB-AB-XX-00-DR-S-0009-P01 to BMERB-AB-XX-XX-DR-S-0015-P01. It is proposed to construct a new two-storey service building, including a single storey basement as part of the SWEC development at the British Museum, with the existing East Road Building demolished to facilitate the redevelopment. The basement development is modest in size such that it does not extend beyond the footprint of the building and is no deeper than one full story below ground level (approximately 3m in depth). We also understand that there will be no soft landscaped areas in the final proposed design.

Due to the nature of the development detailed, this report and associated geoenvironmental assessment has assumed a proposed commercial end use for geoenvironmental assessment.

No elevated contamination concentrations were identified above any of the relevant commercial end use criteria within the 6 No. soil samples analysed.

Based on the above, the levels of soil contaminants recorded in the soils are not considered to represent a significant risk to human health end users associated with the proposed development, given that the proposed end us is for commercial end use with no soft landscaping.

However, consideration should be given to the fact the ground investigation was limited to positions outside of the existing and proposed building footprint, and that potential sources and extent of soil contamination across the site may not have been fully assessed.

Considering the results and that the proposed structures footprint will cover the whole site area, further investigation or remedial action is not considered to be warranted at this stage. The proposed development will break all potential pollutant linkages to human health end users with the exception of inhalation of soil gas/vapours. However, should indications of additional contamination be discovered during development, this should be further assessed, and appropriate action taken, as necessary.

The potential risk to construction workers should be mitigated through a contractor's risk assessment prior to development. If any obviously contaminated soil is encountered the advice of a suitably qualified person should be sought regarding the appropriate course of action.

The result of the asbestos analysis indicates that there were no asbestos fibres detected in any of the soil samples tested, however, asbestos was identified within a bulk asbestos sample taken from TPE at 1.40mbgl. Based on the anthropogenic impacts observed as well as the potential contaminant sources identified in the HGE Stage 1 Tier 1 Preliminary Risk Assessment (Desk Study), there is potential that some ACM could be locally present within made ground across the area.

Should further areas of made ground containing potential asbestos-containing materials (ACMs), or other forms of contamination be discovered during development, this should be further assessed.The following sections are included as examples and should be deleted or amended

An asbestos survey is recommended prior to demolition of any structures. Any subsequent removal to be undertaken by controlled methods by appropriately qualified operators.

Groundwater from the superficial Lynch Hill Gravel Member (Secondary A Aquifer) has been analysed from the cable percussive borehole. Only copper was recorded slightly exceeding a relevant criteria (exceeded its initial EQS criteria of 1ug/l with 1.6ug/l but did not exceed relevant drinking water criteria).

It is considered the concentration of copper is at a level which would be unlikely to be significantly detrimental to the identified controlled waters and likely at background concentrations for the surrounding area.

The appropriate ground gas protection measures for the proposed buildings on the site are based on the GSV and building type. Based on the worst case GSVs for CO2 and CH4 in accordance with BS8485:2015, the site falls within CS1 'Very low hazard potential'. Based on the limited gas monitoring undertaken, a viable source of ground gases has not been found and an assessment of the levels recorded during monitoring suggests that remedial action is not required. However, data should be provided to contractors involved in development to allow them to undertake their own specific risk assessments.

Volatile Organic Compounds (VOCs) were recorded during the ground gas monitoring rounds at concentrations of <10ppm, recorded at a maximum of 0.6ppm and as such do not give cause for concern.

Carbon monoxide and hydrogen sulphide were recorded to have maximum concentrations of 55ppm and 6ppm. No residential screening thresholds are published for carbon monoxide or hydrogen sulphide.

However, the levels recorded do exceed the stringent long-term exposure limits (30ppm and 5ppm respectively published in table 1 of HSE EH40/2005 'workplace exposure limits'). Given that no significant potential source was identified, and that much of the made ground is expected to be removed during construction works, this is not considered to pose a risk to the proposed development. It should however be taken into consideration by the designer.

The potential risk to construction workers should be mitigated through a contractor's risk assessment prior to development. If any obviously contaminated soil is encountered the advice of a suitably qualified person should be sought with regard to the appropriate course of action.

The basic requirement for development standards in the UK is that land should be 'suitable for use' or 'fit for purpose'. It is important to consider the limited nature of the sampling for this investigation, and the possibility of higher concentrations of contaminants and differing ground conditions existing between sample positions. However, providing the recommendations are adhered to, we believe that the site can be suitable for the intended use.

We recommend that this report is submitted to Regulators as part of the planning process. It is recommended that correspondence with the regulators is undertaken before any additional ground investigation and associated assessments are undertaken.

Harrison Group Environmental Limited would be pleased to offer further assistance with the recommended works if requested, and if the client or regulators have any comments or questions, we would be glad to discuss them.

Report prepared by:

James Blyth BSc (Hons) FGS
Senior Geoenvironmental Engineer

Report checked by:

John Keay BS (Hons) FGS
Associate Director

Norwich (Registered Office)

Kimberley Street
Norwich
Norfolk
NR2 2RJ

Tel: 01603 613111

London

12 Waterways Business Centre
Navigation Drive
South Ordnance Road
Enfield, EN3 6JJ

Tel: 020 7537 9233

Cambridge

1 Francis Court
High Ditch Road
Fen Ditton, Cambridge
CB5 8TE

Tel: 01223 781585

Colchester

Colchester Business Centre
1 George Williams Way
Colchester
CO1 2JS

Tel: 01206 986675