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St Pancras Commercial Centre
Contaminated Land Assessment

August 2019

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Proposed redevelopment
St Pancras Commercial Centre
Camden

Ground Investigation Report

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Proposed redevelopment
St Pancras Commercial Centre
Pratt Street
Camden
London
NW1 0BY

GROUND INVESTIGATION REPORT

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ACM UKAS Management Systems 245
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Railway Industry Supplier Qualification Scheme RISQS AUDITED

Aerial photograph of site

Approximate site boundary outlined in **magenta**

Report status and format

Report section	Principal coverage	Report status	
		Revision	Comments
1	Executive summary		
2	Introduction		
3	Desk study information and site observations		
4	Fieldwork		
5	Laboratory testing		
6	Ground conditions encountered		
7	Geotechnical Appraisal		
8	Chemical contamination		
9	Gaseous contamination		
10	Effects of ground conditions on building materials		
11	Classification of waste soils under the Waste Acceptance Criteria		
12	Further investigations		

List of drawings

Drawing	Principal coverage	Status	
		Revision	Comments
01	Site location plan		
02	Plan showing existing site features and location of exploratory points		
03	Plan showing site development proposals and location of exploratory points		
04	Plot summarising in situ density testing		
05	Section showing construction of standpipes installed in boreholes		

List of appendices

Appendix	Content		Status: Revision	Status: Comments
A	Definitions of geotechnical terms used in this report			
B	Definitions of geo-environmental terms used in this report			
C1	Insitu testing in boreholes / trial pits	Details of standard penetration tests (SPT)		
C2		Details of insitu shear strength determinations		
C3		Details of TRL dynamic cone penetration testing		
C4		Results of infiltration testing in boreholes		
D	Trial pits	Hand excavated to expose foundations		
E	Borehole records	Cable and tool percussion drilling		
G1	Copies of laboratory test result certificates (Soil Engineering)	Soil classification testing		
G2		Triaxial testing		
G3		One dimensional consolidation		
H	Copies of laboratory test result certificates (Chemical).	Concentrations of chemical contaminants		
I	Analysis and summary of test data in relation to concentrations of chemical contaminants			
J	Conceptual models for chemical contamination			
K	Record of in-situ gas monitoring results			
L1	Landfill waste acceptance criteria –	Primary classification		
L2		Secondary classification		
L3		Basic categorisation schedules		
M	Copies of statutory undertakers' replies			
N	Copy of desk study information produced by Envirocheck			
O	Copy of Preliminary Analysis of Pressuremeter tests report reference CIR1440/19 dated March 2019 provided by Cambridge Insitu Limited			

Bookmarking

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1 Executive summary

1.1 General

1.1.1 We recommend the following executive summary is not read in isolation to the main report which follows.

1.2 Site description, history and development proposals

1.2.1 The site comprises St Pancras commercial centre and is located within a mixed residential and commercial area on the eastern outskirts of Camden Town. The site is approximately square in plan and at the time of the investigation comprised twelve commercial units with a central yard/parking area surfaced in concrete hardstanding. An area of soft landscaping was present along the eastern site boundary.

1.2.2 Inspection of historical maps dating back to 1873 indicate the site was formerly residential properties and was redeveloped into an Electricity generating station in the 1950s. By the 1960s/70s, the site was recorded as a depot and works before being redeveloped again in the late 1980s to the existing commercial centre. The general area has been a mix of residential and industrial with railway sidings, engine houses, factories, goods depots and garages all recorded within close proximity to the site.

1.2.3 We understand the scheme will comprise demolition of the existing buildings followed by the construction of three six-storey blocks for office/residential use. A joint single-level of basement is also proposed.

1.3 Ground conditions encountered

1.3.1 Ground conditions at the site comprise Made Ground to depths of up to 5.7 overlying fine-grained London Clay Formation. Thanet Sands were encountered at a depth of 41m.

1.3.2 Groundwater is present within the coarse-grained deposits of the Made Ground at depths of approximately 4-5m and within the Thanet Sand Formation at depth.

1.4 Foundation solution

1.4.1 Due to the depth and likely variation of Made Ground across the site we would recommend a piled foundation be adopted at this site. Further details of our foundation assessment can be found in Section 7.

1.5 Chemical and gaseous contamination

1.5.1 No elevated concentrations of contaminants have been identified within the Made Ground. However, a fragment of Asbestos Containing Material has been identified within a sample of the Made Ground and should be considered present within the Made Ground based on limited testing undertaken. Concentrations of hydrocarbons are below guideline values for construction operatives but the concentrations pose a potential risk of vapours to the proposed development.

1.5.2 The site will be fully surfaced in buildings/hardstandings, which will sever pathways to end users. A basement is to be excavated across the site footprint, which will remove a significant proportion of the Made Ground from the site. Should Made Ground remain beneath the proposed building, we recommend a vapour-proof membrane be incorporated in the development.

1.5.3 There is a moderate risk to construction operatives and we recommend adoption of adequate hygiene precautions and dampening down of all soils during earthworks/ground works. In addition, ground and earth works will need to comply with the requirements set out in The Control of Asbestos Regulations (CAR 2012).

1.5.4 Although elevated concentrations of inorganic contaminants have been identified in groundwater, the source is likely to be both on- and off-site. Considering a large proportion of Made Ground will be removed during construction of the proposed basement and the site is of low sensitivity, we are of the opinion that the site represents a low risk of causing harm to water receptors.

1.5.5 The site is located above deep Made ground deposits which are considered a potential source of landfill gas. On this basis, we have undertaken a gas monitoring regime to determine whether any gas protection measures are considered necessary for the proposed building. The results of monitoring indicate the site can be classified as characteristic situation 1 and traffic light colour green and therefore no gas protection measures will be required.

1.6 Landfill classification

1.6.1 Suspected ACM (confirmed following receipt of laboratory testing) has been identified within the Made Ground in one location but no free fibres have been found. Where a waste contains identifiable pieces of ACM, then these pieces must be assessed separately. The waste is hazardous if the concentration of asbestos in the ACM exceeds 0.1%. Made Ground containing ACM would be regarded as a mixed waste and classified as follows:

- **17 06 05*** *(Construction material containing asbestos)* – this relates to the individual pieces of asbestos cement within the soil, which are classified as hazardous waste.
- **17 05 04** *(Soil and stones other than those mentioned in 17 05 03)* – this relates to the main body of the soil, which is classified as stable non-reactive hazardous waste in non-hazardous landfill.

1.6.2 We recommend additional sampling and testing of Made Ground soils be undertaken, which may allow refinement of the current classification.

1.6.3 The London Clay Formation soils can be classified as **inert waste** based on soils being of natural origin and unlikely to be affected by artificial contamination.

1.7 Unexploded Ordnance

1.7.1 We have obtained a preliminary risk review from a UXO specialist to assess the risk and identify any precautionary measures necessary for our intrusive investigations. Based on the history of the site and the level of post-war development, the UXO risk was considered to be medium. A UXO specialist therefore attended site during excavation of boreholes. It is recommended that a Detailed UXO Risk Assessment Report is obtained for the site to determine the risk for the construction phase. UXO specialist attendance may be required during the construction phase.

2 Introduction

2.1 Objectives

2.1.1 This report describes a ground investigation carried out for a proposed redevelopment of St Pancras Commercial Centre, Pratt Street, Camden, London, NW1 0BY.

2.1.2 The objective of the ground investigation was to establish ground conditions at the site, sufficient to identify possible foundation solutions for the development and provide parameters necessary for the design and construction of foundations.

2.1.3 The investigation included an evaluation of potential chemical and gaseous contamination of the site leading to the production of a risk assessment in relation to contamination.

2.1.4 The investigation has also been produced to support a planning application for the site by satisfying National Planning Policy Framework (2018) section 178.

2.1.5 Our brief also included investigations and testing to allow classification of soils at the site to be disposed of to landfill.

2.2 Status of this report

2.2.1 This report is final based on our current instructions.

2.3 Client instructions and confidentiality

2.3.1 The investigation was carried out in February 2019 and reported in May 2019 acting on instructions received through Blackburn and Co Limited on behalf of our mutual client Camden Property Holdings Limited.

2.3.2 This report has been prepared for the sole benefit of our above named instructing client, but this report, and its contents, remains the property of Soiltechnics Limited until payment in full of our invoices in connection with production of this report.

2.3.3 Our original investigation proposals were outlined in our correspondence to AKT II and Blackburn & Co Limited dated 3rd December 2018. The investigation was subsequently amended on site to account for actual ground conditions encountered with laboratory testing schedules again tailored to suit actual soil conditions. Due to obstructions encountered in the ground the number of deep boreholes was reduced from three to two. Borehole BH02 was attempted in three locations but was unable to proceed further than 3m depth in all three locations.

2.4 Site location and scheme proposals

2.4.1 The National Grid reference for the site is 529370,183960. A plan showing the location of the site is presented on Drawing 01.

2.4.2 We understand the scheme will comprise the construction of three, six-storey blocks for office/residential use. A joint single-level of basement is also proposed.

2.4.3 We have received layout drawings of the proposed scheme with the layout presented on Drawing 03.

2.5 Report format and investigation standards

2.5.1 Sections 2 to 6 of this report describe the factual aspects of the investigation with Section 7 presenting an engineering assessment of the investigatory data. Section 8 provides a risk assessment of chemical contamination based on readily available historic records, inspection of the soils and laboratory testing. Section 9 provides a similar risk assessment in relation to gaseous contamination with Section 10 providing a risk assessment relating to construction materials likely to be in contact with the ground. Section 11 provides a classification of waste soils for off-site disposal under the waste acceptance criteria.

2.5.2 Geotechnical aspects.

2.5.2.1 Geotechnical investigations were carried out generally, and where practical following the recommendations of BS EN 1997:2 2007 '*Eurocode 7 – Geotechnical Design – Part 2: Ground Investigation and Testing*'. From a geotechnical viewpoint this is deemed to be a Ground Investigation Report (GIR) as set out in BS EN 1997:2. This report does not however does not constitute a Geotechnical Design Report as defined in section 2.8 of BS EN 1997-1:2004 *'Eurocode 7 – Geotechnical Design – Part 1: General Rules'* and in particular will exclude assessment of lifetime actions to buildings from geotechnical influences.

2.5.3 Geo-environmental aspects

2.5.3.1 The investigation process also followed the principles of BS10175:2011+A2:2017 *'Investigation of potentially Contaminated Sites – Code of Practice'*. In view of the client's requirement for rapid implementation of the investigation, the following elements, defined in BS10175, have been completed and incorporated in this report.

a) Phase I — Preliminary investigation (desk study and site reconnaissance)
b) Phase II — Exploratory and main (intrusive) investigations

2.5.3.2 The extent and result of the preliminary investigation (desk study) is reported in Section 3. Fieldwork combined the exploratory investigation and main investigation stages into one phase with the extent of these works described in Sections 4 and 6 of this report. Any supplementary investigations deemed necessary are identified in Section 12. Based on the results of the investigation section 8 will identify if any remediation is necessary with respect to chemical contamination. Similarly, section 9 will identify if any remediation is necessary with respect to gaseous (landfill gas) contamination.

2.5.3.3 This investigation has been carried out and reported based on our understanding of best practice. Improved practices, technology, new information and changes in legislation may necessitate an alteration to the report in whole or part after publication. Hence, should the development commence after expiry of one year from the publication date of this report then we would recommend the report be referred back to Soiltechnics for reassessment. Equally, if the nature of the development changes, Soiltechnics should be advised and a reassessment carried out if considered appropriate.

2.6 Report distribution

2.6.1 This report has been prepared to assist in the design and planning process of the development and normally will require distribution to the following parties, subject to Soiltechnics liabilities defined below, although this list may not be exhaustive:

Table summarising parties likely to require information contained in this report

Party	Reason
Client	For information/reference and cost planning.
Developer/Contractor/project manager	To ensure procedures are implemented, programmed and costed.
Planning department	Potentially to discharge planning conditions.
Environment Agency	If controlled waters are affected and obtain approvals to any remediation strategies.
Independent inspectors such as NHBC/Building Control	To ensure procedures are implemented and compliance with building regulations.
Project design team	To progress the design.
Principal Designer (PD)	To advise in construction risk identification and management under the Construction (Design and Management) Regulations.
Waste recycling operators	For recycling or reducing hazardous properties.

Table 2.6.1

2.7 Soiltechnics liability

2.7.1 Soiltechnics disclaims any responsibility to our Client and others in respect of any matters outside the scope of this report. This report has been prepared with reasonable skill, care and diligence in accordance with the terms of our contract, taking account of the manpower, resources, investigations and testing devoted to it by agreement with our Client. This report is confidential to our Client and Soiltechnics accepts no responsibility of whatsoever nature to third parties to whom this report or any part thereof is made known. Any such party relies upon the report at their own risk.

3 Desk study information and site observations

3.1 General

3.1.1 We have carried out a desk study which was limited to a review of readily available information including:

a) Review of published Ordnance Survey maps dating back to 1873 at various published scales.

b) Inspection of geological maps produced by the British Geological Survey together with relevant geological memoirs.

c) Consultation with Statutory Undertakers.

d) Site reconnaissance.

e) Other relevant published documents.

3.1.2 We have obtained old Ordnance Survey maps using the Envirocheck database system. In addition to retrieval of historical and current Ordnance Survey data, Envirocheck provide information compiled from outside agencies.

3.1.3 The study did not extend to research of meteorological information or consultation with other interested parties such as English Heritage (ancient monuments), Ordnance Survey (survey control points), Planning Authorities or Archaeological Units.

3.1.4 A copy of records produced by Envirocheck is presented in Appendix N. Envirocheck produce a wealth of factual database information. Although we can provide a discussion on each of the database topics, this would produce a very lengthy document, but some of these discussions would not be relevant to the aims of this report. As a consequence, we have extracted some of the relevant topics and discussed them in this section of the report.

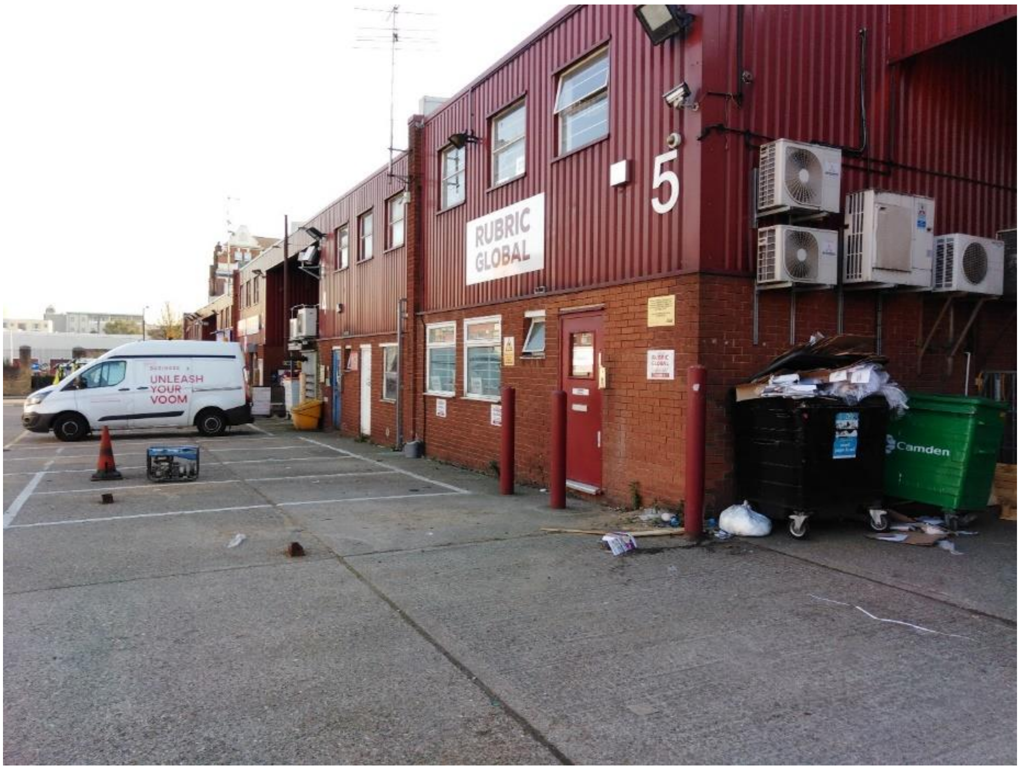
3.2 Description of the site

3.2.1 The site comprises St Pancras commercial centre and is located within a mixed residential and commercial area on the eastern outskirts of Camden Town. Local topography is relatively flat and the nearest watercourse is the Regent Canal located 10m to the north. The channel of the River Thames is located some 2km to the south of the site.

3.2.2 The site is approximately square in plan and is bordered by Georgiana St to the north-west, St Pancras Way to the north-east, Pratt St to the south-east and Royal College St to the south-west.

3.2.3 The site comprised twelve approximately equal sized commercial units in two parallel rows with a central yard/parking area surfaced in concrete hardstanding between them. Between the north-eastern units and the north-eastern site boundary was an area laid to grass. Site levels fall gently in a southerly direction, by approximately 1:40.

3.2.4 The following photographs show site conditions at the time of our investigation.



Photograph 1: The commercial units along the south-western site boundary looking south.

Photograph 2: The site looking north-west.

Photograph 3: The north-eastern extent of the site laid to grass with the rear of north-eastern commercial units on the left, looking north-east.

3.2.5 A plan showing observed site features and location of exploratory points is presented on Drawing 02.

3.3 Injurious and invasive weeds and asbestos

3.3.1 Injurious and invasive weeds

3.3.1.1 The following weeds are controlled under the Weeds Act 1959:

- Common Ragwort
- Spear Thistle
- Creeping or Field Thistle
- Broad leaved Dock
- Curled Dock

3.3.1.2 Whilst it is not an offence to have the above weeds growing on your land, you must:

- Stop them spreading to agricultural land, particularly grazing areas or land used for forage, like silage and hay
- Choose the most appropriate control method for the site
- Not plant them in the wild

3.3.1.3 Should you allow the spread of these weeds to another parties land, Natural England could serve you with an Enforcement Notice. You can also be prosecuted if you allow animals to suffer by eating these weeds.

3.3.1.4 In addition to the above, you must not plant in the wild or cause certain invasive and non-native plants to grow in the wild as outlined in the Wildlife and Countryside Act 1981. It is an offence under section 14(2) of the Act to *'plant or otherwise cause to grow in the wild*' any plants listed in schedule 9, part II. This can include moving contaminated soil or plant cuttings. The offence carries a fine or custodial sentence of up to 2 years. The most commonly found invasive, non-native plants include:

- Japanese knotweed
- Giant hogweed
- Himalayan balsam
- Rhododendron ponticum
- New Zealand pigmyweed

3.3.1.5 You are not legally obliged to remove these plants or to control them. However, if you allow Japanese knotweed to spread to another parties land, you could be prosecuted for causing a private nuisance.

3.3.1.6 The presence of such weeds on site may have considerable effects on the cost/timescale in developing the site. Japanese knotweed can cause significant damage to buildings, roads and pavements following development, if untreated prior to development.

3.3.1.7 Our investigations exclude surveys to identify the presence of injurious and invasive weeds. We did not observe any obvious evidence the above species.

3.3.2 Asbestos

3.3.2.1 Our investigations exclude surveys to specifically identify the presence or indeed absence of asbestos on site. It should be noted that asbestos containing material (ACM) and asbestos fibres were detected in samples of soil submitted for laboratory screening. The implications of the presence of asbestos in soils are discussed in Section 8 (contamination) and Section 11 (waste classification).

3.3.2.2 The presence of asbestos on site may have considerable effects on the cost/timescale in developing the site. There is good guidance in relation to asbestos available on the Health and Safety Executive (HSE) web site.

3.4 History of the site

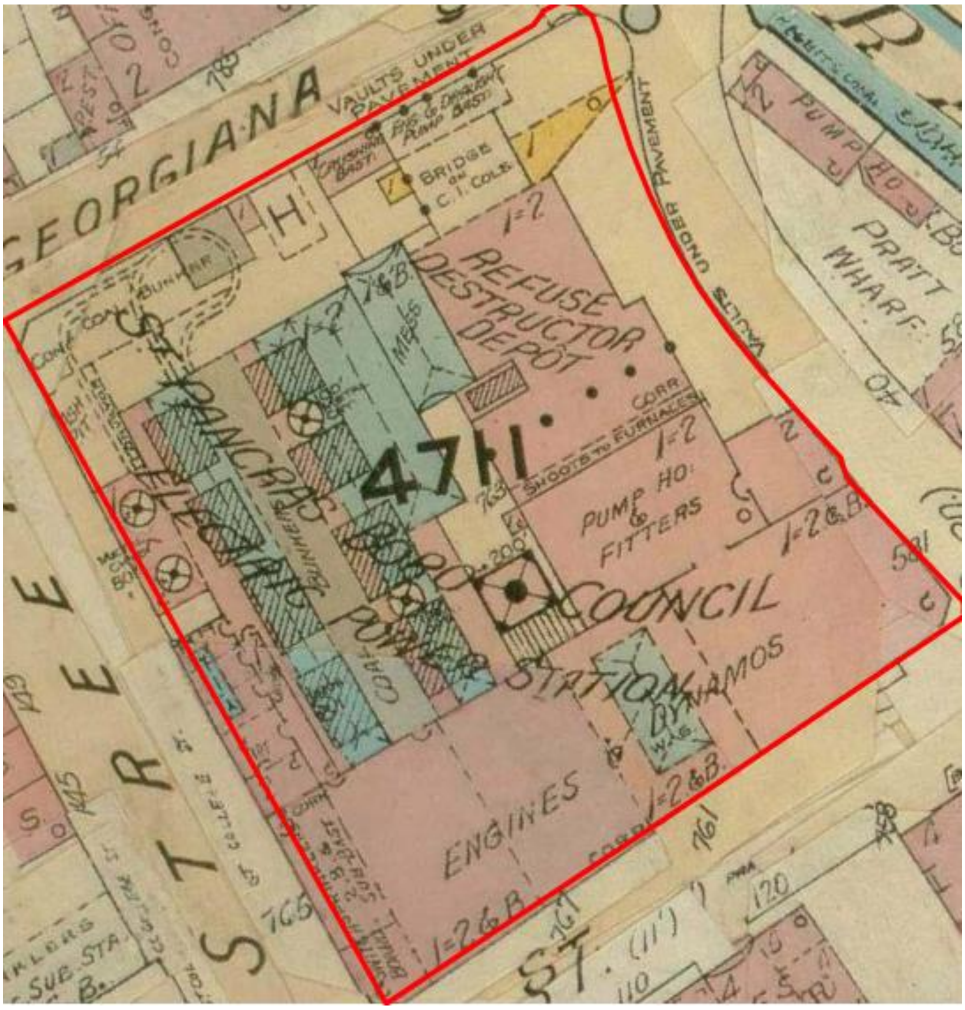
3.4.1 An attempt to trace the history of the site has been carried out by reviewing copies of old Ordnance Survey maps provided by Envirocheck. The recent history of the site based on published Ordnance Survey maps is summarised in the following table:

Summary description of site history from Ordnance Survey maps

Date	Onsite	Offsite
1873 to 1882	The site is fully developed with suspected residential housing.	Site is surrounded by roads with suspected residential housing to the west and south. Likely commercial buildings lie to the north (Bangor Wharf) and east on the banks of the Regent's Canal. Railway sidings/depot is recorded beyond Regent's Canal to the east and includes an area of earthworks, indicated by a number of embankments.
1896	The eastern half of the site is now occupied by suspected industrial buildings.	A coal depot is recorded within the railway sidings to the east. The embankments are no longer present and additional sidings are recorded. A mineral water manufacturer is recorded beyond Pratt Street to the south. A number of commercial buildings have replaced former residential housing in the local area.
1916 to 1951	A row of residential houses remains along the western boundary of the site. the remainder of the site is covered by a large commercial/industrial building and some smaller buildings to the north.	The mineral water manufacturer is recorded as Idris Factories.
1942	Refuse Destruction Depot including coal bunker, engines and dynamos pump house and fitters	
1946	Chimney stack centrally on site	
1953 to 1957	The site is now recorded as St Pancras Generating Station	A transformer is recorded 28m to the west of the site. Commercial activities recorded in the local area include a depot, wharfs and a number of works and factories.
1962 to 1971	The footprint of the buildings on site has changed and it is now recorded as a depot and a works.	By 1968, the Idris Factories to the south are now recorded as GPO garages and workshops. Minor changes in the nature of the surrounding commercial activities.

Summary description of site history from Ordnance Survey maps		
Date	**Onsite**	**Offsite**
1987 to 1994	The site has been redeveloped and is recorded as St Pancras Commercial Centre with the layout as existing.	The railway sidings, goods depot and coal depot to the north-east has now been redeveloped as residential houses. The GPO Garages and Workshops to the south are no longer recorded but the buildings are still present.
1999	No significant change	The buildings formerly recorded as the GPO garages and workshops are no longer present and now appear to be used as car parking and depot.
2006 to 2018	No significant change	No significant change
Table 3.4.1		

3.4.2 In summary, the site was formerly residential properties and was redeveloped into an electricity generating station, understood to have been opened in 1895 for the destruction of municipal waste, envirocheck extract below, this continued to expand until the 1950s, by which time no residential properties remained. By the 1960s/70s, the site was recorded as a depot and works before being redeveloped again in the late 1980s to the existing commercial centre. The general area has been a mix of residential and industrial with railway sidings, engine houses, factories, goods depots and garages all recorded within close proximity to the site.



3.5 Geology and geohydrology of the area

3.5.1 Geology of the area

3.5.1.1 Envirocheck reproduce geological map extracts taken from the British Geological Survey (BGS) digital geological map of Great Britain at 1:50,000 scale (ref Appendix N). A summary of the recorded geological information for the site is presented in the following table:

Summary of Geology and likely aquifer containing strata

Strata	Bedrock or superficial	Approximate thickness	Typical soil type	Likely permeability	Aquifer designation
London Clay Formation	Bedrock	20-25m	Clays	Impermeable	Unproductive strata
Lambeth Group	Bedrock	10-15m	Clay, silt and sand	Potentially permeable	Secondary A
Thanet sands	Bedrock	10m	Fine sands	Permeable	Secondary A
Chalk	Bedrock	200m	Chalk	Permeable	Principal aquifer

Table 3.5.1

3.5.1.2 It should also be noted that a large area of worked ground is recorded immediately south and south-west of the site, but these deposits are not recorded as extending onto the site.

3.5.1.3 Superficial deposits are the youngest geological deposits formed during the Quaternary, which extends back about 2.6 million years. They rest on older deposits or rocks referred to as bedrock. Soil types and assessments of permeability are based on geological memoirs, in combination with our experience of investigations in these soil types.

3.5.1.4 Unproductive strata are defined as deposits exhibiting low permeability with negligible significance for water supply or river base flow. Unproductive Strata are generally regarded as not containing groundwater in exploitable quantities.

3.5.1.5 Secondary A aquifers are predominantly permeable layers capable of supporting water supplies at a local rather than strategic scale. In some cases, Secondary A aquifers can form an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.

3.5.1.6 Principal aquifers are defined as deposits exhibiting high permeability capable of high levels of groundwater storage. Such deposits are able to support water supply and river base flows on a strategic scale.

3.5.2 Water abstractions

3.5.2.1 Two active ground water and four active surface water abstraction points are located within 1000m of the site. The closest surface water abstraction point lies 478m to the south east of the site with water abstracted for Non-Remedial River/Wetland Support. The closest groundwater abstraction point lies 509m to the east of the site with water abstracted for Mineral Products – General use.

3.5.2.2 The site is not located within a zone protecting a potable water supply abstracting from a principal aquifer (i.e. a source protection zone).

3.5.3 Groundwater levels

3.5.3.1 We have carried out a review of borehole records excavated in the local area and held on the British Geological Survey (BGS) web site. Generally, boreholes did not encountered groundwater where they were excavated in London Clay. Some groundwater was recorded in deep Made Ground deposits. Within two deep boreholes to the south of the site, groundwater was recorded at around 71m bgl within the Chalk Formation deposits at depth.

3.5.4 Coal mining and brine extraction

3.5.4.1 The site is not recorded to be within an area affected by past or present coal mining, or minerals worked in association with coal or brine extraction (within the Cheshire Brine Compensation District).

3.5.5 Shallow mining and natural subsidence hazards

3.5.5.1 The British Geological Survey present hazard ratings for shallow mining and natural subsidence hazards. The site has the following ratings;

Table summarising mining and subsidence hazards

Hazard	Rating
Mining hazard in non-coal mining areas	No hazard
Potential for collapsible ground stability hazard	Very low
Potential for compressible ground stability hazard	No hazard
Potential for ground dissolution stability hazard	No hazard
Potential for landslide ground stability hazard	Very low
Potential for running sand ground stability hazard	Very low
Potential for shrinking or swelling clay ground stability hazard	Moderate

Table 3.5.5

3.5.5.2 A moderate risk of shrinking or swelling clay is recorded on site which is likely to be associated with the near surface London Clay Formation deposits. The effects of this potential risk in terms of the proposed development are discussed in Section 7 of this report.

3.5.5.3 In addition to the above hazard ratings, a report completed by Ove Arup and Partners in December 1991, commissioned by the Department of the Environment (DoE) indicates where mining should be borne in mind when considered planning and development of land. The site is **not** recorded as lying in an area of conclusive rock mining as indicated by the report.

3.5.6 Borehole records

3.5.6.1 The British Geological Survey (BGS) retain records of boreholes formed from ground investigations carried out on a nationwide basis. The location of boreholes with records held by the BGS is recorded on the borehole map contained in Appendix N and records are also (in most cases) available on the BGS web site.

3.5.6.2 We have reviewed some borehole records available on the BGS web site and generally these confirm the geology shown on geological maps.

3.6 Landfill and infilled ground

3.6.1 There are no recorded or historical landfill sites within 1000m of the subject site. In addition, we have reviewed old Ordnance Survey maps and there is no obvious evidence of any quarrying in the area which may have been restored with materials which could generate landfill gases.

3.6.2 There are seven areas of potentially infilled land (water) located within 2000m of the site. The nearest area is recorded 648m to the west of the site and is associated with a backfilled canal and basin.

3.7 Radon

3.7.1 Envirocheck use the British Geological Survey database to review reported radon levels in the area in which the site is located to establish recommended radon protection levels for new dwellings. The database records the site as being located where no protection is recommended.

3.7.2 The Building Research Establishment publication applies to all new buildings, conversions and refurbishments whether they are for domestic or non-domestic use.

3.7.3 It is noteworthy that the BRE and BGS/HPA information is based on statistical analysis of measurements made in dwellings in combination with geological units, which are known to emit radon. Consequently, there is a risk for actual radon levels at the site to exceed the levels assessed by the BGS/HPA/BRE. Currently, the only true method of checking actual radon levels is by measurement within a building on the site over a period of several months. It should be noted that it is not currently a requirement of the Building Regulations to test new buildings for radon, however the BRE recommends testing on completion or occupation of all new buildings (domestic and non-domestic), extensions and conversions. Should you wish to undertake radon monitoring following completion of the development, we can provide proposals.

3.8 Flood risk

3.8.1 The site is not located within a fluvial or tidal flood plain. The site is not located within an area at risk of surface water or ground water flooding.

3.8.2 It should be noted that this information does not constitute a site-specific Flood Risk Assessment (FRA), and a full FRA may be required for the development to support a planning application or satisfy planning conditions.

3.9 Enquiries with statutory undertakers

3.9.1 The Client provided the Statutory Undertakers (SUs) records for this site in order to avoid damaging their apparatus during our fieldwork activities. The records included;

a) BT Openreach Ltd
b) National Grid Gas plc
c) Thames Water
d) ESP Utilities Group
e) Zayo Group
f) Cadent Gas
g) UK Power Networks

3.9.2 Copies of responses received prior to publication of this report are presented in Appendix M.

3.9.3 Normally Statutory Undertakers drawings record the approximate location of their services. We recommend further on-site investigations be undertaken to confirm the position of the apparatus and thus establish the effect on the proposed development and the necessity or otherwise for the permanent or temporary diversion of the service to allow the construction of the development to safely and successfully proceed.

3.9.4 It should be noted that statutory undertakers' records normally exclude private services.

3.10 Enquiries with Local Authority building control and environmental health officers

3.10.1 We have contacted Local Authority Building Control however they have commented that the council does not maintain records of the ground conditions in the borough and were unable to answer our queries.

3.10.2 We have also contacted Local Authority Environmental Health Officers to determine if they have any information regarding potential contamination issues in the area but have not received a response. Should any pertinent information be provided following issue of this report, we will provide a copy to the client

3.11 Unexploded Ordnance (UXO) Risk

3.11.1 We have obtained a preliminary risk review from a UXO specialist to assess the risk and identify any precautionary measures necessary for our intrusive investigations. This risk assessment has not been carried out fully in accordance with CIRIA report C681 '*Unexploded Ordnance (UXO) A guide for the construction Industry*'. According to their response, we understand that the site was struck by air dropped munitions during WWII and thus the risk of encountering UXO on site was considered to be medium. A UXO specialist attended site during excavation of boreholes. A magnetometer was suspended down the borehole at regular intervals as it advanced to detect metallic objects. If a metallic object is detected, then drilling is stopped. At this site, metallic objects were detected in BH02 (A, B and C) and BH03 within the Made Ground soils, drilling continued on the basis that the Made Ground deposits are the result of post-war demolition. Excavations were progressed slowly with observations made at 0.3m intervals through the Made Ground soils. It is recommended that a Detailed UXO Risk Assessment Report is obtained for the site to determine the risk for the construction phase. UXO specialist attendance may be required during the construction phase.

4 Fieldwork

4.1 General

4.1.1 Fieldwork comprised the following activities:

- Excavation of five exploratory trial pits: three to expose foundations and two to determine the presence of underground tunnel and vaults.
- Excavation of three exploratory boreholes using cable and tool percussion drilling techniques.
- TRL dynamic cone penetration in four locations.

4.1.2 A plan of the site showing observed/existing site features and position of exploratory points is presented on Drawing 02. The position of exploratory points relative to site development proposals is presented on Drawing 03. The position of exploratory points shown on these plans is approximate only.

4.1.3 The extent of fieldwork activities and position of exploratory points were defined by the Client's Engineer, AKTII.

4.1.4 Exploratory points were positioned to avoid known locations of underground services. Prior to commencement of exploratory excavations an electronic cable locating tool was used to scan the area of the excavation. If we received a response to this equipment, then the excavation would be relocated.

4.1.5 All soils exposed in excavations were described in accordance with BS EN ISO 14688 *'Identification and Classification of soil'* and BS EN ISO 14689 *'Identification and classification of rock'.*

4.2 Site restrictions

4.2.1 At the time of our investigation, Units 1 to 6 and 11 to 12 were occupied and excavations were undertaken outside of access routes and where possible to limit the disruption to the site use.

4.2.2 Trial pit TP01 was proposed to determine the presence of an underground tunnel and vault structures within Unit 7. Prior to our investigations food storage chillers were to be decommissioned to allow for our excavations to take place and reinstated following our investigations. Due to the difficulty of decommission and reinstatement the plan was amended and two trial pits were carried out within the chiller units.

4.3 Exploratory trial pits

4.3.1 Trial pits TP01A to TP04 were excavated using hand tools to a maximum depth of 1.47m. Surface concrete was either broken out using an electrically powered breaker or cored prior to excavation.

4.3.2 Trial pits, TP01A and TP01B, were excavated to determine the presence/absence of underground tunnel and vault structures. Trial pits TP02 to TP04, exposed foundation arrangements to existing buildings within site boundaries. The trial pit excavations were backfilled with excavated material, which was compacted using hand held ramming tools. The surface was reinstated to match the original surroundings. A Geotechnical Engineer supervised the excavations.

4.3.3 Trial pit records are presented in Appendix D.

4.3.4 Soil samples for subsequent laboratory determination of concentration of chemical contaminants were taken from the sides of trial pits and stored in new plastic containers, which were labelled and sealed. If as a consequence of visual or olfactory evidence, a sample was suspected to be contaminated by organic material, the sample was stored in an amber glass jar with a PTFE sealing washer.

4.4 Light cable and tool percussion boring

4.4.1 Boreholes BH01 to BH03 were excavated using light cable percussion boring techniques as described in EN ISO 22475-1:2006 forming 150mm diameter holes. Temporary casing was advanced within the borehole excavation to maintain the stability of the hole. When groundwater was encountered the excavation was temporarily halted to allow for groundwater observations to be made. Following groundwater observations the casing was advanced within the hole and the location of the water strike recorded. The casing was subsequently advanced to maintain the stability of the borehole and seal off the water to prevent further ingress. Additional records were taken when (and if) the casing produced a seal against water ingress and at the commencement and completion of a days drilling operations. When obstructions were encountered a chisel was employed to break through the obstruction. Time taken to progress the excavation using the chisel is recorded on the borehole logs.

4.4.2 On completion of excavations the boreholes were backfilled with excavated soils compacted using drilling tools.

4.4.3 Soil samples for subsequent laboratory determination of concentration of chemical contaminants were taken from 'intact' bulk disturbed samples obtained in the cutting shoe of the drilling rig. With samples stored in new plastic containers, which were labelled and sealed. If as a consequence of visual or olfactory evidence, a sample was suspected to be contaminated by organic material, the sample was stored in an amber glass jar with a PTFE sealing washer.

4.4.4 Water samples collected for laboratory determination of concentration of chemical contaminants was taken from the borehole using new proprietary plastic bailing equipment. The samples were placed in a new amber jar, quickly sealed with a screw cap with a PTFE washer and subsequently labelled.

4.4.5 Bulk soil samples for identification or subsequent 'classification' laboratory testing were taken from borehole cutting equipment. The sample were placed in a plastic bag and subsequently sealed and labelled. Soil samples were obtained where possible to meet category B quality classes 3 to 5 as described in BS EN 1997-2:2007 (table 3.1).

4.4.6 'Undisturbed' 100mm diameter samples were taken in cohesive soils when considered appropriate using a general-purpose open tube thin walled sampler. These samples were obtained with a view to achieve category A sampling methods to meet quality class 1 as described in BS EN ISO 22475-1: 2006 (table 3). The undisturbed sample was obtained in a steel or aluminium liner and sealed with wax prior to labelling. The number of blows of the standard driving hammer required to obtain the sample is recorded on borehole records.

4.4.7 Standard Penetration Testing (SPT) was carried out at regular frequencies in the borehole. The test was carried out in accordance with BS EN ISO 22476-3:2005. Key details of the test, as required by BS EN ISO 22476-3 are recorded in Appendix C1. The drive rods were type AW. Samples taken from the open sampler (SPT) were placed in a plastic bag, sealed and labelled. In coarse granular soils, a solid 60^o cone may have been used to replace the SPT cutting shoe. This test is reported as SPT(C). Summary of standard penetration testing is recorded on borehole logs.

4.4.8 A graphical summary of undrained shear strength derived from insitu testing is presented on Drawing 04.

4.4.9 A pocket penetrometer was used in cohesive soils and is deemed to measure the apparent ultimate bearing capacity of the soil under test. The pocket penetrometer is calibrated in kg/m^2. The reading can be approximately converted to an equivalent undrained shear strength by multiplying the result by a factor of 50. Tests were carried out on 'intact' samples recovered from the cutting shoe. Details of pocket penetrometer determinations are tabulated in Appendix C2. An average of measurements taken at a specific depth are recorded on borehole records. The pocket penetrometer is not covered by British Standards.

4.4.10 The borehole excavations were formed by drillers who are NVQ Level 2 qualified in Land Drilling under the Construction Awards Alliance CAA with samples relogged by an experienced Geotechnical Engineer.

4.4.11 Records of boreholes formed by light cable and tool percussion drilling techniques are presented in Appendix E.

4.4.12 Combined gas and groundwater monitoring standpipes were installed in boreholes BH01 and BH03. The standpipes were installed following the recommendations of BS EN ISO 22475-1:2006 '*Geotechnical Investigation and Testing – Sampling methods and groundwater measurements – Part 1: Technical Principles for execution'* (figure 6) and BS8576:2013 *'Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs)'* (figure 7). Details of the standpipe installation are recorded on Drawing 05.

4.4.13 Water levels in the standpipes have been measured during a return visit to the site. The water level was measured using a measuring tape calibrated in 1mm intervals with an electronic end piece, which emits an alarm sound in contact with water. Water levels are measured from ground levels at the borehole position. Records of water levels are presented in Section 6.

4.4.14 A description of measurement of landfill type gases in gas monitoring standpipes is provided in subsequent report paragraphs below.

4.4.15 Indicative soil infiltration testing was carried out in boreholes BH01 and BH03. The infiltration testing was carried out generally in accordance with the procedure described in Building Research Establishment (BRE) DG 365 (2016) "*Soakaway Design*". Records of test results and calculations to determine a soil infiltration rate are presented in Appendix C4. It should be noted that testing has not been carried out strictly in accordance with the BRE publication, as this does not specifically provide for calculating an infiltration rate in a borehole. We have adapted the BRE method and calculations in order to provide an indicative infiltration rate.

4.5 Measurement of landfill type gases in gas monitoring standpipes

4.5.1 The concentrations of landfill type gases collected within gas monitoring standpipes installed in boreholes BH01 and BH03 were measured using a portable infra-red gas analyser (model GA2000 plus or GA5000, manufactured by Geotechnical Instruments). Initially the gas analyser was connected to the gas valve on the top of the standpipe to allow the flow rate to be measured. Essentially this is a measurement of gas pressure produced in the standpipe, which is compared with atmospheric pressure at the time of measurement to produce an equivalent gas 'flow' in l/hr. The equipment used is capable of measuring to an accuracy of 0.1l/hr; below this the gas analyser records zero flow. Following BS8485:2015 '*Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings* (clause 6.3.4), we assume flows of 0.1l/hr when the gas analyser reads zero, thus producing a pessimistic gas flow rate in our assessment of ground gases.

4.5.2 Following measurement of 'flow' the gas analyser pumps gases contained in the standpipe through the analyser. Initial readings of gas concentrations are noted manually, followed by subsequent recordings at regular time periods until 'steady state' concentrations are achieved. The analyser records 'peak' and 'steady' concentrations of the following gases:

- Methane (CH_4)
- Carbon dioxide (CO_2)
- Oxygen (O_2)

4.5.3 The ambient atmospheric temperature and barometric pressure was also recorded at the site. To determine if the atmospheric pressure is rising or falling we interrogate the internet on a daily basis.

4.5.4 Methane in concentrations of between 5 to 15% in air is potentially explosive. The 5% methane concentration in air is defined as the Lower Explosive Limited (LEL). The gas analyser measures a percentage of the LEL. For example, 10% LEL equates to 10% of 5%, i.e. 0.5% methane concentration in air.

4.5.5 Records of gas monitoring data are presented in Appendix K.

4.6 TRL dynamic cone penetration testing

4.6.1 Transport Research Laboratory Dynamic Cone Penetration (TRL DCP) testing was carried out in four locations across the site. TRL DCP testing consists of manually dropping an 8kg hammer through a height of 575mm and driving a 20mm diameter, 60° cone into the ground. The amount of penetration per blow or set number of blows is recorded.

4.6.2 Field data was then processed using the software *UK Dynamic Cone Penetrometer (DCP) Software Version 3.1*, provided by the Transport Research Laboratory. The software divides the tested soil into layers based on rate of penetration (mm/blow). This is then used to calculate an equivalent CBR (California Bearing Ratio) using the following equation.

$$\text{Log}_{10}(\text{CBR}) = 2.48 - 1.057 \times \text{Log}_{10}(\text{mm/blow})$$

This relationship has been proved empirically by the Transport Research Laboratory.

4.6.3 It should be noted that TRL DCP testing is not a test defined by British Standards. It is however described in interim advice note 73/06 revision 1 (2009) issued by Highways England.

4.6.4 Results and analysis of dynamic cone penetration test data is presented in Appendix C3.

4.7 Sampling strategies

4.7.1 Geotechnical

4.7.1.1 In general we adopted a judgemental sampling strategy in relation to geotechnical aspects of the investigation. The location and frequency of sampling was carried out in consideration of the following:

i) Topography
ii) Geology (including Made Ground)
iii) Nature of development proposals

4.7.2 Environmental

4.7.2.1 Details of sampling with respect to contamination issues are described in Section 8.

4.7.3 Sample retention

4.7.3.1 Samples are stored for a period of one month following issue of this report, unless otherwise requested.

5 Laboratory testing

5.1 Classification and physical testing

5.1.1 Laboratory testing was carried out on samples retrieved from site as summarised in table 5.1.1. The method of testing is recorded on the laboratory test certificate.

Table summarising classification and physical testing

Exploratory point	Depth (m)	Soil type	Testing scheduled (determination of)
BH01	6.0 – 6.45	London Clay	Triaxial Quick Undrained
BH01	11.0 – 11.45		
BH01	14.0 – 14.45		
BH01	18.0 – 18.45		
BH01	24 – 24.45		
BH03	7.0		
BH03	10.0		
BH03	11.0		
BH03	16.0		
BH03	20.0		
BH03	22.0		
BH03	24.0		
BH03	26.0		
BH03	27.0		
BH03	29.0		
BH03	31.0		
BH03	33.0		
BH03	35.0		
BH03	39.0		
BH01	16 – 16.45	London Clay	Triaxial Quick Undrained Quick undrained Triaxial (Multi stage)
BH01	20 – 2.45		
BH01	9 – 9.45	London Clay	Consolidation Triaxial Quick Undrained
BH03	19		
BH03	25		
BH03	37		
BH01	19 – 19.45	London Clay	Atterberg (Definitive - BS 1377) Moisture Content (BS 1377) Triaxial Quick Undrained
BH03	5.1	Made Ground	Atterberg (Definitive - BS 1377) Moisture Content (BS 1377)
BH01	6.5	London Clay	
BH01	13		
BH01	23		
BH03	10.5		
BH03	24.5		
BH03	28		
BH03	36		
BH03	39.5		
BH03	41	Thanet Sand	

Table 5.1.1

5.1.2 Laboratory test certificates are presented in Appendix G1, G2 and G3.

5.2 Chemical testing

5.2.1 Chemical testing was carried out based on ground conditions and with reference to the contamination Initial Conceptual Model as presented in Section 8. The test methods are recorded on the chemical test certificates. The following table summarises the chemical testing scheduled;

Table summarising chemical testing

Exploratory point	Depth (m)	Medium/soil type	Testing scheduled (Refer to Appendix A for details).
BH01	0.9	Made Ground	SOIL Suite 1 SOIL Suite 4
BH01	1.5	Made Ground	Asbestos BULK SOIL Suite 4
TP02	0.6	Made Ground	SOIL Suite 1 Asbestos Screening presence/absence
BH02	0.5	Made Ground	SOIL Suite 1
BH03	3		
TP01A	0.7		
TP04	0.9		
BH03	4	Made Ground	SOIL Suite 4
TP04	0.6		
BH02	0.8	Made Ground	Asbestos Screening presence/absence
TP01A	0.8		
TP04	0.2		
BH03	0.3	Made Ground	Asbestos BULK
BH03	5.74	Water sample	WATER Suite 3 WATER Suite 6

Table 5.2.1

5.2.2 Laboratory test certificates for chemical testing are presented in Appendix H.

6 Ground conditions encountered

6.1 Soils/Rocks

6.1.1 Each exploratory excavation encountered a similar profile of soils considered to be Made Ground overlying London Clay Formation with the Thanet Sand Formation at depth. With the exception of Made Ground, the investigation generally confirmed published geological records.

6.1.2 Made Ground

6.1.2.1 Made Ground was encountered to depths of between 5.1m and 5.7m where the full thickness was proven (BH01 and BH03 only). The Made Ground comprised loose becoming very dense dark brown blackish grey gravelly fine to coarse sand with frequent cobbles of brick and rare cobbles of concrete. Gravels comprised brick, concrete, asphaltic concrete, clinker, fabric, glass, plastic and slag. A suspected concrete obstruction was encountered at BH02, BH02A and BH02B positions at depths of between 2m and 3m. Within trial pits TP01A-B, Made Ground comprised brown sandy gravel of brick and flint to depths in excess of 1m.

6.1.3 London Clay Formation

6.1.3.1 London Clay Formation was encountered in BH01 and BH03, with the base encountered at 41m in BH03. The London Clay comprised very stiff very high strength brown becoming blue grey silty clay with occasional gypsum crystals.

6.1.4 Thanet Sand Formation

6.1.4.1 Thanet Sand Formation extended beyond the termination depth of BH03 and comprised very dense green grey silty sand.

6.2 Geotechnical parameters

6.2.1 The following table summarises test data in the London Clay Formation.

Table summarising soil testing and derived geotechnical parameters					
Geotechnical parameter	**Method**	**Value range**	**Characteristic value**	**Comments**	**Notes**
Weight density	Soil descriptions	19 - 23	19	Derived from BS 8004 figure 1.	
Plasticity index	Laboratory testing	17 - 44	40	High plastic based on a large number of samples recording >40	1
Undrained Shear strength (kN/m^2)	Pocket penetrometer	150 - 225	-	-	1
	Triaxial testing	29 - 361	-	-	1, 2
	SPT testing	75 - 250	-	-	2
	-	-	Cu = 75+6.7z	Z = depth for each 1m penetration into London Clay	2
Standard penetration testing (SPT) (uncorrected)	Insitu testing	19 - 50		-	3
Coefficient of volume compressibility (m^2/MN)	Laboratory testing	0.0095 – 0.24	Varies with depth	-	1

Table 6.2
1. Laboratory testing presented in Appendix G
2. Presented on Drawing 04
3. Presented in Appendix C

6.3 Groundwater

6.3.1 Groundwater inflows were observed in some of the exploratory excavations. A summary of our observations is tabulated below:

Table summarising groundwater observations			
Exploratory point	**Date of observation**	**Depth (m) below ground levels**	**Observations**
BH01	27/02/19	4.80	Rising to 4.11m
BH03	01/03/19	41.0	Measured at 39.3m on completion
BH03	11/03/19	5.48	Monitoring observation
BH01	21/03/19	4.13	Monitoring observation
BH03		4.30	Monitoring observation
BH01	25/03/19	4.15	Monitoring observation
BH03		4.42	Monitoring observation
BH01	03/04/19	4.21	Monitoring observation
BH03		5.05	Monitoring observation

Table 6.4.1

6.4.2 It should be noted that water levels will vary depending generally on recent weather conditions and only long-term monitoring of levels in standpipes will provide a measure of seasonal variations in groundwater levels.

6.5 Evidence of contamination

6.5.1 During excavation of our exploratory points, deep Made Ground was encountered in each location, which included a significant proportion of anthropogenic material. During the excavation of TP02, suspected asbestos containing materials were encountered in Made Ground soils. In addition, a slight TPH odour was observed within BH01 at depths between 0.7m and 1.1m

6.6 Obstructions and instability

6.6.1 The following table summarises obstructions encountered during our exploratory excavations;

Table summarising obstructions and instability observations

Exploratory point	Depth of obstruction	Description of obstruction and/or instability
BH02	2.6m	Suspected concrete obstruction
BH02A	2.0m	
BH02B	3.0m	

Table 6.6.1

6.7 Existing foundation arrangements

6.7.1 Foundations were exposed in exploratory pits TP02 to TP04. Detailed logs of these excavations are presented in Appendix D but are summarised in the following table;

Table summarising foundation arrangement observations

Exploratory point	Depth of foundation	Projection from building line	Founding strata	Comments
TP02	1.69	0.14	Not determined.	Foundation depth determined using drill probe data
TP03	>1.35	0.10	Not determined.	-
TP04	>1.47	0.6	Not determined.	-

Table 6.7.1

7 Geotechnical Appraisal

7.1 General description of the development

7.1.1 The following assessments are made on the investigatory data presented in the preceding sections of this report and are made with reference to specific nature of the development. Should scheme proposals change then it may be necessary to review the investigation and report.

7.1.2 We understand the scheme will comprise the construction of three, six-storey blocks for office/residential use. A joint single-level of basement is also proposed.

7.2 Building regulations and this report section

7.2.1 Building Regulations

7.2.1.1 Current Approved Document A of the building Regulations references Eurocodes and their UK National Annexes as practical guidance in meeting part A requirements. Approved document A advises there may be alternative ways of achieving compliance with requirements where it can be demonstrated that the use of withdrawn standards no longer maintained by the British Standards Institution continues to meet Part A requirements.

7.2.2 This report section

7.2.1.2 This chapter of the report provides both a foundation strategy for the proposed development and geotechnical design parameters to comply with Eurocode 7 (BSEN1997-1:2004 *'Geotechnical Design – part 1 General Rules'* and the corresponding UK National Annex). This chapter also provides building foundation design parameters ('Traditional Methods') which relate (in part) to withdrawn British Standards. It is for the foundation designer to select the design methodology and demonstrate compliance with part A requirements.

7.2.3 Geotechnical terms

7.2.3.1 Definitions of geotechnical terms used in the following paragraphs are provided in Appendix A.

7.2.4 This report

7.2.4.1 This report is a ground investigation report (GIR) and does not constitute a Geotechnical Design Report as defined in section 2.8 of BS EN 1997-1:2004 *'Eurocode 7 – Geotechnical Design – Part 1: General Rules'* and in particular will exclude assessment of lifetime actions to buildings from geotechnical influences.

7.3 The geological model

7.3.1 Strata

7.3.1.1 Two boreholes were formed at the site to depths of 25m and 42m, these encountered a profile of soils which are summarised in the following table:

Summary of ground conditions encountered at the site					
Strata	**Summary soil type**	**Depth to base of strata**		**Groundwater**	
		Range	**Model**	**Range**	**Model**
Made Ground	Dark brown blackish grey gravelly sand	5.1 to 5.7m	5.0m	4.13 to 5.48m	4.0m
London Clay	Brown slightly sandy clay.	41m	40m	-	-
Thanet Sand*	Green grey silty sand	>41m	41m	-	-

Table 7.3.1
***Depth to the top of the Thanet Sands was proven in BH03 only**

7.3.2 Groundwater

7.3.2.1 We have carried out a review of borehole records excavated in the local area and held on the British Geological Survey (BGS) website. Generally, boreholes did not encountered groundwater where they were excavated in London Clay. Some groundwater was recorded in deep Made Ground deposits. The nearest water course is the Regent Canal located 10m to the north.

7.3.2.2 Deep Made Ground was encountered in both exploratory boreholes at the site with groundwater levels recorded in the range of 4.13m and 5.48m below ground level.

7.4 Building foundation solutions

7.4.1 Due to the scale of the proposed development (6 storeys) as well as the nature of the ground conditions (deep Made Ground and groundwater at 4.5m) a piled foundation solution is considered appropriate. It may be an option to construct a basement raft foundation solution, while not considered in detail in this section the potential restrictions are set out in section 7.6.

7.5 Determination of pile bearing resistance to BS EN1997-1:2004 (Eurocode 7)

7.5.1 Geotechnical category

7.5.1.1 In our opinion the project will comprise conventional types of structure and foundations with no exceptional risk, or difficult ground or loading conditions thus meeting the requirements of geotechnical category 2.

7.5.2 Assumptions

7.5.2.1 Eurocode 7 list assumptions made in the provision of the standard (in section 1.3). Comments against some assumptions are provided below.

Assumption	Comment
Data for the design are collected, recorded and interpreted by appropriately qualified personnel	This report follows an in-house procedure of review and checking, ultimately approved by a Director of the company who by virtue of experience in geotechnical engineering and qualification is deemed appropriately qualified
Adequate continuity and communication exist between the personnel involved in data collection, design and construction	This can be challenging in situations in which structural and geotechnical design is carried out by different individuals and indeed different organisations. Invariably the ground investigation is carried out at an early stage of a development and prior to actions on buildings being established let alone their magnitude. It is important that we the geotechnical consultant form part of the design team with continuous review of geotechnical design data in the context of the structural design process.

Table 7.5.2

7.5.3 Likely method of pile installation/construction

7.5.3.1 Given the close proximity to adjacent buildings and knowledge of ground conditions replacement type piles are considered appropriate, and given the relatively high-water table in the Made Ground soils a bored cast in place type pile would be favoured although we have also considered a continuous flight auger solution. We have progressed this report based on these replacement pile solutions, but the final type of pile construction will be determined by a specialist piling company probably appointed under a design and build type contract to design and install the piles to support loads/actions specified by the superstructure designer. The following paragraphs derive pile design parameters, design approaches and preliminary load carrying capacities of axially loaded single replacement type piles to assist project Structural Design Engineers in producing pile layout plans. It should be noted that due to the presence of inground obstructions, likely hardstandings, floor slabs and foundations from the former power plant removal of such obstructions is locally likely required to allow piling.

7.5.3.2 Piled foundations would transmit super structural loads down through the Made Ground to obtain shaft adhesion in the London Clays with end bearing support in the London Clay. We recommend any support from the Made Ground is ignored due to the deposits variable composition and strength/density. In addition, consideration will be required to final site levels when designing piles. The difficulty of boring piles through these soils (taking into consideration ground water) would have to be considered by any specialist piling company and will affect the method of pile installation.

7.5.4 Design approach and pile resistance factors (Structural (STR) and geotechnical (GEO) limit states)

7.5.4.1 Three possible design approaches are defined in EC7. Following table NA.1 of the national annex to BS EN 1997, Design Approach 1 (DA1) has been used

7.5.4.2 For the design of axially loaded single piles, it shall be verified that a limit state of rupture or excessive deformation will not occur with either of the following combinations of sets of partial factors:

- Combination 1: A1 "+" M1 "+" R1
- Combination 2: A2 "+" (M1 or M2) "+" R4

Where "+" implies: "to be combined with".

7.5.4.3 In Combination 1, partial factors are applied to actions and to ground strength parameters. In Combination 2, partial factors are applied to actions, to ground resistances and sometimes to ground strength parameters. In Combination 2, set M1 is used for calculating resistances of piles and set M2 for calculating unfavourable actions on piles owing e.g. to negative skin friction or transverse loading. Based on ground conditions and development proposals, we are of the opinion negative skin friction due to settlement of the Made Ground is unlikely to occur, and at this stage assume no significant transverse loads will be applied to the piles. Based on this M1 partial factor set applied to soil parameters is adopted.

7.5.4.4 In the absence of any pile loading test data (to verify serviceability limit state (SLS)), we have used a model factor of 1.4. Please note this may be reduced to 1.2 if successful pile testing is carried out with results used for review of pile resistance calculations.

7.5.4.5 The following table shows R4 partial factors. Again, in the absence of pile testing to verify serviceability limit state (SLS) the more onerous factors (given in table A.NA.7 of the national annex) have been used.

Table of partial factors (R4)

Design case	Pile type	Shaft adhesion	End bearing	Model factor
R1	CFA	1.0	1.0	1.4
	Bored	1.0	1.0	1.4
R4 (assume no explicit verification of SLS)	CFA	1.6	2.0	1.4
	Bored	1.6	2.0	1.4

Table 7.5.4.5

7.5.4.6 Pile testing may allow the use of less onerous factors, and thus a more economic pile design, providing results are favourable in verifying serviceability limit state and adopted geotechnical design parameters.

7.5.5 Shaft adhesion

7.5.5.1 We have assumed no positive contribution from the Made Ground and the underside of pile cap is about 1.2m below formation levels. Based on a 3.5m deep basement the the assumed pile cap depths will be in te range of 19.4 to 22.0 mAOD .

7.5.5.2 The ultimate shaft adhesion for piles in London Clays soils is determined from measured undrained shear strengths. The undrained shear strengths are also used to 'calibrate' the conversion of standard penetration test (SPT) data to undrained shear strength. A summary of undrained shear strength data is presented on Drawing 04, which also derives a characteristic undrained shear strength relationship with depth.

7.5.5.3 The adhesion factor, α, of 0.5 in the London Clays has been obtained from guidance provided in '*Guidance notes for the design of straight shafted bored piles in London Clay'* produced by the London District Surveyors Association (LDSA) (referenced in BS 8004:2015 *'Code of Practice for Foundations'*). Achieving a good alpha value in clay needs good site construction processes. Alpha reduces where:

- There are no major water seepages in the London Clays which are defined as those that wet more than 20% of the pile shaft prior to concreting.
- Piles are not constructed using drilling fluid (e.g. bentonite)
- The piles are concreted within 12 hours of start of boring in the London Clays (or 12 hours below casing depth)
- Underpowered CFA rigs are used.

7.5.5.4 Refer to the LDSA document for further notes on pile design and construction requirements

7.5.5.5 The LDSA published guidance also recommends the adhesion is limited to 110kN/m^{2,} which equates to a limit on the undrained shear strength of the clays of about 220kN/m^2. This limit could be reconsidered if pile testing is carried out to demonstrate higher values of shaft adhesion.

7.5.6 Summary of characteristic and design geotechnical parameters

7.5.6.1 The table below shows selected characteristic and design geotechnical parameters used for the calculation of bearing resistances for piles. Values have been chosen with reference to the following, (in descending order or preference):

- Laboratory test results
- In-situ field test results
- Published geotechnical data
- Engineering judgement based upon experience

Bored/CFA piles Parameter	Characteristic value	Design value	Comments/derivation
Weight densities			
London Clay (kN/m^3)	19 - 21.4	19	From laboratory measurements (triaxial testing)
Groundwater			
Groundwater level (m)		4	Based on the geological model and from monitoring
Undrained shear strength in London Clays soils			
London Clay (kN/m^2)	-	75 + 6.9z	Refer drawing 04
α - Adhesion factor depending upon soil strength, effective overburden pressure, pile type and method of execution			
London Clay	-	0.5	LDSA *'Guidance notes for the design of straight shafted bored piles in London Clay'*
Nc – Bearing pressure coefficient			
London Clay	-	9	From table 10 of BS8004

Table 7.5.6.1

7.5.7 Method of determination of pile resistances

7.5.7.1 We have followed the methods to determine shaft and end bearing resistances as described in BS 8004:2015 '*Code of practice for foundations*' using the above tabulated design values and appropriate partial factors in determination of pile resistances.

7.5.8 Pile resistances

7.5.8.1 The following charts provide pile resistances for differing pile diameters, pile types, and indeed the two combinations associated with design approach 1. In using these charts, the following is very important to note:

1. These charts are to assist the foundation designer in establishing a foundation layout. It is for the pile designer (commonly as part of a design and build contract) to take design liability. We do not take pile design responsibility.

2. Actions associated with the two combinations will require the application of appropriate partial factors described in Eurocodes.

7.5.8.2 It is recommended that a piling contractor is consulted at an early stage to confirm pile installation methodology. It is further recommended that piling is carried out in accordance with the *"Specification for Piling and Embedded Retaining Walls"* produced by the Institution of Civil Engineers.

7.5.8.3 Pile calculations have been undertaken with the aid of Pile, a specialist software programme developed by OASYS. It is anticipated that the piles will be founded entirely within the London Clay.

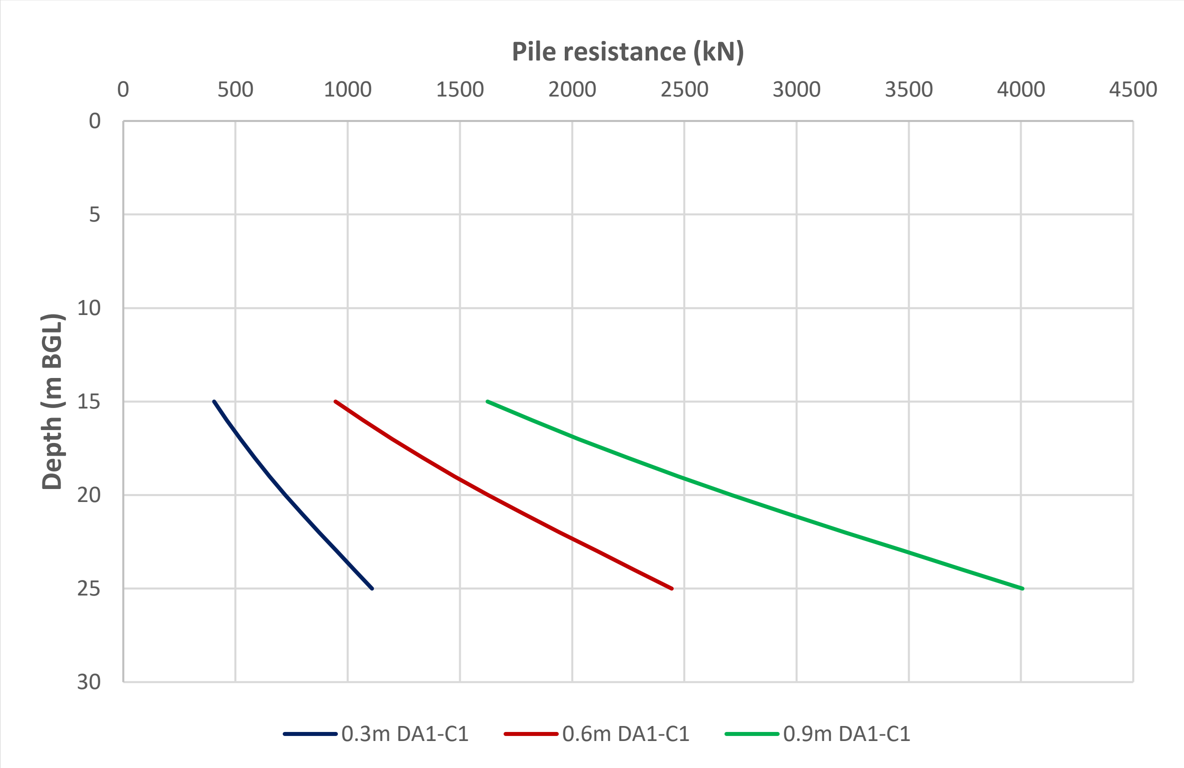


Figure 7-A: Graph showing variation of pile resistances with toe level for Combination 1 for a selection of pile diameters

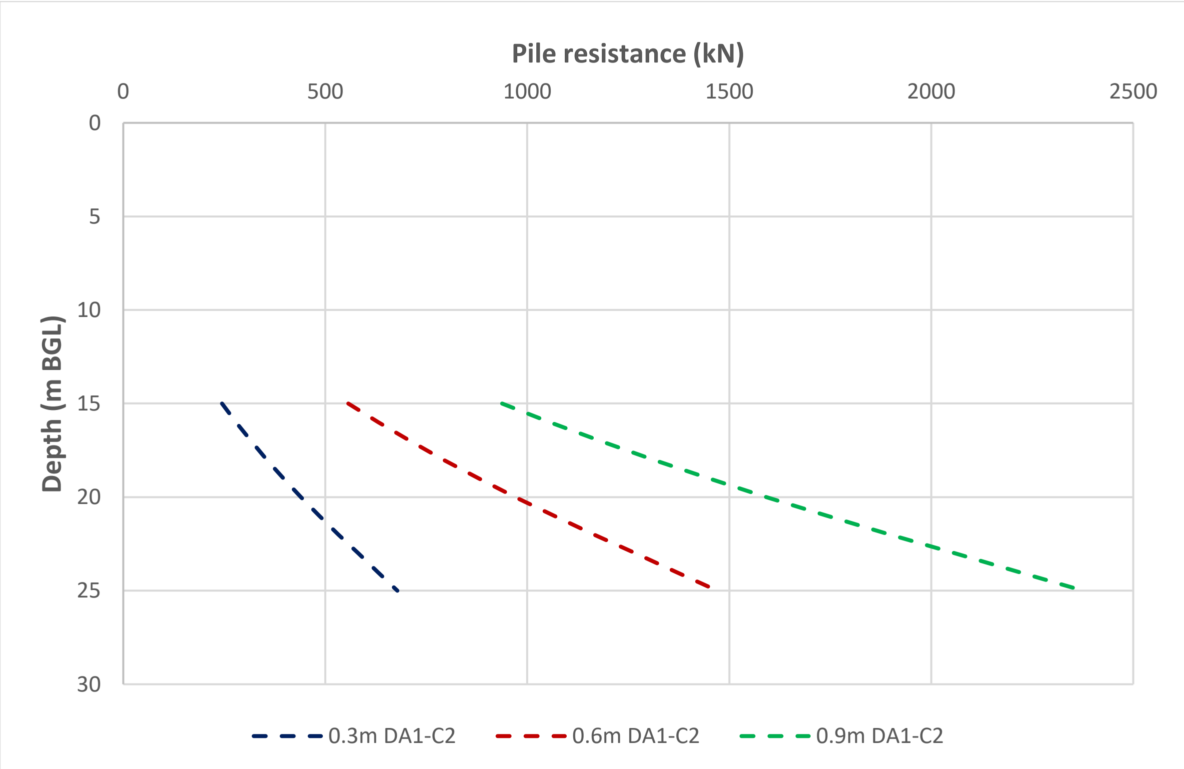


Figure 7-A: Graph showing variation of pile resistances with toe level for Combination 2 for a selection of pile diameters

7.5.9 Pile spacing and pile groups

7.5.9.1 Refer to BS 8004:2015 section 6.3.3 for pile spacing requirements and section 6.1.7 for pile groups.

7.5.10 Pile settlements

7.5.10.1 Based on a review of pile tests the ICE manual of Geotechnical Engineering (2012) reports (section 54.5) that at typical working loads (factor of safety of 2 or more) the single pile settlement would be expected to be less than about 1% of the pile diameter.

7.5.11 Pile testing

7.5.11.1 Pile testing may permit the design to be refined and potentially, if successful, result in shorter pile lengths if testing is carried out in advance of the main piling activities (preliminary testing). We can assist in deriving a pile testing regime.

7.5.11.2 A good treatise on pile testing is provided in section 54.7 of the ICE manual of Geotechnical Engineering (2012).

7.5.12 Pile design and installation

7.5.12.1 We have endeavoured to provide sufficient information to allow detailed design of piles to be completed. The above pile resistances have been produced in good faith based on our current understanding of design procedures for the purposes of producing a preliminary foundation layout by a Structural Engineer. We recommend the design and installation of the piles are determined by a specialist piling contractor who has experience in pile installation in these or similar ground conditions, and may be able to interpret the observed ground conditions in a different and potentially more beneficial manner. We recommend the specialist piling contractor assumes responsibility for the choice, design and installation of the piles.

7.5.12.2 We recommend piling be carried out following the *"Specification for Piling and Embedded Retaining Walls"* produced by the Institution of Civil Engineers.

7.5.13 Piling mat

7.5.13.1 It is likely that a 'piling mat' will have to be constructed in advance of piling operations. This will be designed following the Building Research Establishment publication '*Working Platforms for tracked plant: good practice guide to the design, installation, maintenance and repair of ground supported working platforms'*. We will be pleased to assist in the design and specification of such a platform on further instructions.

7.5.14 Piling constraints

7.5.14.1 It should be noted that London Clay Formation at depth were encountered in a very stiff state, and localised layers of mudstone rock have been encountered in such deposits. This will need to be taken into account in the type of equipment chosen to excavate pile bores.

7.5.14.2 Water will also be encountered during piling operations. A summary of groundwater observations is presented in Table 6.3.1.

7.6 Basement

7.6.1 Basement raft considerations

7.6.1.1 Raft foundations have the ability to spread super structural loads over the footprint of the building thus substantially reducing stresses imparted to the ground compared with spread foundations transferring more concentrated loads to the ground.

7.6.1.2 At this stage we understand that a single storey basement is being considered common to all three proposed buildings. Due to the presence of MadeGround to depths of approximately 5m either, over excavation of soils will be required with a suitable engineered fill, or increase of basement depth could be considered. It should be noted however, that excavation of these soils based on their waste classification, refer section 11, may prove costly.

7.6.1.3 As the basement structure is likely to be relatively complex in loading pattern, we can provide further analysis of basement raft, heave/settlement analysis, on provision of raft depth, load pattern etc.

7.6.2 Basement retaining walls and excavations

7.6.1 An embedded piled wall around the perimeter of the proposed basement will be required to facilitate excavation and construction of the basement. We understand the basement structural slab level will be positioned at 3.5m below ground level with the slab assumed to be some 500m thick, thus excavation to formation level will be about 4m below ground level. We have assumed the the basement slab will be suspended off piled foundations. At a basement formation level of around 4m below ground level, there will be about 1.0 to 1.5m thickness of Made Ground remaining below the slab.

7.6.2 Groundwater was encountered generally in the Made Ground, and we have subsequently measured levels in the range of 4.13m to 5.48m below groud level. Whilst the groundwater levels were reasonably consistent it is possible that basement excavations may encounter perched groundwater at high levels within the Made Ground.

7.6.3 Based on the above the retaining walls will retain the Made Ground. The following table presents geotechnical parameters for retaining wall design:

Table summarising basement retaining wall parameters for Made Ground soils		
Parameter	**Value**	**Origin**
Characteristic weight density above the water table	16 kN/m^3	BS8004:2015 fig 1
Characteristic weight density Below the water table	18 kN/m^3	BS8004:2015 fig 2
Characteristic constant volume (known as critical state) effective angle of shearing resistance ϕ	22^o	Lower bound picked from Building response to tunnelling in consideration of potential variability of Made Ground material
Table 7.6.3		

7.6.4 Some movement of the retaining walls will occur to generate active/passive pressures. The amount of movement which could occur for active situations in non-cohesive soils is described in BSEN1997-1:2004 annex C.3.

7.6.5 The basement walls will require propping both in the permanent and temporary states, dependent upon the method/sequence of construction. It should be recognised that some inward yielding of supported sides of strutted excavations and accompanying settlement of the retained ground surface adjacent to the excavation will occur even if structurally very stiff strutting is employed. We recommend retaining walls are monitored during basement construction and if appropriate propping adjusted to reduce inward yielding. CIRIA report C760 '*Guidance on embedded retaining wall design*' provides good advice on construction methodology and means of estimating ground movements based on observations from other similar structures.

7.6.6 Some hydrostatic pressures will be produced from the Made Ground. Water levels (probably from perched water) vary based on monitoring and we therefore recommend a conservative water level should be adopted for basement design purposes.

7.7 Basement Floor Construction

7.7.1 Subject to the design level of the basement floor consideration will need to be given to how this floor is supported, and how it resists any heave and hydrostatic pressure from perched or continuous groundwater. Following adoption of a design level we can provide further analysis on heave/settlement acting on the basement floor.

7.8 Influence of trees and other major vegetation

7.8.1 The results of plastic and liquid limit determinations performed on samples of the London Clay indicate these deposits are soils of high volume change potential when classified in accordance with National House Building Council (NHBC) Standards, Chapter 4.2. Foundations are likely to be piles and therefore will not be affected by the presence of trees.

7.9 Service trench stability and excavation

7.9.1 It is difficult to predict the stability of trench sides from borehole investigations. Based on observations within shallow hand pits and boreholes, soils were observed in a dense state. However, the Made Ground was variable and there is a possibility that some over break/instability in Made Ground deposits may occur, potentially requiring shoring to maintain an open excavation. It is considered unlikely significant water inflows will occur as confined water was generally encountered towards the base of the Made Ground. However, some minor water inflows may occur, possibly requiring nominal pumping to control inflows.

7.9.2 It should be noted that near surface soils were noted to be in a stiff/dense state, making excavation difficult by hand. In addition, concrete obstructions were encountered (as detail in Section 5) in a number of locations. Based on our investigations, the extent of each obstruction is not known.

7.9.3 We recommend any trench excavation requiring human entry is shored as necessary to conform with current best practice, and accepted by the Health and safety Executive (HSE) and in particular, following guidance provided in the HSE publication '*Health and Safety in Construction (HSG 150)*' (www.hse.gov.uk).

7.10 Infiltration Potential

7.10.1 Requirements for use of infiltration systems

7.10.1.1 It is a requirement under H3 (3) of the current building regulations to discharge stormwater collected by a development to soakaways as a priority (as opposed to water courses and sewers).

7.10.2 Infiltration measurements

7.10.2.1 The London Clay Formation deposits are, in our opinion, effectively impermeable and would not be able to dispose of water using soakaway systems.

7.10.2.2 Although, based on testing in BH03, the Made Ground deposits are permeable there is a risk that as the site sits within the assumed former reduced level excavation, of the former power station, likely excavated London Clay. On this basis soakaways could potentially concentrate water filling the potentially confined Made Ground resulting in raising the groundwater level.

7.10.2.3 Records of the test results and calculation to determine the soil infiltration rate is presented in Appendix E. Details of the standpipe installations (in which the tests were carried out) are recorded on Drawing 04. Records of testing and calculations are presented in Appendix C4.

7.10.2.4 In addition, consideration should be given the potential contamination in the Made Ground and infiltration systems promoting mobilisation of such contaminants.

7.11 Pavement Foundations

7.11.1 Criteria for design of the pavement foundation.

7.11.1.1 The thickness of the pavement foundation (typically unbound granular materials- or sub-base and capping materials) is derived from a combination of the following:

- Number of passes of standard (80kN) axles from construction traffic (HGV). ie construction traffic loading which the foundation is required to carry.
- The location of the water table.
- Weather conditions at the time of construction.
- The strength of the subgrade, determined by measurement of the California Bearing Ratio (CBR).

7.11.1.2 For road designs meeting the requirements of the Highways Agency, then subgrade CBR will derive a foundation layer thickness relating to differing subgrade stiffness's. (refer interim advice note 73/06).

7.11.2 Methods of determination of CBR values

7.11.2.1 The following table identifies common methods of determination of CBR values

Common methods of CBR determination

Method	reference	Outline methodology	Advantages	Disadvantages
Direct on soil in CBR mould	BS1377 and Interim advice note 73/06 (2009)	Soil sample in steel mould. Can be undisturbed or disturbed (recompacted in mould). Load measured to force 50mm diameter steel plunger 2.5 and 5mm into soil to derive CBR	BS procedure Department for transport procedure	CBR measured at water content at time of test. CBR may not reflect changes in water content during life of pavement. Unsuitable for very coarse grained (> 20mm) soils
Plate bearing test	Interim advice note 73/06 (2009)	Load required to displace a 762mm diameter steel plate 1.25mm into the subgrade to derive a CBR	Department for transport procedure. Suitable for coarse grained soils	CBR measured at water content at time of test. CBR may not reflect changes in water content during life of pavement. Reasonably slow procedure.
Dynamic cone	Interim advice note 73/06 (2009)	Record number of blows of 8kg drop weight falling 575mm to drive 20mm 60-degree steel cone 50 to 550mm into the subgrade.	Department for transport procedure. Reasonably rapid assessment.	CBR measured at water content at time of test. CBR may not reflect changes in water content during life of pavement. Unsuitable for very coarse-grained soils
Soil classification characteristics	LR 1132 structural design of bituminous roads (Transport Research laboratory)	Measurement of plasticity or particle side distributions, and knowledge of location of water table required to derive CBR for varying construction conditions	CBR derive for subgrade during life of pavement. Simple testing. Relates to long term research and experience at the TRL	Interim Advice note 73/06 (section 5.5) says this should only be used samples cannot be taken for laboratory testing.

Undrained shear strength	TRRL report 889 Strength of clay fill subgrades: its prediction in relation to road performance.	CBR = Cu/23, where Cu is the undrained shear strength (kN/m2).	Cu could be measured by hand held shear vane rapidly and in great quantities. Relates to long term research and experience at the TRL	Cu measured at water content at time of test. Derived CBR may not reflect changes in water content during life of pavement. Unsuitable for coarse grained soils

Table 7.11.2

7.11.2.2 Methodology can sometimes be dictated by design manuals of a local highway authority who may adopt the road network, and would probably favour methods described in Interim advice note 73/06.

7.11.2.3 We understand the project will not include roads which will be offered for adoption. We have determined CBR values based dynamic probing carried out following procedures described in Interim Advice Note HD26/06 (2009).

7.11.3 Location of the pavement formation

7.11.3.1 We anticipate that the proposed access road and associated hardstanding areas will be located at or about existing ground levels with formation located on Made Ground soils.

7.11.4 Determination of subgrade CBR using the Dynamic Cone Penetrometer

7.11.4.1 The Dynamic Cone Penetrometer (DCP) is a device incorporating an 8kg drop weight that falls vertically through 575mm onto a relatively light steel anvil. The anvil is attached via steel rods to a 20mm diameter 60^{o} steel cone which is driven vertically into the ground. The distance in mm per blow is recorded between 50mm and 550mm of penetration from top of the subgrade level. These results are input into a standard computer programme developed by the Transport Research Laboratory (TRL) and results are presented in Appendix C3 with the location of probe positions shown on Drawing 02.

7.11.4.2 Based on the DCP results a subgrade CBR of 2.3% can be deduced.

7.11.5 Settlement

7.11.5.1 Made Ground deposits at the site exhibit a degree of variation in compactness. Some long-term settlement of hardstandings will occur due to consolidation of the Made Ground deposits and from applied loads, particularly uniformly distributed loads. It is difficult to accurately predict levels of settlement, as potentially applied loading patterns are not known. Assuming a constantly applied uniformly distributed load of say 10kN/m^2, settlement in the order of 5mm could occur within 5 to 10 years of construction. Equally, some differential settlement could occur in the long term, if hardstandings are not uniformly loaded. We suggest that pavements under transient (vehicular) loads are unlikely to generate significant levels of settlement.

7.11.6 Treatment of formation

7.11.6.1 Once formation levels have been established it is recommended that the formation be trimmed and rolled following current requirements of the Highways Agency Specification for Highways Works (clause 616) (refer www.dft.gov.uk/ha/standards/mchw/vol1). Such a process will identify any soft areas, which we recommend be either excavated out and backfilled with a suitable well compacted material similar to those exposed in the sides of the resulting excavation, or large cobbles of a good quality stone rolled into the formation to stabilise the 'soft' area.

7.11.7 Subgrade frost susceptibility

7.11.7.1 The Made Ground deposits soils are considered frost susceptible and this may override the CBR criteria for pavement foundation design purposes.

7.11.8 Moisture susceptibility

7.11.8.1 The silty nature of the Made Ground will render them moisture susceptible with small increases in moisture content giving rise to a rapid loss of support to construction plant. We therefore recommend, as soon as formation is trimmed and rolled, that sub-base is laid in order to avoid deterioration of the subgrade in wet or frosty conditions.

7.12 Reuse of excavated soils from the site

7.12.1 Based on current development proposals reuse of excavated soils is considered unlikely with the exception of possible reclamation of aggregate from current and historic concrete structures.

8 Chemical contamination

8.1 Contaminated land, regulation and liabilities

8.1.1 Statute

8.1.1.1 Part IIA of the Environment Protection Act 1990 became statute in April 2000. The principal feature of this legislation is that the hazards associated with contaminated land should be evaluated in the context of a site-specific risk-based framework. More specifically contaminated land is defined as:

"any land which appears to the Local Authority in whose area it is situated to be in such a condition, by reasons of substances in, on or under the land, that:

a) Significant harm is being caused or there is a significant possibility of such harm being caused; or
b) Pollution of controlled waters is being or is likely to be caused".

8.1.1.2 Central to the investigation of contaminated land and the assessment of risks posed by this land is that:

i) There must be contaminant(s) at concentrations capable of causing health effects (*Sources).*
ii) There must be a human or environmental receptor present, or one which makes use of the site periodically *(Receptor)*; and
iii) There must be an exposure pathway by which the receptor comes into contact with the environmental contaminant *(Pathway).*

8.1.1.3 In most cases the Act is regulated by Borough or District Councils and their role is as follows:

i) Inspect their area to identify contaminated land
ii) Establish responsibilities for remediation of the land
iii) See that appropriate remediation takes place through agreement with those responsible, or if not possible:
- by serving a remediation notice, or
- in certain cases, carrying out the works themselves, or
- in certain cases, by other powers

iv) keep a public register detailing the regulatory action which they have taken

8.1.1.4 For "special" sites the Environment Agency will take over from the Council as regulator. Special sites typically include:

- Contaminated land which affects controlled water and their quality
- Oil refineries
- Nuclear sites
- Waste management sites

8.1.2 Liabilities under the Act

8.1.2.1 Liability for remediation of contaminated land would be assigned to persons, organisations or businesses if they caused, or knowingly permitted contamination, or if they own or occupy contaminated land in a case where no polluter can be found.

8.1.3 Relevance to predevelopment conditions

8.1.3.1 For current use, Part IIA of the Environmental Protection Act 1990 provides the regulatory regime. The presence of harmful chemicals could provide a 'source' in a 'pollutant linkage' allowing the regulator (Local Authority or Environment Agency) to determine if there is a significant possibility of harm being caused to humans, buildings or the environment. Under such circumstances the regulator would determine the land as 'contaminated' under the provision of the Act requiring the remediation process to be implemented.

8.1.4 Relevance to planned development

8.1.4.1 The developer is responsible for determining whether land is suitable for a particular development or can be made so by remedial action. In particular, the developer should carry out an adequate investigation to inform a risk assessment to determine:

a) Whether the land in question is already affected by contamination through source – pathway – receptor pollutant linkages and how those linkages are represented in a conceptual model
b) Whether the development proposed will create new linkages e.g. new pathways by which existing contaminants might reach existing or proposed receptors and whether it will introduce new vulnerable receptors, and

c) What action is needed to break those linkages and avoid new ones, deal with any unacceptable risks and enable safe development and future occupancy of the site and neighbouring land?

8.1.4.2 Building control bodies enforce compliance with the Building Regulations. Practical guidance is provided in Approved documents, one of which is Part C, '*Site preparation and resistance to contaminants and moisture'* which seeks to protect the health, safety and welfare of people in and around buildings, and includes requirements for protection against harm from chemical contaminants.

8.1.5 Pollution of controlled waters

8.1.5.1 Part IIA of the Environment Protection Act 1990, defines pollution of controlled waters as

'The entry into controlled waters of any poisonous, noxious or polluting matter or any solid waste matter'

8.1.5.2 Paragraphs A36 and A39 of statutory guidance (DETR 2000) further define the basis on which land may be determined to be contaminated land on the basis of pollution of controlled waters.

'Before determining that pollution of controlled waters is being, or likely to be, caused, the Local Authority should be satisfied that a substance is continuing to enter controlled waters, or is likely to enter controlled waters. For this purpose, the local authority should regard something as being likely when they judge it more likely than not to occur'

'Land should not be designated as contaminated land where:

a) A substance is already present in controlled waters:
b) Entry into controlled waters of that substance from the land has ceased, and
c) It is not likely that further entry will take place.

Substances should be regarded as having entered controlled waters where:

a) They are dissolved or suspended in those waters; or
b) If they are immiscible with water, they have direct contact with those waters, or beneath the surface of the waters'

8.1.5.3 Controlled waters are defined in statute to be:

> *'territorial waters which extend seawards for 3 miles, coastal waters, inland freshwaters, that is to say, the waters in any relevant lake or pond or of so much of any relevant river or watercourse as is above the freshwater limit, and groundwaters, that is to say, any waters contained in underground strata.'*

8.1.6 Further information

8.1.6.1 The above provides a brief outline as regards current statute and planning controls. Further information can be obtained from the Department for the Environment, Food and Rural Affairs (DEFRA) and their website www.defra.gov.uk.

8.2 Objectives and procedures

8.2.1 Objectives

8.2.1.1 This report section discusses investigations carried out with respect to chemical contamination issues relating to the site. As stated in Section 2.4.2, the investigation process followed the principles of BS10175: 2011 *'Investigation of potentially contaminated sites – Code of Practice',* with the investigation combining a desk study (preliminary investigation) together with the exploratory and main investigations (refer BS10175: 2011 for an explanation).

8.2.1.2 This section of the report produces *'Conceptual models'* based on investigatory data obtained to date. The conceptual model is constructed by identification of *contaminants* and establishment of feasible *pathways* and *receptors.* The conceptual model allows a *risk assessment* to be derived. Depending upon the outcome of the risk assessment it may be necessary to carry out remediation and/or further investigations with a view to eliminating, reducing or refining the risk of harm being caused to identified receptors. If appropriate, our report will provide recommendations in this respect.

8.2.1.3 Clearly, we must consider the current pre-development condition, establishing risks which may require action to render the site safe to all relevant (current) receptors meeting the requirements of current legislation (Part IIA of the Environmental Protection Act 1990).

8.2.1.4 Definition of terms used in the preceding paragraph and subsequent parts of this section of the report are presented in Appendix B.

8.2.2 Procedure to assess risks of chemical contamination

8.2.2.1 For the purposes of presenting this section of this report, we have adopted the following sequence in assessing risks associated with chemical contamination.

Table outlining sequence to assess risk associated with chemical contamination

Conceptual model element	Contributory information	Outcome
Receptor	Development categorisation	Identification of receptors at risk of being harmed Method of analysing test data Criteria for risk assessment modelling
Pathways	Geology and ground conditions Development proposals	Identification of critical pathways from source to receptor
Source	Previous site history Desk study information Site reconnaissance Fieldwork observations	Testing regime Identification of a chemical source Analysis of test data and other evidence

Table 8.2.2

8.2.2.2 We have adopted, in general, the procedures described in CIRIA C552 *'Contaminated land risk assessment - a guide to good practice'* in deriving a risk assessment. Initially we have carried out a 'phase 1 assessment' based on desk study information and site reconnaissance, to produce an initial conceptual model and thus a preliminary risk assessment. This model/assessment is then used to target fieldwork activities and laboratory testing, with the results of this part of the investigation used to allow a phase 2 assessment to be produced by updating the conceptual model and refining the risk assessment.

8.3 Development characterisation and identified receptors

8.3.1 Site characterisation

8.3.1.1 The nature of the site has a significant influence the likely exposure pathways between potentially contaminated soils and potential receptors. The following table summarises elements which characterise the site based on site observations and desk study information.

Summary of site characteristics		
Element	**Source/criteria**	**Characteristic**
Current land use	Observations	Mixed use commercial units
Future land use	Advice	Mixture of offices, light industrial and residential flats with small areas of soft-landscaping.
Site history	Desk study	Formerly occupied by terraced houses before being recorded as St Pancras generating station from the 1895's and subsequently a depot/works in the 1960s. The current development was recorded from the late 1980s.
Geology	Desk study and Site investigation	Made Ground to depths of around 5m overlying London Clay Formation with Thanet Sands at depth.
Ground water	Aquifer potential	Unproductive strata within the London Clay. Thanet Sands recorded as a secondary A aquifer.
	Abstractions	Nearest is 509m east of the site with water abstracted for mineral products (general use).
	Source protection zone	Site not within a source protection zone.
Surface waters	Location	Regent's Canal 10m north east of the site.
	Abstractions	Nearest is 478m south east of the site with water abstracted for non-remedial wetland support.
Table 8.3.1		

8.3.2 Identified receptors

8.3.2.1 The principal receptors subject to harm caused by any contamination of the proposed development site are as follows.

Principle Receptor	Detail
Humans	Users of the current site
	End user of the developed site
	Construction operatives and other site investigators
Vegetation	Plants and trees, both before and after development
Controlled waters	Surface waters (Rivers, streams, ponds and above ground reservoirs)
	Ground waters (used for abstraction or feeding rivers/streams etc.)
Building materials	Materials in contact with the ground
Table 8.3.2	

8.3.2.2 This section of the report assesses those receptors listed above. Section 10 provides a risk assessment in relation to building materials.

8.3.3 Human receptors

8.3.3.1 The Contaminated Land Exposure Assessment (CLEA) model can be used to derive guideline values, against which land quality data can be compared to allow an assessment of the likely impacts of soil contamination on humans. The parameters used within the model can be chosen to allow guideline values to be derived for a variety of land uses and exposure pathways. For example, a construction worker is likely to be exposed in different ways and for different durations than an adult in a residential setting.

8.3.3.2 On the basis that the current site is restricted to commercial activities, an adult is considered the appropriate critical receptor. Following completion of the mixed-use development, which includes residential end use, the critical site user (receptor) is considered to be a child under the age of 6 years. These criteria have been used in the conceptual model for the current and future site use. Our assessment also considers construction operatives as adult receptors.

8.3.4 Vegetation receptors

8.3.4.1 Soil contaminants can have an adverse effect on plants if they are present at sufficient concentrations. The effects of phytotoxic contaminants include growth inhibition, interference with natural processes within the plant and nutrient deficiencies.

8.3.4.2 Small areas of soft landscaping are currently present on the site and therefore current vegetation is considered a potentially sensitive receptor. We have not received layout proposals at this time and therefore we are not aware if there are any areas of soft landscaping proposed. However, based on the drawings provided of the proposed building footprint, a basement is proposed across the entire site footprint. Any future planting is likely to be undertaken within imported soils/planters and therefore vegetation is not considered to be a potentially sensitive receptor.

8.3.5 Water receptors

8.3.5.1 The site lies in an area designated as unproductive strata due to the impermeable London Clay Formation deposits. On this basis, groundwater is not considered to be a potentially sensitive receptor of contamination on site.

8.3.5.2 The Regent's Canal is located approximately 10m to the north of the site. However, a road and buildings lie between the site and the canal, which will restrict lateral flow of water from the site to the canal. In addition, the canal is likely to be lined, which will further restrict potential contaminants originating from the site impacting this watercourse. On this basis, the Regent's Canal is not considered a potentially sensitive water receptor.

8.3.6 Summary of identified receptors

8.3.6.1 Based on the above assessments, the following table summarises identified and critical receptors.

Table summarising identified (viable) receptors				
Principle Receptor	Detail	Viable and critical receptors		
		Viability and justification		Critical receptor
Humans	Users of the current site	Yes	Active commercial units on site	Adult
	End user of the developed site	Yes	Residential and commercial development	Child
	Construction operatives and other site investigators	Yes	To be redeveloped	Adult
Vegetation	Current site	Yes	Vegetation and soft landscaping present	Vegetation
	Developed site	No	Any proposed vegetation unlikely to be in contact with existing soils.	-
Controlled waters	Surface waters (Rivers, streams, ponds and above ground reservoirs)	No	Regent's Canal likely to be lined and significant development between the site and the canal.	-
	Ground waters (used for abstraction or feeding rivers / streams etc)	No	Site over impermeable London Clay	-
Building materials	Materials in contact with the ground	Yes	Assessed in report section 10	Building materials

Table 8.3.6

8.4 Identification of pathways

8.4.1 Pathways to human receptors

8.4.1.1 Guidance published by the Environment Agency in Science Report SC050021/SR3 *'Updated technical background to the CLEA model'* provides a detailed assessment of pathways and assessment and human exposure rates to source contaminants. In summary, there are three principal pathway groups for a human receptor:

Table summarising likely pathways	
Principal pathways	**Detail**
Ingestion through the mouth	Ingestion of air-borne dusts
	Ingestion of soil
	Ingestion of soil attached to vegetables
	Ingestion of home-grown vegetables
Inhalation through the nose and mouth.	Inhalation of air-borne dusts
	Inhalation of vapours
Absorption through the skin.	Dermal contact with dust
	Dermal contact with soil

Table 8.4.1

8.4.1.2 The site is currently occupied with commercial units with some areas of soft landscaping and therefore all the above pathways are considered to be present with the exception of those associated with the consumption of vegetables.

8.4.1.3 Following redevelopment, the site will be predominantly covered in buildings/hardstandings, possibly with areas of soft landscaping or gardens. However, any landscaping will likely be within imported soils due to presence of basement. On this basis, none of the above pathways are considered potentially viable with the exception of inhalation of vapours.

8.4.1.4 All of the above pathways are considered potentially viable for construction operatives with the exception of those associated with the consumption of vegetables.

8.4.2 Pathways to vegetation

8.4.2.1 Guidance published by the Environment Agency in Science Report SC050021/SR (Evaluation of models for predicting plant uptake of chemicals from soil) provides a detailed assessment of plant uptake pathways. In summary, plants are exposed to contaminants in soils by the following pathways:

- Passive and active uptake by roots.
- Gaseous and particulate deposition to above ground shoots.
- Direct contact between soils and plant tissue.

8.4.2.2 All of the above routes of exposure are considered to be present for vegetation.

8.4.3 Pathways to controlled waters

8.4.3.1 As we have not identified any potentially receptors, we have not considered potential pathways further.

8.4.4 Summary of identified likely pathways

8.4.4.1 Based on the above assessments, the following table summarises likely pathways of potential chemical contaminants at the site to identified receptors.

Table of likely pathways		
Receptor group	**Critical receptor**	**Pathway**
Current site users and construction operatives	Adult	Ingestion of air-borne dusts
		Ingestion of soil
		Inhalation of air-borne dusts
		Inhalation of vapours
		Dermal contact with dust
		Dermal contact with soil
Proposed site users	Child	Inhalation of vapours
Current vegetation		Root uptake, deposition to shoots and foliage contact.
Table 8.4.4		

8.5 Assessment of sources of chemical contamination

8.5.1 Introduction

8.5.1.1 Initially, potential sources of contamination are assessed using the following elements of the investigation process.

- History of the site
- Desk study information
- Site reconnaissance
- Geology
- Fieldwork

8.5.1.2 These elements will dictate a relevant soil/water testing regime to quantify possible risks of any identified contaminative sources which may harm identified receptors.

8.5.2 Source assessment – History of the site

8.5.2.1 The history of the site and its immediate surroundings based on published Ordnance Survey maps is described in Section 3.

8.5.2.2 Based on published historical maps the subject site was once an Electricity Generating Station. This former site usage is included in *'Power Stations'* published by the department of the Environment, which provides an indication of the type of chemical contaminants likely to be used by the industry. The commonly occurring contaminants from this site use include heavy metals, PAHs, TPHs, PCBs, solvents, inorganic contaminants and asbestos.

8.5.2.3 In addition, prior and subsequent to the electricity generating station, the site appears to have been occupied by commercial/industrial units of unknown use. Such site uses may have been potential sources of contamination including inorganics, PAHs, hydrocarbons and solvents.

8.5.2.4 With regard to adjacent sites, historical maps indicate a large number of industrial activities within the local area. These include wharfs, factories, garages, workshops and a transformer within 100m of the site. Railway sidings and a coal depot also lie beyond Regent's Canal to the east. All these site uses are considered to be potential sources of contamination. However, given the area is underlain by impermeable London Clay Formation, migration of contaminants will be severely restricted. On this basis, it is considered unlikely these historical activities will pose a significant risk to the subject site.

8.5.3 Source assessment – Desk study information

8.5.3.1 Envirocheck presents a detailed database of environmental information in relation to the site including;

- Pollution incidents
- Landfill sites
- Trading activities

8.5.3.2 Based on the Envirocheck data (refer Appendix N), there are no recorded pollution incidents, landfill sites or recorded areas of infilled ground, within 250m of the subject site.

8.5.3.3 The site is recorded as St Pancras Commercial Centre and four activities are recorded on site comprising clothing and confectionary manufacturers although other light industrial and commercial uses were noted during our site reconnaissance. Given the nature of the activities on site, it is considered low-likelihood that they will be significant sources of contamination.

8.5.4 Source assessment – Site reconnaissance

8.5.4.1 A full description of the site and observed adjacent land uses is provided in Section 3 of this report. A plan summarising observations made on site during our site reconnaissance visit is presented on Drawing 02.

8.5.4.2 At the time of the investigation, the site was occupied by a number of light industrial and commercial units. We were unable to access a number of the units as they were active but they were noted to include a studio, a printers and suppliers of goods including electronics and food products. No tanks or chemical storage was observed in external areas. On this basis, it is considered unlikely such activities will be sources of significant contamination although localised contamination cannot be discounted, particularly within units.

8.5.5 Source assessment – Geology

8.5.5.1 The geological map of the area indicates the topography local to the site is formed in deposits of London Clay Formation. Typically, and in our experience, the London Clays do not exhibit any abnormal concentrations of naturally occurring chemical contaminants.

8.5.6 Source assessment - Fieldwork observations

8.5.6.1 During excavation of our exploratory points, deep Made Ground was encountered in each location, which included a significant proportion of anthropogenic material. In addition, a slight TPH odour was observed within BH01 at depths between 0.7m and 1.1m. On this basis, Made Ground is considered to be a potential source of contamination.

8.5.7 Source assessment - summary

8.5.7.1 Based on the paragraphs above, we have identified the following potential sources of contamination:

Table summarising results of source assessment

Source	Origin of information	Possible contaminant	Probability of risk occurring	Likely extent of contamination
On site				
Former industrial/ commercial activities	Historical maps	Heavy metals, PAHs, TPHs, PCBs, inorganic contaminants and asbestos	Likely	Potentially site wide
Existing commercial units	Desk study information and site reconnaissance	Inorganics, TPHs, Solvents	Low-likelihood	Localised hotspots.
Made Ground	Fieldwork	Heavy metals, PAHs, asbestos	Likely	Potentially site wide
Adjacent sites				
Historical and adjacent commercial/ industrial activities	Historical maps and desk study information	Various inorganic and organic contaminants.	Unlikely	N/A

Table reference 8.5.7

8.6 Initial Conceptual Model

8.6.1 Based on our assessment of potential contaminative sources, identified receptors and viable pathways to receptors described in preceding paragraphs, we have produced an initial conceptual model in the form of a table which is presented in Appendix J.

8.6.2 Based on the conceptual model there are risks which exceed the low category which in our opinion are unacceptable and require either remedial action or further investigation by laboratory testing of soil/water samples to refine the risk assessment.

8.7 Laboratory testing

8.7.1 Testing regime

8.7.1.1 Based on our source assessment (and our initial conceptual model) there are potential sources of contamination on site. In order to carry out a quantitative assessment, we have scheduled testing to measure the concentration of commonly occurring inorganic and organic contaminants.

8.7.1.2 The following table summarises the chemical testing scheduled as well as a rationale for the testing;

Table summarising scheduled testing

Exploratory point	Depth (m)	Strata/ medium	Targeted sampling?	Scheduled testing (refer to Appendix B)	Rationale
BH01	0.9	Made Ground	N	SOIL Suite 1 SOIL Suite 4	General site coverage and TPH odour
BH01	1.5	Made Ground	N	Asbestos Screening presence/ absence SOIL Suite 4	General site coverage
TP02	0.6	Made Ground	N	SOIL Suite 1 Asbestos Screening presence/ absence	General site coverage
BH02	0.5	Made Ground	N	SOIL Suite 1	General site coverage
BH03	3				
TP01A	0.7				
TP04	0.9				
BH03	4	Made Ground	N	SOIL Suite 4	General site coverage
TP04	0.6				
BH02	0.8	Made Ground	N	Asbestos Screening presence/ absence	General site coverage
TP01A	0.8				
TP04	0.2				
BH03	0.3	Made Ground	N	Asbestos Screening presence/ absence	General site coverage
BH03	5.74	Water sample	N	WATER Suite 3 WATER Suite 6	General site coverage

Table 8.7.1.2

8.7.1.3 Obviously, additional testing (quantity and types) would allow a more accurate risk assessment to be made. The results of laboratory determination of concentration of chemical contaminants are presented in Appendix H.

8.7.2 Criteria for assessment of test data – Human receptors

8.7.2.1 Assessment of laboratory test data has been carried out with reference to current nationally recognised documents listed in the final page of Appendix B. Due to changes in guidance on contaminated land, items 6-8 and item 10 in the document listing above have been withdrawn. In the absence of alternative guidance however we have used these documents. Where new guidance is available, this has been followed in preference to superseded guidance.

8.7.2.2 The Land Quality Management (LQM) and the Chartered Institute of Environmental Health (CIEH) have derived Suitable for Use Levels (S4ULs) which are presented in *'The LQM/CIEH S4ULs for Human Health Risk Assessment'* (2015). S4ULs have been used as a screening tool to assess the risks posed to the health of humans from exposure to soil contamination in relation to appropriate land uses. Where published S4ULs are not available, we have adopted C4SLs (Category 4 Screening Levels) produced by DEFRA or SGVs (Soil Guideline Values) as appropriate. In the absence of any of these criteria we have adopted Soil Screening Values (SSV) derived by Soiltechnics and by Atkins (SSV^{ATK}). The CLEA model used to derive SSVs has been used with toxicology data presented by the EA, LQM/CIEH and Atkins (in that order of preference). SSVs produced by Atkins are presented on their $ATRISK^{SOIL}$ website.

8.7.2.3 S4ULs, C4SLs, SGVs, SSVs and SSV^{ATK}s represent 'intervention values'; indications to an assessor that soil concentrations above these levels might present an unacceptable risk to the health of site users. These guideline values have been produced using conceptual exposure models, which use assumptions and are applied to differing end uses of land. If the values are exceeded, it does not necessarily imply there is an actual risk to health and site-specific circumstances should be taken into account. Conversely, where a critical pathway or chemical form of the contaminant has not been evaluated, a risk may be present even if the adopted guideline value has not been exceeded.

8.7.2.4 For evaluation of test data in relation to polycyclic aromatic hydrocarbon (PAH), phenols and total petroleum hydrocarbon (TPH) contamination, we have compared measured concentrations with corresponding S4ULs. The S4UL fractions are dependent on the Soil Organic Matter (SOM) content of the soils. We have adopted the relevant guideline values based on SOM testing.

8.7.2.5 We have followed procedures outlined by the CIEH to compare measured concentrations of metals and PAH contaminants against guideline values. TPH contamination results are compared directly with the relevant guideline values. The guidance presents an approach to data analysis and includes the examination of data for potential outliers, assessment of the normality of the test data and the calculation of a 95% Upper Confidence Limit (UCL). The UCL provides an estimate of the population mean, based on test data, with a 95% confidence that the actual mean does not exceed this value. The UCL is compared to the guideline value for the site.

8.7.2.6 We have adopted an industrial/commercial land use for current site users. In the absence of guidelines we have adopted industrial guideline values for assessment of construction operatives.

8.7.2.7 Although the site will be used for residential, a basement is proposed across the full footprint of the site and therefore all the pathways will be severed with the exception of possible vapours. On this basis, we have not compared concentrations to residential guideline values. However, should a risk of possible vapours be present, this will be considered in our assessment.

8.7.3 Criteria for assessment of test data – Construction operatives

8.7.3.1 In the absence of guidelines we have adopted industrial guideline values for assessment of construction operatives.

8.7.4 Criteria for assessment of test data – Vegetation

8.7.4.1 Guidance published by Forest Research in "*BPG Note 5 - Best Practice Guidance for Land Regeneration*" suggests that a residential without plant uptake or industrial/commercial CLEA model should be adopted for this receptor although specific guideline values are provided for copper and zinc at 130mg/kg and 300mg/kg respectively. As a practice we have adopted the industrial/commercial CLEA model for assessment of test data for vegetation.

8.7.5 Criteria for assessment of test data – Controlled waters

8.7.5.1 For interpretation of test data in relation to water receptors we have directly compared measured values with the Environmental Quality Standards (EQS) and UK Drinking Water Standards (UKDWS). In the absence of EQS or UKDWS we have adopted World Health Organisation Drinking Water Guidelines (WHODWG).

8.7.5.2 EQS values are published by the Environment Agency in their publication, "*Environment Agency technical advice to third parties on Pollution of Controlled Waters for Part 11A of the Environmental Protection Act 1990*". EQS values for most inorganic contaminants in freshwater are dictated by the hardness of the receiving watercourse. The hardness of water is a measure of the concentration of calcium carbonate in the water. Although we have not sampled water from nearby watercourses, we have reviewed information supplied by the Thames Water website, which indicates the water in the area Is classified as hard with carbonate concentrations of 276mg/l. Although not an in-situ groundwater measurement, such results are likely to be similar to those that would be measured in groundwater in the local area.

8.7.5.3 Using this information for List II substances (DOE Circular 7/89) we have compared the measured values with the EQS values relative to the hardness of the receiving watercourse assuming a worst-case scenario of the watercourse supporting 'sensitive' aquatic life.

8.7.5.4 UKDWS are presented in the Water Supply (Water Quality) Regulations.

8.7.5.5 Following our receptor assessment (outlined in Section 8.3.5), we have adopted EQS values in preference to alternative guidelines where possible.

8.7.6 Evaluation of test data – Human receptors

8.7.6.1 Tables summarising and analysing test data are presented in Appendix I. The following table summarises the outcome of the analyses.

Table summarising assessment of test data for human receptors					
Analysis tables	**Receptor group**	**Critical receptor**	**CLEA model**	**Inorganic contaminants**	**Organic contaminants**
1 and 2	Current site users and construction operatives	Adult	Industrial/ commercial	No exceedances	No exceedances

Table 8.7.6.1

8.7.6.2 Based on the above, laboratory testing has not identified any measured concentrations of contaminants which exceed current guideline values for human receptors. Based on the above evaluation, the concentrations of contaminants measured on soil samples taken from the site are considered unlikely to exhibit significant contamination from a perspective of human receptors.

8.7.6.3 Concentrations of TPH fractions are all below the guideline values for current site users and construction operatives. However, total concentrations were measured up to 10,00mg/kg within BH01 at 0.9m although measured concentrations at depth were significantly lower. However, given the variability of the Made Ground and limited testing, the risk of vapours will need to be considered with regard to both end users and construction operatives.

8.7.6.4 In addition to the above, asbestos fibres/clumps were not detected in any of the samples submitted for screening. However, a fragment of amosite board was detected in a sample from TP02 at 0.6m. On this basis, the Made Ground soils are considered a potential risk to human receptors due to the presence of asbestos.

8.7.7 Evaluation of test data – Vegetation

8.7.7.1 Comparison of test data with guideline values is presented on Tables 2 and 3 in Appendix I. None of the measured concentrations exceed the adopted guideline values with the exception of zinc. The UCL for zinc was measured at 440.7mg/kg, which exceeds the BPG5 guideline value of 300mg/kg. Concentrations of zinc ranged from 82mg/kg to 470mg/kg.

8.7.7.2 It is difficult to quantify the phytotoxicity of a contaminant as large variations exist between plant tolerances, soil effects and synergistic/antagonistic reactions between chemicals. Due to the complexities of the effects of soil contamination on different plant species, we recommend that the test results presented in this report are passed to a landscape architect for the selection of suitable planting.

8.7.8 Evaluation of test data – Controlled waters

8.7.8.1 Inorganic contaminants

8.7.8.1.1 With reference to Table 5 in Appendix I, none of the measured concentrations of inorganic contaminants exceed the relevant guideline outlined in Section 8.7.5 with the exception of selenium and sulphate. The concentration of selenium was measured at 20mg/kg, which exceeds the UKDWS guideline of 10µg/l. The concentration of sulphate was measured at 4100mg/l compared to an EQS value of 4000mg/l.

8.7.8.2 Organic contaminants (polycyclic aromatic hydrocarbons)

8.7.8.2.1 For the analysis of PAH contamination, the sum of the following contaminants has been compared to a UKDWS.

- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(ghi)perylene
- Indeno(1,2,3-cd)pyrene

8.7.8.2.2 The summed concentration of the PAH 'suite' do not exceed the UKDWS. In addition, the leachable concentration of benzo(a)pyrene and naphthalene, do not exceed their respective guideline values.

8.7.8.3 Organic contaminants (total petroleum hydrocarbons)

8.7.8.3.1 None of the measured concentrations of TPH or BTEX exceed the relevant guideline outlined in Section 8.7.5.

8.7.8.4 Summary

8.7.8.4.1 Based on the above evaluation, there are elevated concentrations of selenium and sulphate within groundwater. It is considered likely the source of contamination is the Made Ground but it is possible the origin is off-site and maybe associated with the large area of Made Ground recorded to the south of the site.

8.8 Updated conceptual model

8.8.1 Having now completed analysis of laboratory testing, we can now update our conceptual model which is presented in Appendix J.

8.8.2 Based on the conceptual model there are risks which exceed the low category which in our opinion are unacceptable and require remedial action which is discussed below.

8.9 Remedial action

8.9.1 Based on the above we recommend the following action is taken:

a) It is likely Made Ground will remain on site following basement/foundation excavations, unless the basement is deepened beyond the level of the Made Ground. On this basis, we recommend a vapour proof membrane be introduced to mitigate against future vapour nuisance.

b) Adoption of adequate hygiene precautions for construction operatives.

c) Dampening down of all soils during earthworks/ground works.

d) Ground and earthworks to comply with the requirements set out in The Control of Asbestos Regulations (CAR 2012).

e) Made Ground on site potentially poses a risk to groundwater but we are aware that Made Ground soils are also likely to be present off-site (based on geological mapping). A large proportion of the Made Ground and thus the on-site source of contamination, will be removed from site during construction of the basement. In addition, the presence of buildings/basement across the site will prevent infiltration of rainwater and leachate formation. On this basis, together with the relatively low sensitivity of the site (no close water abstractions, underlying geology recorded as unproductive strata and groundwater likely to be perched within the Made Ground), no additional remedial works are considered necessary with regard to groundwater.

8.9.2 It should also be noted that the soils encountered currently pose a potential risk to current site users. The site is predominantly surfaced in hardstanding, which will sever the pathway between site users and contaminated soils. However, should the redevelopment not go ahead, consideration may be required with regard to any current risks to site users.

8.10 Risk assessment in relation to use of infiltration systems

8.10.1 With reference to Environment Agency publication '*Groundwater protection: Policy and practice (GP3)* 2012, outside of SPZ1, the EA will support sustainable drainage systems for new discharges to ground. This is subject to an appropriate risk assessment to demonstrate that ground conditions are suitable and infiltration systems do not present an unacceptable risk of promoting mobilisation of contaminants or creating new pathways for contaminant migration.

8.10.2 We have not carried out leachate testing on samples of Made Ground at this stage. However, based on the results of laboratory testing, there are contaminants within the Made Ground which could be mobilised by infiltration systems. Should it be proposed to adopt soakaways at the site, further assessment would be required into the potential risks from leachate formation.

8.11 Risk assessment summary and recommendations

8.11.1 Based on our assessments described above, we can provide the following summary and recommendations for each identified receptor.

8.11.2 Current site users

8.11.2.1 Although existing soils pose a potential risk to current site users through the presence of asbestos fragments, the site is predominantly surfaced in buildings/hardstandings, which will severely restrict access to soils. However, there are some areas of soft landscaping and should redevelopment not occur, consideration should be given to any current risks to site users.

8.11.3 End users

8.11.3.1 Based on the current development proposals, providing a vapour proof membrane is introduced if Made Ground remains beneath the proposed building, we are of the opinion that the site represents a low risk of causing harm to the health of future end users of the developed site. Should development proposals change, particularly to include gardens/soft landscaping in direct contact with existing soils, this may require reassessment.

8.11.4 Construction operatives and other site investigators

8.11.4.1 The risk of damage to health of construction operatives and other site investigators is, in our opinion, high as a result of ACM on site. The risk of harm to construction operatives will be limited by taking adequate hygiene and safety precautions on site. Such precautions would be:

- Wearing protective clothing particularly gloves to minimise ingestion from soil contaminated hands.
- Avoiding dust by dampening the soils during the works.
- Wearing masks if processing produce dust.
- Mitigation measures in accordance with the requirements of The Control of Asbestos Regulations (CAR 2012) where necessary. Further guidance should be sought from specialist asbestos contractor in this regard.

8.11.4.2 Guidance on safe working practices can be obtained from the following documents

- The Health and Safety Executive Publication *“Protection of Workers and the General Public during the Development of Contaminated Land”* (HMSO) and

- *“A Guide to Safer Working on Contaminated Sites”* (CIRIA Report 132).

8.11.4.3 In addition, reference should be made to the Health and Safety Executive. In all cases work shall be undertaken following the requirements of the Health and Safety at Work Act 1974 and regulations made under the Act including the COSHH regulations.

8.11.4.4 If during the course of excavations hydrocarbon type odours become evident, we recommend works are halted, and the air quality measured to determine if the excavation can be safely entered. If the air quality is unacceptable then appropriate personal protective equipment, will be required for human entry into the excavation. If elevated concentrations of airborne hydrocarbons/vapours are detected on site, we recommend Soiltechnics are advised to determine an appropriate course of action with respect to building construction.

8.11.5 Controlled waters

8.11.5.1 Although elevated concentrations of inorganic contaminants have been identified in groundwater, the source is likely to be both on- and off-site. Considering a large proportion of Made Ground will be removed during construction of the proposed basement and the site is of low sensitivity, we are of the opinion that the site represents a low risk of causing harm to water receptors.

8.11.6 Vegetation

8.11.6.1 Should any areas of soft landscaping/vegetation be proposed that will be in contact with existing soils, consideration should be given to the concentrations of lead within the Made Ground.

8.12 Final conceptual model

8.12.1 On the assumption that remedial action described above has been successfully completed, we have produced a final conceptual model which is presented in Appendix J, which shows the risks have been reduced to acceptable levels and the site therefore fit for purpose.

8.13 Statement with respect to National Planning Policy Framework

8.13.1 Providing the recommendations described above are satisfactorily completed, we are of the opinion the proposed development will be safe and suitable for use for the purpose for which it is intended, thus meeting the requirements of the National Planning Policy Framework section 178, and compliant with the Building Regulations Part C, '*Site preparation and resistance to contaminants and moisture'*

8.14 On Site Monitoring

8.14.1 We have attempted to identify the potential for chemical contamination on the site, however, areas, which have not been investigated at this stage, may exhibit higher levels of contamination. If such areas are exposed at any time during construction we will be pleased to re-attend site to assess what action is required to allow the development of safely proceed.

9 Gaseous contamination

9.1 Legislative framework

9.1.1 There is currently a complex mix of documentation relating to legislative and regulatory procedures on the issue of contamination and it is not considered a purpose of this report to discuss the detail of these regulations. Essentially, Government Policy is based on *'suitable for use approach',* which is relevant to both the current and proposed future use of land. For current use Part IIA of the Environmental Protection Act 1990 provides the regulatory regime (see Section 8.1 above). The presence of harmful soil gases could provide a 'source' in a 'pollutant linkage' allowing the regulator (Local Authority) to determine if there is a significant possibility of harm being caused to humans, buildings or the environment. Under such circumstances the regulator would determine the land as 'contaminated' under the provision of the Act requiring the remediation process to be implemented with the Environment Agency responsible for enforcement.

9.1.2 The Town and Country Planning (General Development Procedure) Order 1995, requires the planning authority to consult with the Environment Agency before granting planning permission for development on land within 250 metres of land which is being used for deposit of waste, (or has been at any time in the last 30 years) or has been notified to the planning authority for the purposes of that provision.

9.1.3 Building control bodies enforce compliance with the Building Regulations. Practical guidance is provided in Approved documents, one of which is Part C, '*Site preparation and resistance to contaminants and moisture'* which seeks to protect the health, safety and welfare of people in and around buildings and includes requirements for protection against harm from soil gas.

9.2 General

9.2.1 The following assessment relates to the potential for, and the effects of, gases generated by biodegradable matter. The potential for the development to be affected by radon gas is considered in Section 3. The principal ground gases are carbon dioxide (CO_2) and methane (CH_4). The following table provides a summary of the effects of these gases when mixed with air.

Significant gas concentrations in air		
Gas	**Concentration by volume**	**Consequence**
Methane	0.25%	Ventilation required in confined spaces
	5 - 15%	Potentially explosive when mixed with air
	30%	Asphyxiation
	75%	Death after 10 minutes
Carbon Dioxide	0.5%	8 hour long term exposure limit (LTEL) (HSE workplace limit)
	1.5%	15 min short term exposure limit (STEL) (HSE workplace limit)
	>3%	Breathing difficulties
	6 – 11%	Visual distortion, headaches, loss of consciousness, possible death
	>22%	Death likely to occur

Table 9.2.1

9.2.2 Following the current Building Regulations Approved Document C1, Section 2 *'Resistance to Contaminants'* (2004 incorporating 2010 and 2013 amendments) a risk assessment approach is required in relation to gaseous contamination based on the source-pathway-receptor conceptual model procedure. We have adopted procedures described in the following reference documents for investigation and assessments of risk of the development being affected by landfill type gases (permanent gases) and if appropriate the identification of mitigation measures.

- BS10175:2011 *'Investigation of potentially contaminated sites- Code of Practice'*
- BS8576:2013 '*Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs)*'
- BS8485:2015 '*Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings*'
- CIRIA Report C665 '*Assessing risks posed by hazardous ground gases to buildings*' (2007)
- NHBC report No 10627-R01(04) '*Guidance on development proposals on sites where methane and carbon dioxide are present*' (January 2007)
- CL:AIRE Research Bulletin RB17 *'A pragmatic approach to ground gas risk assessment'* (November 2012)

9.2.3 Whilst we have followed the guidance and recommendations of BS8576, we have used BS8485:2015 to derive recommendations for protective works where considered necessary supplemented by NHBC report No 10627-R01(04).

9.2.4 An assessment of the risk of the site being affected by ground gases is based on the following aspects:

a) Source of the gas
b) Investigation information
c) Migration feasibility
d) Sensitivity of the development and its location relative to the source

9.3 Assessment of source of gases

9.3.1 General sources

9.3.1.1 The following table summarises the common sources of ground gases and parameters affecting the generation of ground gases:

Source and control of gases	
Type	**Parameters affecting the rate of gassing**
Landfills	Portion of biodegradable material, rate reduces with time.
Mineworkings	Flooding reduces rate of gassing.
Dock silt	Portion of organic matter.
Carbonate deposits	Ground/rainwater (acidic) reacts with some carbonates to produce carbon dioxide.
Made Ground	Thickness of Made Ground and proportion of degradable organic matter.
Naturally deposited soils/rocks	Portion of organic matter.
Table 9.3.1	

9.3.1.2 The rate of decomposition in gas production is also related to atmospheric conditions, pH, temperature, and water content/infiltration.

9.3.1.3 As the site is not within a dockland environment or an area affected by mineworkings, and near surface soils do not exhibit high carbonate content, then potential gas sources are limited to landfills and/or soils with a high proportion of organic matter.

9.3.2 Landfill and infilled ground sources

9.3.2.1 Waste Management Paper 27 (1991) produced by the Department of the Environment '*Control of Landfill Gases'* contains the recommendation to avoid building within 50m of a landfill site actively producing large quantities of landfill type gases and to carry out site investigations within a zone 250m beyond the boundary of a landfill site. No distinction is made between sites of differing ground conditions, but the paper does not advocate the site is safe beyond the 250m zone, dependent, of course, upon the type of landfill and potential for migration of landfill gases.

9.3.2.2 Envirocheck reports there are no recorded landfill sites/artificial deposits/BGS Recorded Mineral Sites within 1000m of the subject site. In addition, we have reviewed old Ordnance Survey maps and there is no obvious evidence of any quarrying in the area which may have been restored with materials which could generate landfill gases. On the above basis there is no recorded evidence to suggest a source of landfill gases from such past activities.

9.3.2.3 There are seven areas of potentially infilled land (water) located within 1000m of the site. The nearest area is recorded 648m to the west of the site and is associated with a backfilled canal and basin. Given the distance from the site and the size of the infilled land, it is considered unlikely significant concentrations of landfill gas would feasibly migrate to the subject site from these potential sources.

9.3.3 Soil conditions

9.3.3.1 None of the soils observed in exploratory excavations, in our opinion, exhibit significant concentrations of organic matter which are likely to produce elevated quantities of carbon dioxide and/or methane gas.

9.3.3.2 Made Ground on site was encountered to depths of 5.7m and laboratory testing indicates that the Made Ground soils beneath the site contain between 0.97% and 8.8% of organic matter, with an average of 3.35%. The Made Ground was noted to be relatively homogenous with noticeable instances of anthropogenic material (e.g. brick and concrete, but no observed easily degradable material such as wood, paper, textile or waste food. With reference to Figure 6 in BS8576:2013 *'Guidance on investigations for ground gas – permanent gases and volatile organic compounds'*, Made Ground displaying these properties would fall within the 'very low generation potential of source' category, indicating that monitoring might not be necessary.

9.3.3.3 Based on an assessment of 'deep' geological conditions we are of the opinion that it is unlikely that the subject site would be affected by significant quantities of carbon dioxide and methane generated by soils/rocks at depth.

9.3.4 Source assessment summary

9.3.4.1 The following table summarises the possibility of a source of landfill type gases.

Source assessment summary

Potential source origin	Viability of source	Evidence
Landfills	Unlikely	Desk study information
Mineworkings	Unlikely	Desk Study information Geological conditions not amenable
Dock silt	Unlikely	Site remote from dockland environment
Carbonate deposits	Unlikely	Recorded and observed soil conditions do not indicate high concentrations of carbonates
Made Ground	Low-likelihood	Made Ground >5m thickness with TOC generally <5%
Soils / rocks	Unlikely	Soils exposed in exploratory excavations do not exhibit high concentrations of organic matter

Table 9.3.4

9.3.4.2 Based on the above it there is a possibility of a source of potential landfill gases which may affect the subject site. On this basis, it is considered necessary to consider possible pathways for migration of ground gases from this potential source to the site.

9.4 Gas migration

9.4.1 Exploratory excavations encountered predominantly granular Made Ground to depths of 5.7m. In our opinion, such soils are relatively permeable and would provide little resistance to both lateral and vertical migration of landfill type gases from the Made Ground. As these soils are at surface across the site, it is therefore considered possible that landfill type gases could feasibly migrate into proposed buildings.

9.5 Conceptual model

9.5.1 Based on the above, there is a potential source of landfill type gases, and a feasible migration pathway to the site via potentially permeable Made Ground soils. Our conceptual model is tabled below. On this evidence we are of the opinion that the site is at risk of being affected by ground gases (carbon dioxide/methane) sufficient to potentially cause harm to human end users of the site, construction operatives or indeed buildings. On this basis, we have installed monitoring standpipes in boreholes, and implemented a monitoring regime, generally following procedures described in BS8576:2013 to quantify the risk and, if appropriate, identify mitigation measures.

Conceptual model		
Potential source origin	**Potential pathway**	**Receptors at risk**
Made Ground on site	Via Made Ground	End users Construction operatives Buildings

Table 9.5.1

9.6 Development categorisation

9.6.1 With reference to BS8485:2015 (table 3), the proposed building type would be classified as *'Type B - Private or commercial/public, possibly multiple'.*

9.7 Monitoring observations

9.7.1 Two standpipes have been installed at the site in accordance with BS9576:2013, Section 9 (refer Drawing 05). Following BS8576:2013 (Figure 6) and CIRIA Report C665 (Tables 5.5a and 5.5b) we have provisionally assessed the site as very low risk of generation potential of source ideally requiring six monitoring visits over a two month period. We have initially proposed to undertake three gas monitoring visits with further visits implemented should it be considered necessary based on the results of testing.

9.7.2 We have returned to site for all of our proposed monitoring visits to obtain measurements of landfill type gases at atmospheric conditions in the range of 998 to 1032mb and temperatures in the range of 8°C to 12°C. Essentially, concentrations of methane were below detectable limits and concentrations of carbon dioxide were measured in the range of 0.1 to 0.2%. If flows were detected during our monitoring visits then these are recorded, but where no flow is detected then we have assumed flow at the detection limit of the monitoring equipment at 0.1l/s.

9.7.3 Gas monitoring results are summarised in Appendix K.

9.8 Classification of site characteristic gas situation

9.8.1 Using test data obtained to date, and with reference to Table 2 of BS8485:2015, the site would be classified as characteristic gas situation one and traffic light colour 'Green' in accordance with NHBC report No 10627-R01(04).

9.8.2 Clearly further monitoring will increase the accuracy of this risk assessment, however in our opinion we have followed current best practice with respect to investigations completed to date, the monitoring regime and analysis of data, and again in our opinion, the data categories used in the analysis is considered to be *'representative and comprehensive'* as defined in section 6.3.7 of BS8485:2015.

9.8.3 In addition we have assessed the sufficiency of data in accordance with annex F of BS8576:2013. The following table summarises our assessment.

Action	Result
From current results (concentration, flow rates and pressure) estimate likely risk associated with ground gas (note steady state flow results are to be used, not peak values that only last a few seconds on opening the gas tap)	Current estimate of risk GSV = gas concentration x borehole flow rate. GSV = 0.2/100 x 0.1 = 0.0002l/hr Characteristic situation 1 (maximum limit is 0.07l/hr or CO2 >5%)
What increase in gas concentration is required to increase the estimated risk and level of gas protection to be provided?	Estimate increase in gas concentration Keeping the flow rate constant, the gas concentration would need to exceed 70% to increase the GSV into the next band. This is considered unlikely.
What increase in flow rate is required to increase the estimated risk and level of gas protection to be provided?	Estimate increase in flow rate: Keeping the concentration constant, the flow rate would need to exceed 35l/hr to move into the next risk band. From current data and knowledge of the gas source and generation potential, this is not considered feasible.
Is the increase in gas concentration feasible given the known source of the gas?	No. All measured concentrations were similar and below 1%. It is unlikely that further monitoring would identify concentrations in excess of 5% (to consider an increase) or to 70% to increase the GSV into the next band.
Is the increase in flow rate feasible when compared to gas generation and migration model results, the collected gas monitoring data and the conceptual site model?	No. Again, flow was measured at 0.1l/hr on each visit. It is unlikely that flow rates exceeding 35l/hr would be identified during further monitoring.
Decide whether further monitoring is required.	Based on the above analysis, further gas monitoring is not required.

Table 9.8.3

9.9 Gas protective measures – new buildings

9.9.1 Based on monitoring, development categorisation (section 9.6 above), and the site characteristic gas situation (section 9.8 above) and with reference to Table 4 of BS8485:2015, the development does not require any gas protective measures.

9.10 Statement with respect to National Planning Policy Framework

9.10.1 Based on investigations completed to date with respect to gaseous contamination, we are of the opinion the proposed development will be safe and suitable for use for the purpose for which it is intended (without the need for any remedial action) thus meeting the requirements of the National Planning Policy Framework section 178, and compliant with the Building Regulations Part C, '*Site preparation and resistance to contaminants and moisture.*

10 Effects of ground conditions on building materials

10.1 General

10.1.1 Building materials are often subjected to aggressive environments which cause them to undergo chemical or physical changes. These changes may result in loss of strength or other properties that may put at risk their structural integrity or ability to perform to design requirements. Aggressive conditions include:

- Severe climates
- Coastal conditions
- Polluted atmospheres
- Aggressive ground conditions

10.1.2 This report section only considers aggressive ground conditions in relation to buried concrete and water pipes. Ground conditions may affect other materials but have not been considered here.

10.2 Concrete - Sulphate attack

10.2.1 Hazard

10.2.1.1 Sulphate attack on concrete is characterised by expansion, leading to loss of strength, cracking, spalling and eventual disintegration. There are three principal forms of sulphate attack, as follows:

- Formation of gypsum through reaction of calcium hydroxide and sulphate ions.
- Ettringite formation through reaction of tricalcium allulminate and sulphite ions.
- Thaumasite formation as a result of reactions between calcium silicate hydrates, carbonate ions (from aggregates) and sulphate ions.

10.2.2 Assessment

10.2.2.1 The hazard of sulphide attack is addressed by reference to procedures described in Building Research Establishment (BRE) Special Digest 1: 2005 *'Concrete in Aggressive Ground'* to establish a design sulphate class (DS) and the *'Aggressive Chemical Environment for Concrete'* (ACEC). These procedures have been followed during our investigation and are described in the following paragraphs.

10.2.3 Desk Study Information

10.2.3.1 The first step in the procedure is to consider specific elements of the desk study. These are tabulated below.

Summary of desk study information			
Element	**Interrogation**	**Outcome**	**SD1: 2005 reference**
Geology	Likelihood of soils containing pyrites	**Likely**	Box C6
Past industrial uses	Brownfield site?	**Yes**	C2.1.2

Table 10.2.3

10.2.3.2 A brownfield site is defined in SD1: 2005 as a site, or part of a site which has been subject to industrial development, storage of chemicals (including for agricultural use) or deposition of waste, and which may contain aggressive chemicals in residual surface materials, or in ground penetrated by leachates. Where the history of the site is not known, it should be treated as brownfield until there is evidence to classify it as natural.

10.2.3.3 Based on the above it is necessary to follow the procedures described in Section C5.1.4 ('*Brownfield locations that contain pyrite*').

10.2.4 Laboratory testing

10.2.4.1 The following table summarises ground conditions and laboratory testing.

Item	Soil type	Outcome
Soil		
Number of samples	Made Ground	4
	London Clay	1
	Thanet Sand	1
Characteristic w/s sulphate	Made Ground	1300 mg/l
	London Clay	440 mg/l
	Thanet Sand	360 mg/l
Characteristic pH	Made Ground	8.3
	London Clay	8.5
	Thanet Sand	8.6
Characteristic total acid soluble sulphate	Made Ground	2.3
	London Clay	0.11
	Thanet Sand	0.14
TPS	Made Ground	5.10%SO^4
	London Clay	1.29%SO^4
	Thanet Sand	2.16%SO^4
OS	Made Ground	2.8%SO^4. Pyrite is probably present.
	London Clay	1.18%SO^4. Pyrite is probably present.
	Thanet Sand	2.02%SO^4. Pyrite is probably present.
Groundwater		
Number of samples	-	2
Characteristic sulphate	-	4100 mg/l
Mobility	-	Mobile

Table 10.2.4

10.2.5 Disturbed ground

10.2.5.1 Forming foundations by, for instance, cutting a trench through naturally deposited soils or driving pre-cast concrete piles through naturally deposited soils does not, generally, create disturbed ground as defined in BRE SD 1:2005. However, any arisings resulting from replacement piling or spread footing excavations used for bulk filling on site would be classified as disturbed ground.

10.2.6 Assessment of design sulphate class (DC) and aggressive chemical environment for concrete (ACEC)

10.2.6.1 Based on the design sulphate class, characteristic value of pH and assessment of groundwater mobility, and with reference to table C2 of SDI: 2005, the ACEC class for each soil type is presented in Table 10.2.6.

Summary of concrete classification

Soil type	Disturbed ground?	Consider TPS?	DS class	ACEC class
Made Ground	Yes	Yes	DS-5	AC-5
London Clay Formation (undisturbed)	No	No	DS-1	AC-1
London Clay Formation (disturbed)	Yes	Yes	DS-4	AC-3s
Thanet Sand Formation (undisturbed)	No	No	DS-1	AC-1
Thanet Sand Formation (disturbed)	Yes	Yes	DS-4	AC-4
Groundwater samples	N/A	N/A	DS-4	AC-4

Table reference 10.2.6

10.2.6.2 Where concrete is in contact with more than one soil/groundwater source, the more onerous of design sulphate class and ACEC class should be adopted.

10.2.6.3 Please note that you cannot use skin friction piles when AC-5 is derived (i.e. concrete needs a protective membrane which will eliminate skin friction support).

10.3 Concrete - Chloride attack

10.3.1 Hazards

10.3.1.1 There are a number of ways in which chlorides can react with hydrated cement compounds in concrete. These are as follows:

- Chlorides react with calcium hydroxide in the cement binder to form soluble calcium chloride. This reaction increases the permeability of the concrete reducing its durability.

- Calcium and magnesium chlorides can react with calcium aluminate hydrates to form chloroaluminates which result in low to medium expansion of the concrete.

- If concrete is subject to wetting and drying cycles caused by groundwater fluctuations, salt crystallisation can form in concrete pores. If pressure produced by crystal growth is greater than the tensile strength of the concrete, the concrete will crack and eventually disintegrate.

10.3.2 Risk assessment

10.3.2.1 Chlorides of sodium, potassium, and calcium are generally regarded as being non-aggressive towards mass concrete; indeed, brine containers used in salt mines have been known to be serviceable after 20 years service. Depending upon the type of concrete, and the cement used up to 0.4% chloride is allowed in BS8110: Part 1.

10.3.2.2 In view of the past use of the site we consider the likelihood of elevated concentrations of chlorides in the ground is not likely to occur and on this basis have not specifically measured concentrations of chlorides and, in our opinion, the risk of buried concrete being affected by chlorides is considered low.

10.4 Concrete - Acid attack

10.4.1 Hazards

10.4.1.1 Concrete being an alkaline material is vulnerable to attack by acids. Prolonged exposure of concrete structures to acidic solutions can result in complete disintegration.

10.4.2 Risk assessment

10.4.2.1 The rate of acid attack on concrete depends upon the following:

- The type of acid
- The acid concentration (pH)
- The composition of the concrete (cement/aggregate)
- The soil permeability
- Groundwater movement

10.4.2.2 British Standard BS8110: Part 1 classifies extreme environment as one where concrete is exposed to flowing groundwater that has a pH<4.5. The standard also warns that Portland Cement is not suitable for acidic conditions with a pH of 5.5 or lower.

10.4.2.3 The pH of the soil/groundwater was measured exceeding 5.5 and on this basis the risk of concrete being affected by acidic conditions is considered low.

10.5 Concrete - Magnesium attack

10.5.1 Hazards

10.5.1.1 Magnesium salts (excepting magnesium hydrogen carbonate) are destructive to concrete. Corrosion of concrete occurs from cation exchange reactions where calcium in the cement paste hydrates and is replaced with magnesium. The cement loses binding power and eventually the concrete disintegrates.

10.5.2 Risk assessment

10.5.2.1 In practise 'high' concentrations of magnesium will be found in the UK only in ground having industrial residues. Following BRE Special Digest 1:2005, measurement of the concentration of magnesium is recommended if sulphate concentrations in water extract or groundwater exceed 3000mg/l. Once measured the concentration of magnesium is considered further in BRE Special Digest in establishing the concrete mix to resist chemical attack.

10.5.2.2 We have measured the concentration of magnesium in groundwater samples at the site which produced results in the range of 1.9mg/l to 490mg/l. These results fall in the range of >300 but <1000mg/l thus indicating an exposure class of XA1.

10.6 Concrete - Ammonium attack

10.6.1 Hazards

10.6.1.1 Ammonium salts, like magnesium salts act as weak acids and attack hardened concrete paste resulting in softening and gradual decrease in strength of the concrete.

10.6.2 Risk assessment

10.6.2.1 UK guidance is not available on the concentration of ammonium which may affect concrete. BS EN 206-1: 2000 '*Concrete - Part 1: Specification, performance, production and conformity*' does, however, provide exposure classes for concrete in contact with water with varying concentrations of ammonia for the design/specification for concrete mixes.

10.6.2.2 We have measured the concentration of ammonia in groundwater samples at the site, and there is a potential possibility that concrete for the building may be in contact with groundwater during its life. The concentrations of ammonia were measured in the range of <50ug/l to 4.2mg/l. These results fall below the range of the exposure classes and thus the risk of concrete being affected by ammonia is considered low.

10.7 Plastic Pipes

10.7.1 Hazards

10.7.1.1 Plastic pipes are predominantly manufactured from PVC and PE but other materials can be used. In general, they perform well but it is known that chemical attack and permeation of contaminants through the pipes can result from use in contaminated land. A published review on plastic pipes reports the following:

- Polyethylene (PE) - good resistance to solvents, acids and alkalis.
- Poly vinyl chloride (PVC) - most common form of pipe. Good general resistance to chemical attack but can be attacked by solvents such as ketones, chlorinated hydrocarbons and aromatics.
- Polypropylene (PP) - chemically resistant to acids, alkalis and organic solvents but not recommended for use with storing oxidising acids, chlorinated hydrocarbons and aromatics.
- Poly vinylidene fluoride (PVDF) - inert to most solvents, acids and alkalis as well as chlorine, bromide and other halogens.
- Polytetrafluoroethylene (PTFE) - one of the most inert thermoplastics available. PTFE has good chemical resistance to solvents, acids and alkalis.

10.7.1.2 A survey carried out by the Water Research Centre (WRc) on reported incidents of permeation (more than 25), only two involved PVC with these incidents relating to spillages of fuel.

10.7.2 Assessment

10.7.2.1 A survey carried out by the Water Research Centre (WRc) on reported incidents of permeation (more than 25), only two involved PVC with these incidents relating to spillages of fuel.

10.7.2.2 The UK Water Industry research (UKWIR) have published a document entitled *'Guidance for the selection of Water supply pipes to be used in Brownfield sites'*. The publication defines brownfield sites as

> *'Land or premises that have been used or developed. They may also be vacant, or derelict. However, they are not necessarily contaminated'*

10.7.2.3 The subject site has not previously been developed and used, and on this basis could potentially be considered brownfield in accordance with the UKWIR document.

10.7.2.4 Whilst we have not carried out a full investigation set out in guidance in the UKWIR document, the subject site does exhibit a degree of localised hydrocarbon (PAH & TPH) contamination. The UKWIR document advises a trigger concentration of 0.125mg/kg for their 'extended VOC (Volatile Organic Carbons) suite' which includes the PAH suite which we have results for. The measured concentration of individual contaminates forming part of the PAH suite exceeds the trigger value of 0.125mg/kg. On this basis, it is considered likely that barrier pipes will have to be installed at this site. We recommend Thames Water is consulted on this to gain their opinion and requirements.

11 Classification of waste soils under the Waste Acceptance Criteria

11.1 The Landfill Directive

11.1.1 The Landfill Directive represents an important change in the way we dispose of waste. It encourages waste minimisation by promoting increased levels of recycling and recovery. The Landfill Directive became law in 1999 and was transcribed into the Landfill (England and Wales) Regulations which came into force in 2002. These Regulations were amended in 2005 by introducing criteria to classify soils for disposal to landfill. It is the duty of the waste producer (the client) to classify the soils for this purpose.

11.2 Classification of soil types

11.2.1 Our investigations consider two soil types which may be generated as wastes as part of construction operations, potentially contaminated soil and uncontaminated soil. A full hazard assessment and subsequent testing for waste acceptance criteria is undertaken on soils which are not considered to be naturally deposited or are likely to be affected by artificial contamination. For soils that are unlikely to be affected by artificial contamination (such as natural soils), specific testing in relation to the classification process is not necessary.

11.3 Waste acceptance criteria (WAC)

11.3.1 The Environment Agency publication, *'Framework for the classification of contaminated soils as hazardous wastes'* (July 2004), provides an appropriate procedure for establishing if the soils are hazardous or non-hazardous and applies to soils that are identified as potentially contaminated. Uncontaminated, natural soils are considered separately (see Section 11.6).

11.3.2 Primary classification

11.3.2.1 The first stage in classifying a potentially 'contaminated' soil for disposal to landfill is to establish its chemical status by first identifying potential sources/types of chemical contamination (desk study) followed by intrusive site investigations to obtain samples for undefined testing of soil samples to measure concentrations of chemical contaminants. Such data provides information to partly complete the basic characteristic checklist.

11.3.2.2 Laboratory test data is then compared with the Environment Agency publication '*hazardous waste – Interpretation of the definition and classification of hazardous waste (second edition, version 2.1)'*. Where the waste is suspected to contain oil, we have referred to the Environment Agency draft consultation paper *'How to Find Out if Waste Oil and Wastes that Contain Oil are Hazardous'* (Draft Version 2.5 – October 2006). With reference to these documents a hazard assessment has been carried out to enable categorisation of the material as hazardous or non-hazardous and to subsequently establish the European Waste Catalogue (EWC) code (ref Section 11.3.4).

11.3.3 Secondary classification

11.3.3.1 If the soil is deemed hazardous then measurement of organic contaminants and leachable inorganic contaminants is necessary for comparison with values listed in the Environment Agency publication '*Guidance on sampling and testing of wastes to meet landfill waste acceptance procedures'* (April 2005) Table 5.1. Similarly should the soil be deemed as non-hazardous then such testing may also be undertaken to determine if it is potentially inert. This document also provides guidance on sampling materials and frequency as well as test procedures and quality assurance of testing.

11.3.3.2 The above procedures are described with respect to the subject site in Sections 11.4 (primary) and 11.5 (secondary), leading to basic characterisation of soils for disposal. Subject to the results of the categorisation and anticipated development methodology, consideration should be given by the developer to reduce volumes of disposal or treatment to allow reclassification.

11.3.4 European waste catalogue (EWC) coding

11.3.4.1 The EWC 2002 is a catalogue of all wastes, grouped according to generic industry, process or waste type. It is divided into twenty main chapters, each with a two digit code between 01 and 20. Following the EWC, in our opinion, soils considered as part of this investigation would be categorised within 'Group 17' of the EWC catalogue, which comprises 'Construction and Demolition Wastes (including excavated soils from contaminated sites)'.

11.3.4.2 The Catalogue further categorises the waste, such that soils considered as part of this investigation would be classified as either 17 05 04 defined as *'soil and stones (other than those mentioned in 17 05 03)';* or 17 05 03* defined as soil or stones containing dangerous substances (where hazardous wastes are described by entries followed by an asterisk).

11.4 Primary classification

11.4.1 Soil types

11.4.1.1 Based on soils exposed in exploratory excavations, in combination with anticipated construction works, we assume soils requiring off-site disposal will comprise Made Ground, London Clay Formation and potentially Thanet Sand Formation generated from general site clearance, basement excavation, service trenches and piling works.

11.4.2 Classification as hazardous or non-hazardous waste

11.4.2.1 The Environment Agency publication '*Framework for the classification of contaminated soils as hazardous wastes'* (July 2004) provides the following procedure for establishing if the soils are hazardous or non-hazardous. The first stage in classifying a potentially 'contaminated' soil for disposal is to establish its chemical status by first identifying potential sources/types of chemical contamination (desk study) followed by intrusive site investigations to obtain samples for laboratory testing of soil samples to measure concentrations of chemical contaminants.

11.4.2.2 An assessment of potential source of contamination is presented in Section 8 of this report. Laboratory testing has been set as deemed appropriate to our source assessment.

11.4.2.3 We have carried out an analysis of test data for each chemical contaminant considered in this investigation. A conservative approach has been adopted for the analysis whereby the maximum test value for each contaminant has been adopted as a preliminary screening process to determine if the soils are hazardous or non-hazardous. Should the analysis indicate potentially hazardous properties then a process of zoning by further analysing the site history, geological conditions and analytical data may be undertaken.

11.4.2.4 Laboratory test data measures the concentration of anions, which are unlikely to exist in the pure metallic form in the soil, but probably exist as a compound. Following guidance provided in the Environment Agency Technical Guidance WM3 *'Guidance on the classification and assessment of waste'* (2015), we have reviewed a variety of compounds for each of the metallic and semi metallic elements we have tested.

11.4.2.5 To determine the hazardous waste properties for each element, we have reviewed chemical compounds listed in Table 3.2 of Annex VI of the European Regulation (1272/2008) for Classification, Labelling and Packaging (CLP) of chemicals which has now superseded the Approved Supply List (Published by the Health and Safety Executive) for the classification of hazardous chemicals in the UK. In order to provide a 'worst case' scenario, initially we adopt the most severe hazardous properties (risk phrases) associated with the various compounds for each element under review. If measured concentrations produce a hazardous outcome then the element or elements are reassessed on a site specific basis. For review of organic contamination, we have directly adopted the threshold concentrations for the appropriate organic compounds listed in Table 3.2.

11.4.2.6 The compound or compounds adopted for each element is used to convert the measured metallic concentration to the substance concentration using their respective molecular weights. This derived conversion factor is then used in the threshold concentration spreadsheet (refer paragraph 11.4.2.8).

11.4.2.7 Our assessment of each of the chemical substances is maintained on our files and is available for confidential review/audit by the Environment Agency.

11.4.2.8 A spreadsheet detailing the hazard assessment following the procedures described in *'framework for the classification of contaminated soils as hazardous wastes'* is presented in Appendix L1.

11.4.2.9 The spreadsheet indicates the soils are **hazardous** by virtue of elevated combined metals and total petroleum hydrocarbons.

11.4.2.10 It should be noted that the above primary classification relates to Made Ground ***not containing asbestos***; see Section 11.5.6 for the classification of soils containing asbestos.

11.5 Secondary assessment

11.5.1 Following '*Guidance on sampling and testing of wastes to meet landfill waste acceptance procedures'* produced by the Environment Agency (Version 1, April 2005) we have scheduled testing of **two** samples to measure the parameters listed in table 5.1 (landfill waste acceptance criteria) included in the above publication. A copy of the test result certificate is presented in Appendix H. The source of the composite samples is detailed below:

Composition of soil samples for classification testing

Strata	Source	Soil Type
WAC01 *Shallow Made Ground*	BH01 – 0.3, 0.6, 0.9 BH02 – 0.2, 1.1 TP01A – 0.4 TP01B – 0.3 TP02 – 0.2	Brown gravelly sand. Gravel consists of brick, concrete, flint, asphaltic concrete, clinker, fabric, plastic, slag and flint.
WAC02 *Deep Made Ground*	BH01 – 1.0, 1.5, 2.5, 4.0 BH03 – 2.0, 3.0, 4.0	Dark brown grey gravelly sand. Gravel consists of brick, concrete, asphaltic concrete, clinker, fabric and flint.

Table 11.5.1

11.5.2 The samples were deemed representative of Made Ground soils as described in Section 5. The sample was formed by combining individual samples taken from exploratory excavations within the Made Ground. The combined sample was then quartered in the laboratory to produce a representative sample for subsequent testing.

11.5.3 Laboratory test data has been compared with the landfill waste acceptable criteria (table 5.1) to allow the secondary assessment to be completed. A copy of table 5.1 is presented in Appendix L2 with test result data added for ease of comparison.

11.5.4 Comparison of test data with landfill waste acceptance criteria indicates that Made Ground soils are suitable for disposal as stable non-hazardous non-reactive hazardous waste in non-hazardous landfill.

11.5.5 It should be noted that only one sample of deep Made Ground has been tested for primary classification. Elevated combined metals, TPH and asbestos were not recorded within this sample.

11.5.6 We recommend further testing be undertaken within all soils likely to be removed off-site, which would allow this assessment to be refined and may allow reclassification of some or all soils.

11.5.5 Classification of soils containing asbestos

11.5.5.1 Asbestos in the form of amosite board was found to be present within the Made Ground in TP02. No asbestos was detected in five of the six samples submitted to determine the presence of absence of asbestos within soils. With reference to the Environment Agency publication '*Guidance on the classification and assessment of waste – WM3 (1st Edition, 2015)*', wastes containing greater than 0.1% free and dispersed asbestos fibres are classified as **hazardous waste** with the code 17 05 03* (soils and stones containing hazardous substances). Where a waste contains identifiable pieces of ACM, then these pieces must be assessed separately. The waste is hazardous if the concentration of asbestos in the ACM exceeds 0.1%. Made Ground containing ACM would be regarded as a mixed waste and classified as follows:

- **17 06 05*** *(Construction material containing asbestos)* – this relates to the individual pieces of asbestos cement within the soil, which are classified as hazardous waste.
- **17 05 03*** *(Soil and stones other than those mentioned in 17 05 03)* – this relates to the main body of the soil, which is classified as stable non-reactive hazardous waste in non-hazardous landfill.

11.5.5.2 Again, due to the limited sampling undertaken to date and as asbestos was only identified within one sample, It may be possible, through additional sampling and analysis, to reclassify some of the Made Ground soils going off-site.

11.5.5.3 Due to the high costs associated with disposal of asbestos containing wastes, we recommend that the development is designed with a view to limiting as far as possible the removal from site of asbestos containing soils.

11.6 Naturally deposited soils not affected by artificial contaminants

11.6.1 With reference to the European Waste Catalogue and table 5.1 of the Environment Agency publication '*a better place – guidance for waste destined for disposal in landfills – version 2 June 2006*', naturally occurring soils not likely to be affected by contamination can be classified as inert waste, with a EWC code of 17 05 04. Should any of the naturally deposited soils be suspected to contain contamination (by virtue of visual of olfactory evidence) upon excavation, then such soils should be stockpiled appropriately, and additional testing carried out as considered necessary. Based on evidence obtained during our investigations, we are of the opinion that the London Clay Formation at the site are not likely to be affected by chemical contamination and thus can be classified as **inert waste.**

11.7 Basic categorisation

11.7.1 Based on the preceding assessment, we have produced three basic categorisation schedules relating to the Made Ground and London Clay Formation deposits, which are presented in Appendix L3. These schedules should be provided together with a copy of this report to an appropriately licensed landfill facility to demonstrate the material can be deposited at this facility.

11.7.2 We understand that some landfill sites have licences which have restrictions on concentrations of chemical contaminants and thus we recommend this report is provided to the selected landfill facility to confirm (or otherwise) it can accept the waste. Please be aware that landfill sites are obligated to undertake in house quality assurance tests and thus may require further WAC testing for any soils encountered as part of this investigation. There is no obligation on any landfill operator to accept waste if they choose not to and waste operators may require additional testing of untested waste soils prior to acceptance at landfill in accordance with the landfill regulations.

11.8 Treatment of waste

11.8.1 Treatment of wastes is now a requirement of the landfill directive applied by the Landfill (England and Wales) Regulations 2002. Landfill cannot accept untreated waste (be it hazardous or non-hazardous), thus waste producers have the choice of treating it themselves on site or treating it elsewhere prior to disposal to landfill. The regulations require:

> *'10 – (1) The operator of a landfill shall ensure that the landfill is only used for landfilling waste which is subject to prior treatment unless:*
>
> *a) It is inert waste for which treatment is not technically feasible; or*
>
> *b) It is waste other than inert waste and treatment would not reduce its quantity or the hazards which it poses to human health or the environment.'*

11.8.2 Regulation 2 defines treatment as: *'physical, thermal, chemical or biological processes (including sorting) that change the characteristics of waste in order to reduce its volume or hazardous nature, facilitate its handling or enhance recovery.'*

11.8.3 A treatment option must comply with the definition of treatment. This involves a 'three point test' against which treatment is assessed i.e.

1. It must be a physical, thermal, chemical or biological process including sorting
2. It must change the characteristics of the waste: and
3. It must do so in order to:
    a) Reduce its volume: or
    b) Reduce its hazardous nature: or
    c) Facilitate its handling: or
    d) Enhance its recovery.

11.8.4 Treatment of inert wastes

11.8.4.1 Inert waste does not need to be treated if it is not technically feasible however treatment should reduce the amount of waste which goes to landfill and enhance its recovery (by re-use or recycling). Inert wastes are often suitable for recycling, for example as an aggregate or an engineering fill material. A fact sheet on treatment of inert wastes is available on the following website www.environment-agency.gov.uk.

11.8.4.2 Clearly, excavations in the London Clay Formation will generate inert wastes which could be reused on site or off site for bulk filling, subject of course to maintenance of an acceptable water content and provided that it is fit for its intended purpose.

11.8.5 Treatment of non-hazardous waste

11.8.5.1 Guidance and indeed examples of treatment is provided in the Environment Agency publication '*Treatment of non-hazardous wastes for landfill – your waste – your responsibility,'* again available on the EA website.

11.8.6 Treatment of hazardous waste

11.8.6.1 Made Ground soils at the site have been classified stable non-reactive hazardous waste. We recommend that a licenced waste carrier who is experienced in handling, treatment and disposal of hazardous waste is consulted to gain their recommendations on the most economical way to dispose of waste at the site.

11.8.7 Landfill operators

11.8.7.1 It is a requirement of the landfill operator to check if the waste soils taken to the facility have been treated.

11.9 Reuse of Soils - Materials Management Plans

11.9.1 Where soils are to be moved and reused onsite, or are to be imported to the site, a Waste Exemption or an Environmental Permit is required.

11.9.2 An alternative is the use of a Materials Management Plan (MMP) to determine where soils are and are not considered to be a waste. By following *'The Definition of Waste: Development Industry Code of Practice'* published by CL:AIRE (produced in 2008 and revised in March 2011), soils that are suitable for reuse without the need for remediation (either chemical or geotechnical) and have a certainty of use, are not considered to be waste and therefore do not fall under waste regulations. In addition, following this guidance may present an opportunity to transfer suitable material between sites, without the need for Waste Exemptions or Environmental Permits.

11.9.3 MMPs offering numerous benefits, including maximising the use of soils onsite, minimising soils going to landfill and reducing costs and time involved in liaising with waste regulators.

11.9.4 We can provide further advice on this and provide fees for producing a Materials Management Plan on further instructions.

12 Further investigations

12.1	Further investigations

12.1 Although we have endeavoured to provide a comprehensive investigation for the proposed development within budgetary constraints there are areas, which may require further investigations to be carried out.

12.2 Initially, it was proposed to carry out three boreholes on the site with one borehole per proposed building location. Due to concrete obstructions in BH02 we were only able to carry out two of the proposed boreholes.

12.3 Pressure meter testing was proposed at intermittent depths within two borehole locations. The time frame of the investigation was interrupted by the aforementioned concrete obstructions and all pressure meter testing was carried out in one borehole down to a depth of 45m in BH03.

12.4 Should it be considered that there is an insufficient quantity of data within the London Clay Formation the additional borehole could be completed during pre-construction phase or during demolition works.

12.5 Further sampling and testing of Made Ground soils, including for asbestos, in order to refine the waste classification of these soils.

12.6 We would be pleased to carry out the additional fieldworks described above and provide proposals with costings on further instructions.

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Definition of geotechnical terms used in this report - foundations

Strip foundations.
A foundation providing a continuous longitudinal ground bearing.

Trench fill concrete foundation.
A trench filled with mass concrete providing continuous longitudinal ground bearing.

Pad foundation.
An isolated foundation to spread a concentrated load.

Raft foundation.
A foundation continuous in two directions, usually covering an area equal to or greater than the base area of the structure.

Substructure.
That part of any structure (including building, road, runway or earthwork) which is below natural or artificial ground level. In a bridge this includes piers and abutments (and wing walls), whether below ground level or not, which support the superstructure.

Piled foundations and end bearing piles. A pile driven or formed in the ground for transmitting the weight of a structure to the soil by the resistance developed at the pile point or base and the friction along its surface. If the pile supports the load mainly by the resistance developed at its point or base, it is referred to as an end-bearing pile; if mainly by friction along its surface, as a friction pile.

Bored cast in place pile.
A pile formed with or without a casing by excavating or boring a hole in the ground and subsequently filling it with plain or reinforced concrete.

Driven pile.
A pile driven into the ground by the blows of a hammer or a vibrator.

Precast pile.
A reinforced or prestressed concrete pile cast before driving.

Driven cast in place pile.
A pile installed by driving a permanent or temporary casing, and filling the hole so formed with plan or reinforced concrete.

Displacement piles.
Piled formed by displacement of the soil or ground through which they are driven.

Skin friction.
The frictional resistance of the surrounding soil on the surface of cofferdam or caisson walls, and pile shafts.

Downdrag or negative skin friction. A downwards frictional force applied to the shaft of a pile caused by the consolidation of compressible strata, e.g. under recently placed fill. Downdrag has the effect of adding load to the pile and reducing the factor of safety.

Definition of geotechnical terms used in this report – bearing values

Ultimate bearing capacity.
The value of the gross loading intensity for a particular foundation at which the resistance of the soil to displacement of the foundation is fully mobilised.

Presumed bearing value.
The net loading intensity considered appropriate to the particular type of ground for preliminary design purposes. The particular value is based on calculation from shear strength tests or other field tests incorporating a factor of safety against shear failure.

Allowable bearing pressure.
The maximum allowable net loading intensity at the base of the foundation, taking into account the ultimate bearing capacity, the amount and kind of settlement expected and our estimate of ability of the structure to accommodate this settlement.

Factor of safety.
The ratio of the ultimate bearing capacity to the intensity of the applied bearing pressure or the ratio of the ultimate load to the applied load.

Definition of geotechnical terms used in this report – road pavements

The following definitions are based on Transport and Road Research Laboratory (TRRL) Report LR1132.

Equilibrium CBR values.
A prediction of the CBR value, which will be attained under the completed pavement.

***Thin pavement*.**
A thin pavement (which includes both bound and unbound pavement construction materials 1 in 300mm thick and a thick pavement is 1200mm thick (typical of motorway construction).

Definition of geo-environmental terms used in this report

Conceptual model
Textual and/or schematic hypothesis of the nature and sources of contamination, potential migration pathways (including description of the ground and groundwater) and potential receptors, developed on the basis of the information obtained from the investigatory process.

Contamination
Presence of a substance which is in, on or under land, and which has the potential to cause harm or to cause pollution of controlled water.

Controlled water
Inland freshwater (any lake, pond or watercourse above the freshwater limit), water contained in underground strata and any coastal water between the limit of highest tide or the freshwater line to the three mile limit of territorial waters.

Harm
Adverse effect on the health of living organisms, or other interference with ecological systems of which they form part, and, in the case of humans, including property.

Pathway
Mechanism or route by which a contaminant comes into contact with, or otherwise affects, a receptor.

Receptor
Persons, living organisms, ecological systems, controlled waters, atmosphere, structures and utilities that could be adversely affected by the contaminant(s).

Risk
Probability of the occurrence of, and magnitude of the consequences of, an unwanted adverse effect on a receptor.

Risk Assessment
Process of establishing, to the extent possible, the existence, nature and significance of risk.

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Definition of environmental risk/hazard terms used in this report.

Based on CIRIA report C552 '*Contaminated land risk assessment – A guide to good practice*'.

Potential hazard severity definition

Category	Definition
Severe	Acute risks to human health, catastrophic damage to buildings/property, major pollution of controlled waters
Medium	Chronic risk to human health, pollution of sensitive controlled waters, significant effects on sensitive ecosystems or species, significant damage to buildings or structures.
Mild	Pollution of non sensitive waters, minor damage to buildings or structures.
Minor	Requirement for protective equipment during site works to mitigate health effects, damage to non sensitive ecosystems or species.

Probability of risk definition

Category	Definition
High likelihood	Pollutant linkage may be present, and risk is almost certain to occur in long term, or there is evidence of harm to the receptor.
Likely	Pollutant linkage may be present, and it is probable that the risk will occur over the long term
Low likelihood	Pollutant linkage may be present, and there is a possibility of the risk occurring, although there is no certainty that it will do so.
Unlikely	Pollutant linkage may be present, but the circumstances under which harm would occur are improbable.

Level of risk for potential hazard definition

Probability of risk	Potential severity			
	Severe	Medium	Mild	Minor
High Likelihood	Very high	High	Moderate	Low/Moderate
Likely	High	Moderate	Low/Moderate	Low
Low Likelihood	Moderate	Low/Moderate	Low	Very low
Unlikely	Low/Moderate	Low	Very low	Very low

Refer sheet 2 for definitions of 'very high' to 'low'

Definition of environmental risk/hazard terms used in this report.

Based on CIRIA report C552 '*Contaminated land risk assessment – A guide to good practice*'.

Risk classifications and likely action required:

Very high risk
High probability that severe harm could arise to a designated receptor from an identified hazard OR there is evidence that severe harm to a designated receptor is currently happening. This risk, if realised is likely to result in substantial liability. Urgent investigation and remediation are likely to be required.

High risk
Harm is likely to arise to a designated receptor from an identified hazard. This risk, if realised, is likely to result in substantial liability. Urgent investigation is required and remedial works may be necessary in the short term and are likely over the long term.

Moderate risk
It is possible that harm could arise to a designated receptor from an identified hazard. However, it is either relatively unlikely that any such harm would be severe, or if any harm were to occur it is likely that the harm would be relatively mild. Investigation is normally required to clarify risks and to determine potential liability. Some remedial works may be required in the long term.

Low risk
It is possible that harm could arise to a designated receptor from an identified hazard but it is likely that this harm, if realised, would at worst normally be mild.

Very low risk
It is a low possibility that harm could arise to a designated receptor. On the event of such harm being realised it is not likely to be severe.

List of documents used in assessment of chemical contamination

No.	Title	Publication reference / publisher
1	Human health toxicological assessment of contaminants in soil	EA Science Report – SC050021/SR2
2	Updated technical background to the CLEA model	EA Science Report – SC050021/SR3
3	CLEA Software (Version 1.03 beta) Handbook	EA Science Report - SC050021/SR4
4	Guidance on comparing Soil Contamination Data with a Critical Concentration	CIEH
5	The LQM/CIEH S4ULs for Human Health Risk Assessment (2015)	LQM/CIEH
6	Assessment of Risks to Human Health from Land Contamination: An overview of the development of soil guideline values and related research	R&D Publication, Contaminated Land Report CLR 7
7	Contaminants of Soil: Collation of Toxicological Data and Intake Values for Humans	R&D Publication, Contaminated Land Report CLR 9
8	The Contaminated Land Exposure Assessment Model (CLEA): Technical Basis and Algorithms	R&D Publication, Contaminated Land Report CLR 10
9	Model Procedures for the Management of Land Contamination	R&D Publication, Contaminated Land Report CLR 11
10	Contaminants in Soil: Collection of Toxicological Data and Intake Values for Human Values	R&D Publications, Tox. 6
11	Soil Guideline Values for Contamination (2002)	R&D Publications, SGV 10
12	Soil Guideline Values (2009)	EA Science Reports – SC050021
13	Atkins ATRISK^{SOIL} (2011)	http://www.atrisksoil.co.uk
14	Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination (September 2014)	CL:AIRE

CIEH Chartered institute of Environmental Health
LQM Land Quality Management
EA Environment Agency
CL:AIRE Contaminated Land: Applications in Real Environments

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Testing suite summary

Table summarising testing suites		
Suite	**Parameters**	**Medium**
Suite 1	Arsenic, beryllium, boron, cadmium, chromium (total and VI), copper, lead, mercury, nickel, selenium, vanadium zinc, cyanide (free, total and complex), organic matter content, PAH (16 speciated), pH, phenol (total), TOC	Soil
Suite 2	Arsenic, boron (water soluble), beryllium, cadmium, chromium (total), copper, lead, mercury, nickel, selenium, vanadium, zinc, cyanide (free, total and complex, PAH (16 speciated), pH, phenol (total), sulfate (water soluble), sulfide, nitrate	Leachate
Suite 3	Arsenic, boron (water soluble), beryllium, cadmium, chromium (total), copper, lead, mercury, nickel, selenium, vanadium, zinc, cyanide (free, total and complex, PAH (16 speciated), pH, phenol (total), sulfate (water soluble), sulfide, nitrate	Water
Suite 4	TPH Texas Banding Aliphatic/Aromatic Split, PAH (16 speciated), TOC	Soil
Suite 5	TPH Texas Banding Aliphatic/Aromatic Split, PAH (16 speciated)	Leachate
Suite 6	TPH Texas Banding Aliphatic/Aromatic Split, PAH (16 speciated)	Water
Suite 7	TPH Texas Banding Aliphatic/Aromatic Split, TOC, organic matter	Soil
Suite 8	Sulphur (total), sulphate (water and acid soluble), pH	Soil
Suite 9	Sulphate, ammoniacal nitrogen, dissolved magnesium, pH	Water
Suite 10	VOC, SVOC, TOC, organic matter	Soil
Suite 11	VOC, SVOC	Leachate
Suite 12	VOC, SVOC	Water
Suite 13	Organotins dibutyltin/ tributyl-tin/tetrabutyltin/triphenyl-tin, Tetraethyl-lead/tetramethyl-lead	Soil
Suite 14	Organotin	Leachate
Suite 15	Organotin	Water
Suite 16	TPH Texas Banding Aliphatic/Aromatic Split, BTEX, VOC, SVOC	Soil, water, leachate
Suite 17	TPH Texas Banding Aliphatic/Aromatic Split, BTEX, SVOC, VOC, arsenic, boron (water soluble), beryllium, cadmium, chromium (total), copper, lead, mercury, nickel, selenium, vanadium, zinc, cyanide (free, total and complex, pH, phenol (total), sulfate (water soluble), sulfide, nitrate	Soil, water, leachate
Concrete BRE suite	pH, sulphate (water and acid soluble), magnesium (water soluble), ammonia (water soluble), chloride, nitrate	Soil

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Standard Penetration Test Results

Location	Depth to top of SPT (m)	Results								Penetration (mm)			
		Seating 1	Seating 2	Main 1	Main 2	Main 3	Main 4	Total Seating	Total Main	Total Seating	Total Main	Relative Density	Strata
BH01	1.5	1	7	25				8	25	150	10	Medium dense	MADE GROUND
	3	4	11	13	16	11		15	40	150	180	Dense	MADE GROUND
	4	7	14	15	21	14		21	50	150	195	Very dense	MADE GROUND
	7	1	3	4	4	5	6	4	19	150	300		LONDON CLAY FORMATION
	10	2	3	4	4	5	6	5	19	150	300		LONDON CLAY FORMATION
	12	2	3	4	5	6	6	5	21	150	300		LONDON CLAY FORMATION
	22	4	6	7	9	10	12	10	38	150	300		LONDON CLAY FORMATION
	25	4	6	8	9	11	14	10	42	150	300		LONDON CLAY FORMATION
BH02	1.5	3	4	4	5	6	6	7	21	150	300	Medium dense	MADE GROUND
BH03	5.5	1	2	3	4	4	4	3	15	150	300		LONDON CLAY FORMATION
	12	2	3	5	5	6	7	5	23	150	300		LONDON CLAY FORMATION
	14	3	5	6	7	8	8	8	29	150	300		LONDON CLAY FORMATION
	17	4	5	7	8	9	9	9	33	150	300		LONDON CLAY FORMATION
	23	5	6	8	9	10	12	11	39	150	300		LONDON CLAY FORMATION
	28	6	8	10	10	12	13	14	45	150	300		LONDON CLAY FORMATION

Notes

1) Relative Density in accordance with BS 5930 2015 - Table 10 for granular soils only.

Title	Appendix
Table summarising results of standard penetration testing	C1

Standard Penetration Test Results

Location	Depth to top of SPT (m)	Results						Penetration (mm)				Relative Density	Strata
		Seating 1	Seating 2	Main 1	Main 2	Main 3	Main 4	Total Seating	Total Main	Total Seating	Total Main		
BH03	30	6	9	11	13	14	12	15	50	150	290		LONDON CLAY FORMATION
	32	7	9	12	14	14	10	16	50	150	275		LONDON CLAY FORMATION
	34	6	10	13	15	16	6	16	50	150	245		LONDON CLAY FORMATION
	36	8	10	12	16	18	4	18	50	150	235		LONDON CLAY FORMATION
	38	10	14	16	17	17		24	50	150	225		LONDON CLAY FORMATION
	40	10	15	18	21	11		25	50	150	200		LONDON CLAY FORMATION
	41.5	12	13	31	19			25	50	135	100	Very dense	THANET SAND FORMATION

Notes

1) Relative Density in accordance with BS 5930 2015 - Table 10 for granular soils only.

Title	Appendix
Table summarising results of standard penetration testing	C1

Pocket Penetrometer Results

Location	Depth (m)	Results				Undrained Shear Strength (kN/m^2)	Strength Term	Strata
		1	2	3	Av.			
BH01	6.5	3.25	3.25	3.25	*3.3*	*163*	Very high	LONDON CLAY FORMATION
	7	3.75	4	4	*3.9*	*196*	Very high	LONDON CLAY FORMATION
	9.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	10	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	11.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	12	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	13	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	14.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	16.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	18.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	19	3.75	3.75	3.75	*3.8*	*188*	Very high	LONDON CLAY FORMATION
	20.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	22	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	23	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	24.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	25	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
BH03	5.1	3	3	3	*3.0*	*150*	Very high	LONDON CLAY FORMATION
	5.5	3	3	3.25	*3.1*	*154*	Very high	LONDON CLAY FORMATION
	7.5	4	4	4	*4.0*	*200*	Very high	LONDON CLAY FORMATION
	10.5	3.5	3.5	4	*3.7*	*183*	Very high	LONDON CLAY FORMATION
	11.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	12	4	4	4	*4.0*	*200*	Very high	LONDON CLAY FORMATION
	14	3.25	3.25	3.25	*3.3*	*163*	Very high	LONDON CLAY FORMATION
	16.5	4	4.5	4.5	*4.3*	*217*	Very high	LONDON CLAY FORMATION
	17.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	19.5	3	3	3.25	*3.1*	*154*	Very high	LONDON CLAY FORMATION
	20.5	3	3	3.25	*3.1*	*154*	Very high	LONDON CLAY FORMATION
	22.5	3	3	3.25	*3.1*	*154*	Very high	LONDON CLAY FORMATION
	23	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION

Notes

1. Pocket penetrometer determinations converted to undrained shear strength using a factor of 50.

2. Undrained shear strength is based on average pocket penetrometer determination.

3. Strength terms in accordance with BS EN ISO 14688-2 2004.

Title	Appendix
Table summarising results of pocket penetrometer determinations	C2

Pocket Penetrometer Results

Location	Depth (m)	Results				Undrained Shear Strength (kN/m^2)	Strength Term	Strata
		1	2	3	Av.			
BH03	24.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	25.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	26.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	27.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	28	3.75	4	4.25	*4.0*	*200*	Very high	LONDON CLAY FORMATION
	29.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	30	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	31	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	32	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	33.6	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	35.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	36	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	37.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	39.5	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION
	40	4.5	4.5	4.5	*4.5*	*225*	Very high	LONDON CLAY FORMATION

Notes

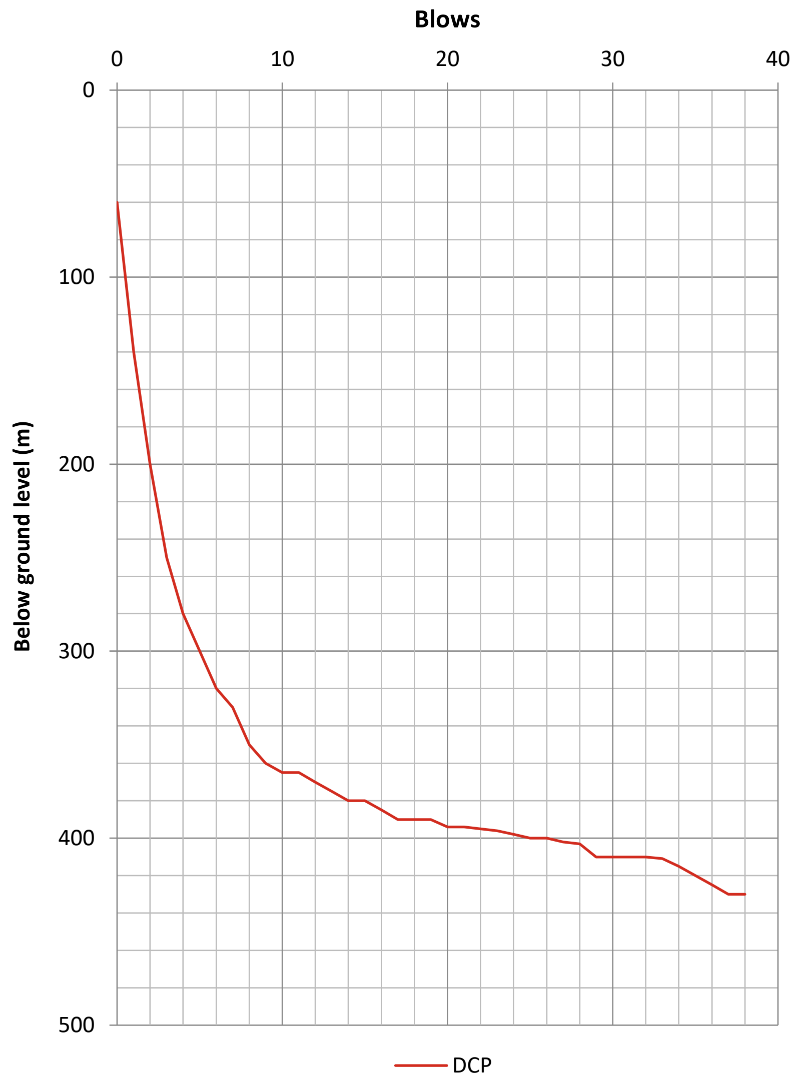
1. Pocket penetrometer determinations converted to undrained shear strength using a factor of 50.

2. Undrained shear strength is based on average pocket penetrometer determination.

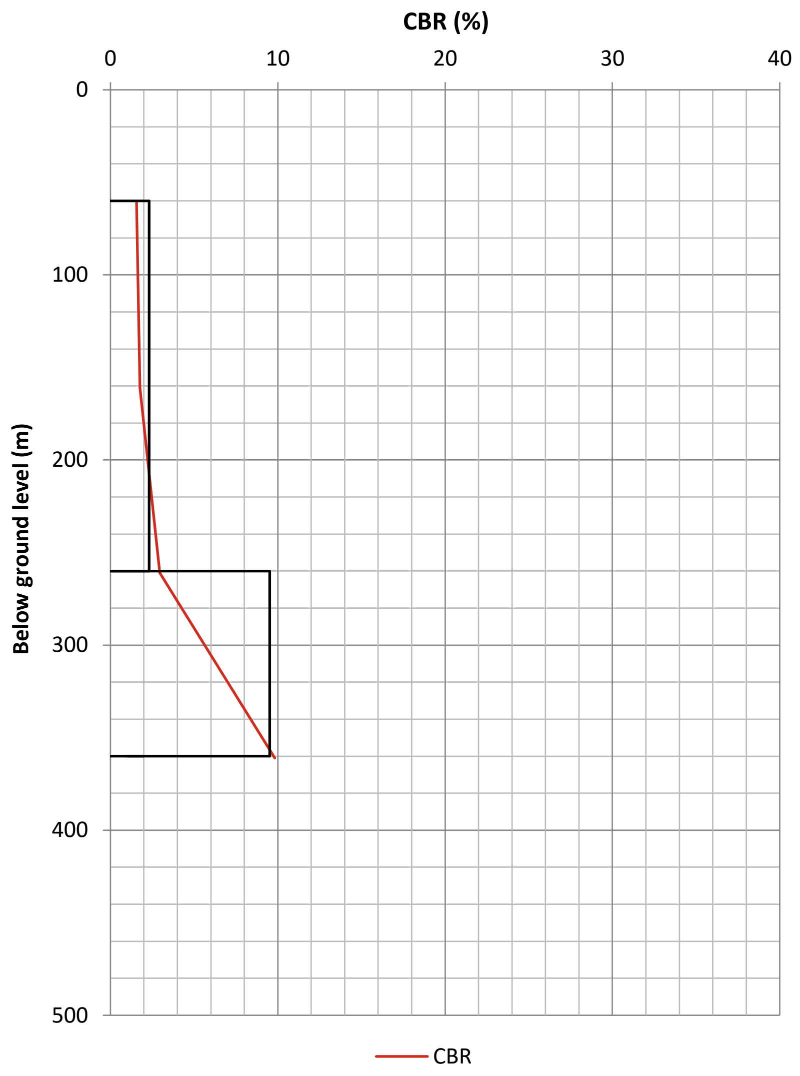
3. Strength terms in accordance with BS EN ISO 14688-2 2004.

Title	Appendix
Table summarising results of pocket penetrometer determinations	C2

Plot showing number of blows against depth:



Plot showing CBR (%) against depth:



Test results:

Cumulative Blows	Penetration Depth (mm)	Cumulative Blows	Penetration Depth (mm)
0	60	36	425
1	140	37	430
2	200	38	430
3	250		
4	280		
5	300		
6	320		
7	330		
8	350		
9	360		
10	365		
11	365		
12	370		
13	375		
14	380		
15	380		
16	385		
17	390		
18	390		
19	390		
20	394		
21	394		
22	395		
23	396		
24	398		
25	400		
26	400		
27	402		
28	403		
29	410		
30	410		
31	410		
32	410		
33	411		
34	415		
35	420		

Layer properties:

Layer Number	CBR (%)	Thickness (mm)	Base of layer below ground level (mm)
1	**2.3**	200	260
2	**9.5**	100	360

Calculations:

$\text{Log}_{10}\ (\text{CBR}) = 2.48 - 1.057\text{Log}_{10}(\text{mm/blow})$

Mod.CBR (%) = UC - (UC (ϰ (1-α)))

UC = 'uncorrected CBR'
ϰ = depth factor
α = soil condition adjustment factor

Notes:

1) Test procedure following Highways England Interim Advice Note 73/06 Revision 1 (2009) 'Design Guidance for Road Pavement Foundations' (Draft HD25), Chapter 7.
2) Surface moisture determined based upon Fieldwork observations.

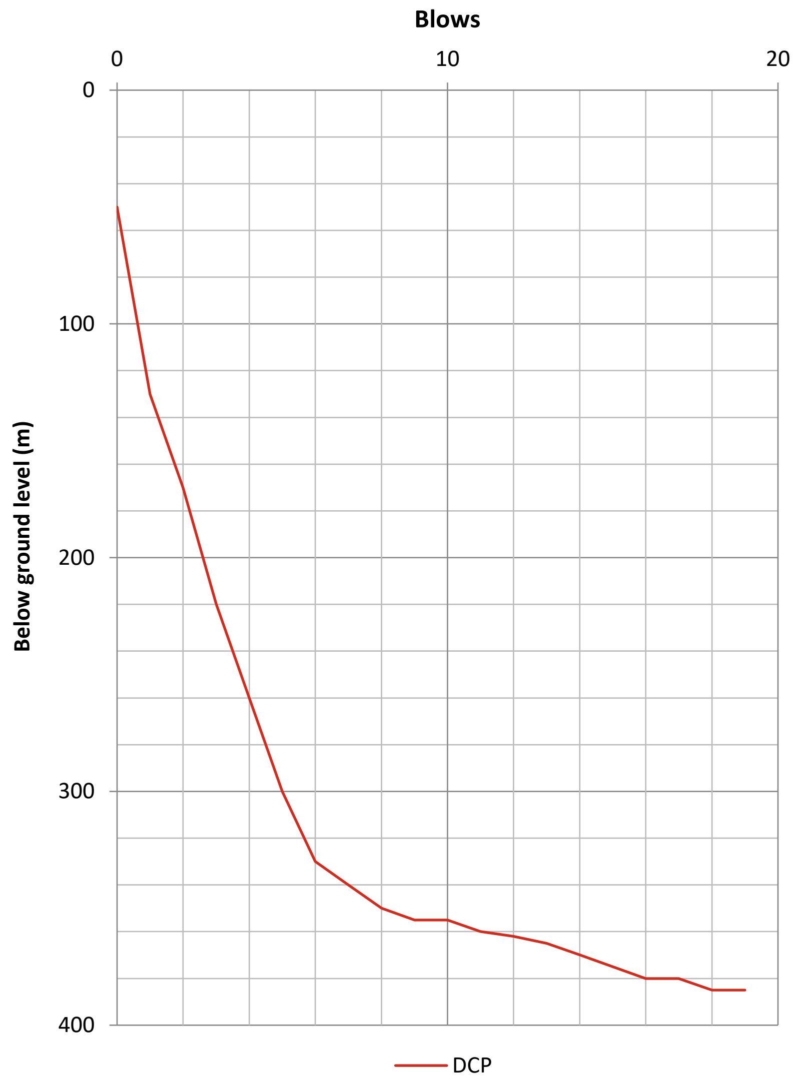
Operator	Surface moisture [2]
BH/AC	Not assessed

Terminated due to competency of materials

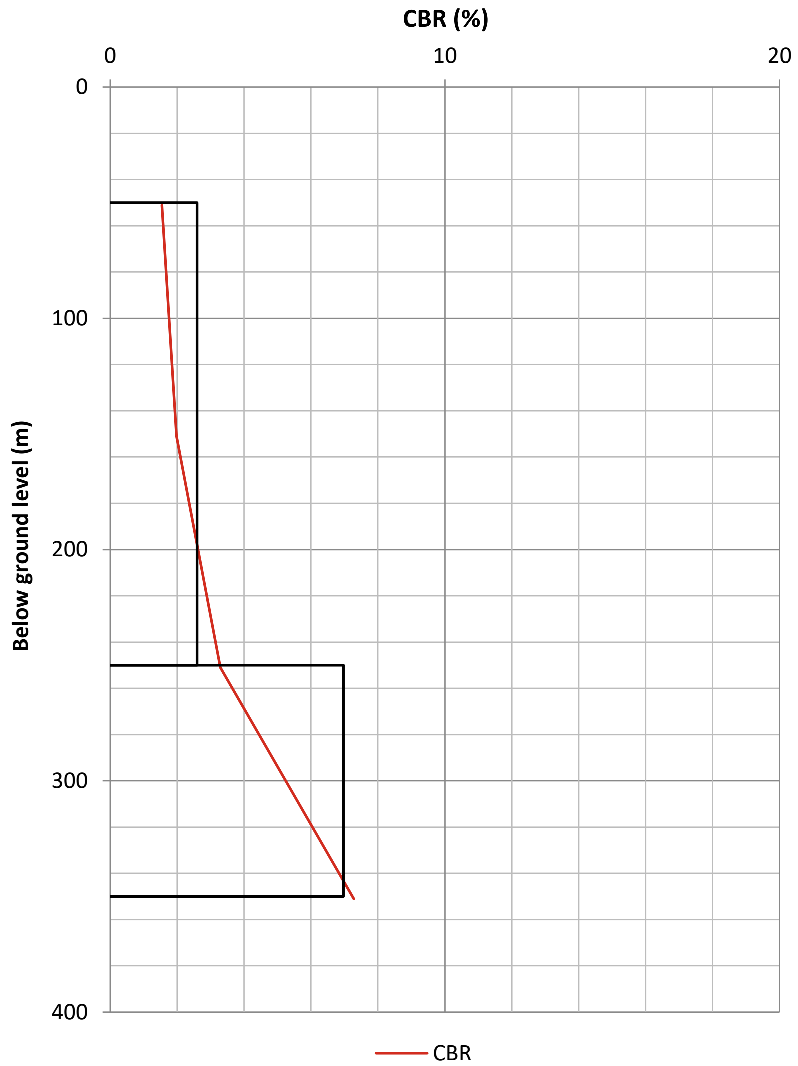
Start depth from ground level (mm)
60

Title	
Dynamic Cone Penetrometer (DCP) test	
Location ref.	Date of test
TRL-BH02A	25/02/2019

Plot showing number of blows against depth:



Plot showing CBR (%) against depth:



Test results:

Cumulative Blows	Penetration Depth (mm)	Cumulative Blows	Penetration Depth (mm)
0	50		
1	130		
2	170		
3	220		
4	260		
5	300		
6	330		
7	340		
8	350		
9	355		
10	355		
11	360		
12	362		
13	365		
14	370		
15	375		
16	380		
17	380		
18	385		
19	385		

Layer properties:

Layer Number	CBR (%)	Thickness (mm)	Base of layer below ground level (mm)
1	**2.6**	200	250
2	**7.0**	100	350

Calculations:

Log_{10} (CBR) = 2.48 - 1.057Log_{10}(mm/blow)

Mod.CBR (%) = UC - (UC (ϰ (1-α)))

UC = 'uncorrected CBR'
ϰ = depth factor
α = soil condition adjustment factor

Notes:

1) Test procedure following Highways England Interim Advice Note 73/06 Revision 1 (2009) 'Design Guidance for Road Pavement Foundations' (Draft HD25), Chapter 7.
2) Surface moisture determined based upon Fieldwork observations.

Operator	Surface moisture [2]	Title	
BH/AC	Not assessed	Dynamic Cone Penetrometer (DCP) test	
Terminated due to competency of materials			
Start depth from ground level (mm)		Location ref.	Date of test
50		TRL-BH02B	25/02/2019

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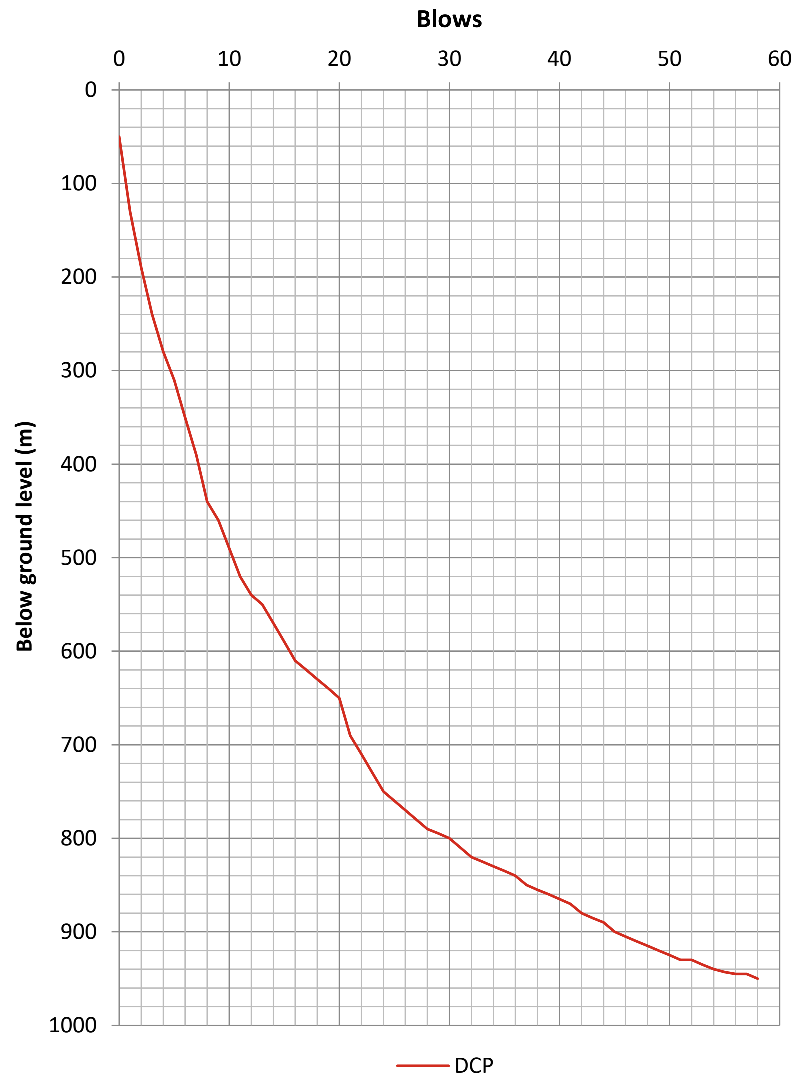
Plot showing number of blows against depth:



Plot showing CBR (%) against depth:

Test results:

Cumulative Blows	Penetration Depth (mm)	Cumulative Blows	Penetration Depth (mm)
0	50	36	840
1	130	37	850
2	190	38	855
3	240	39	860
4	280	40	865
5	310	41	870
6	350	42	880
7	390	43	885
8	440	44	890
9	460	45	900
10	490	46	905
11	520	47	910
12	540	48	915
13	550	49	920
14	570	50	925
15	590	51	930
16	610	52	930
17	620	53	935
18	630	54	940
19	640	55	943
20	650	56	945
21	690	57	945
22	710	58	950
23	730		
24	750		
25	760		
26	770		
27	780		
28	790		
29	795		
30	800		
31	810		
32	820		
33	825		
34	830		
35	835		

Layer properties:

Layer Number	CBR (%)	Thickness (mm)	Base of layer below ground level (mm)
1	**3.2**	400	450
2	**11.4**	200	650
3	**8.5**	100	750
4	**31.5**	100	850

Calculations:

Log_{10} (CBR) = 2.48 - 1.057Log_{10}(mm/blow)

Mod.CBR (%) = UC - (UC (ϰ (1-α)))

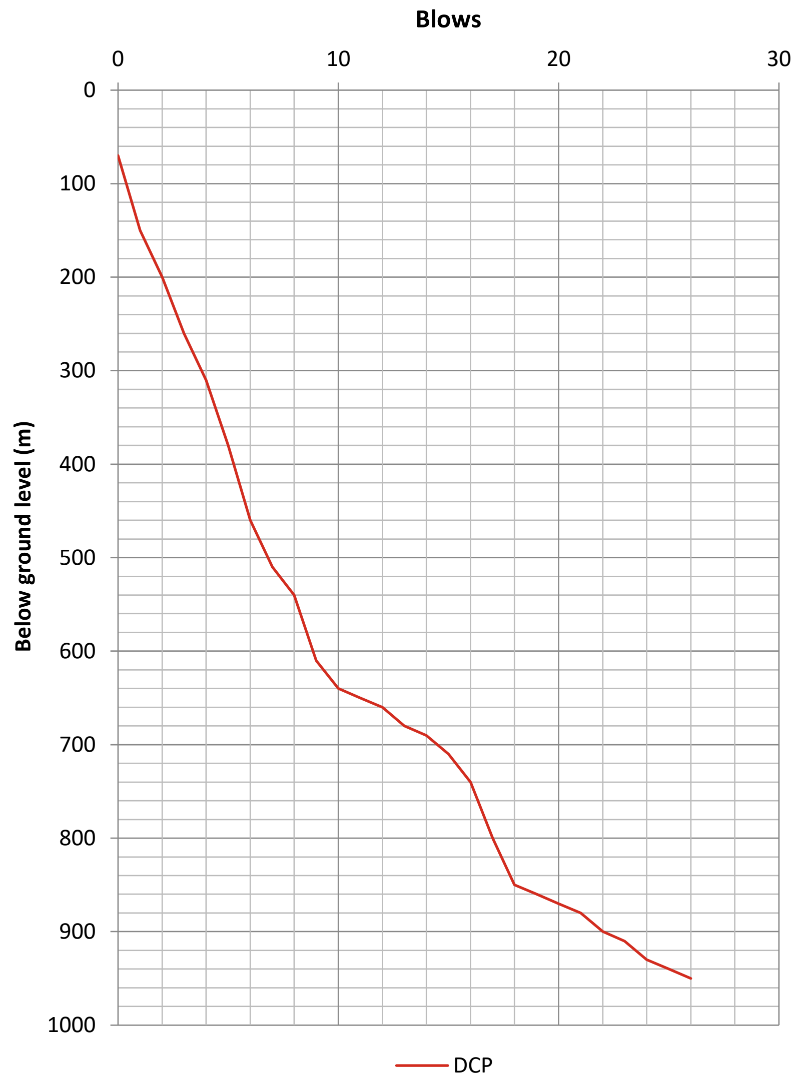
UC = 'uncorrected CBR'
ϰ = depth factor
α = soil condition adjustment factor

Notes:

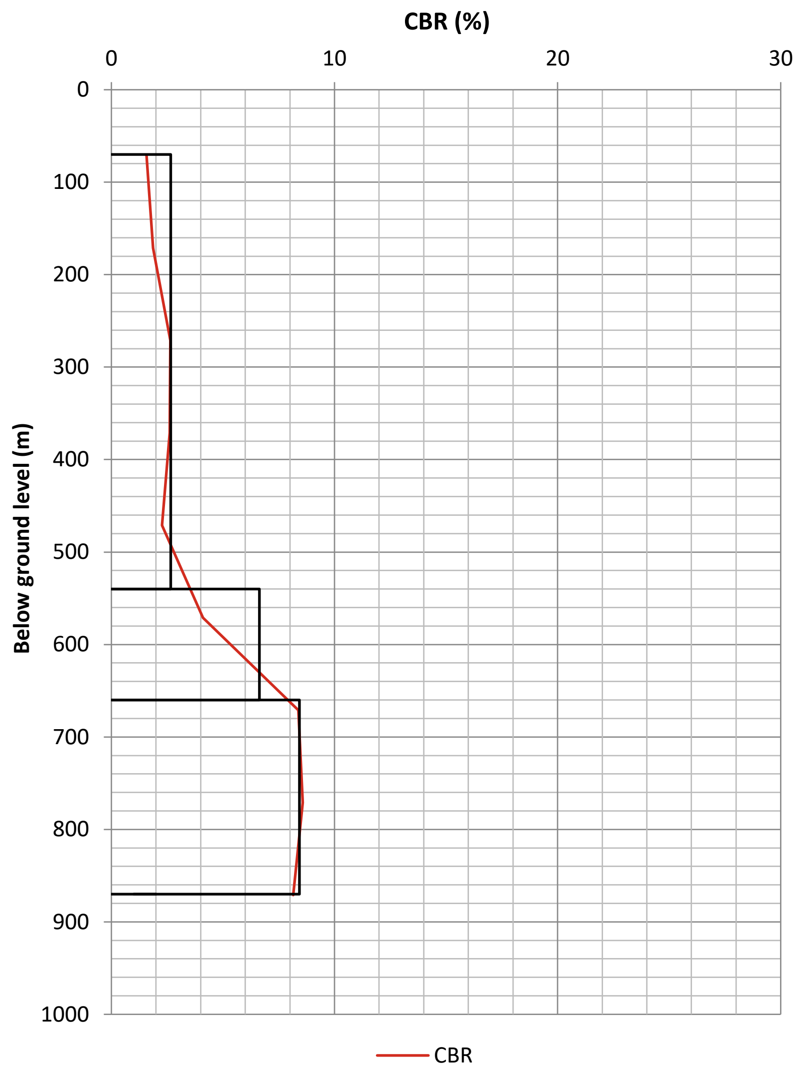
1) Test procedure following Highways England Interim Advice Note 73/06 Revision 1 (2009) 'Design Guidance for Road Pavement Foundations' (Draft HD25), Chapter 7.
2) Surface moisture determined based upon Fieldwork observations.

Operator	Surface moisture [2]	Title	
BH/AC	Not assessed	Dynamic Cone Penetrometer (DCP) test	
Terminated due to competency of materials			
Start depth from ground level (mm)		Location ref.	Date of test
50		TRL-BH03	25/02/2019

Plot showing number of blows against depth:



Plot showing CBR (%) against depth:



Test results:

Cumulative Blows	Penetration Depth (mm)	Cumulative Blows	Penetration Depth (mm)
0	70		
1	150		
2	200		
3	260		
4	310		
5	380		
6	460		
7	510		
8	540		
9	610		
10	640		
11	650		
12	660		
13	680		
14	690		
15	710		
16	740		
17	800		
18	850		
19	860		
20	870		
21	880		
22	900		
23	910		
24	930		
25	940		
26	950		

Layer properties:

Layer Number	CBR (%)	Thickness (mm)	Base of layer below ground level (mm)
1	**2.7**	470	540
2	**6.6**	120	660
3	**8.4**	210	870

Calculations:

$\text{Log}_{10}(\text{CBR}) = 2.48 - 1.057\text{Log}_{10}(\text{mm/blow})$

$\text{Mod.CBR}(\%) = \text{UC} - (\text{UC}(\varkappa(1-\alpha)))$

UC = 'uncorrected CBR'
ϰ = depth factor
α = soil condition adjustment factor

Notes:

1) Test procedure following Highways England Interim Advice Note 73/06 Revision 1 (2009) 'Design Guidance for Road Pavement Foundations' (Draft HD25), Chapter 7.
2) Surface moisture determined based upon Fieldwork observations.

Operator	Surface moisture [2]	Title	
BH/AC	Not assessed	Dynamic Cone Penetrometer (DCP) test	
Terminated due to competency of materials			
Start depth from ground level (mm)		Location ref.	Date of test
70		TRL-TP03	25/02/2019

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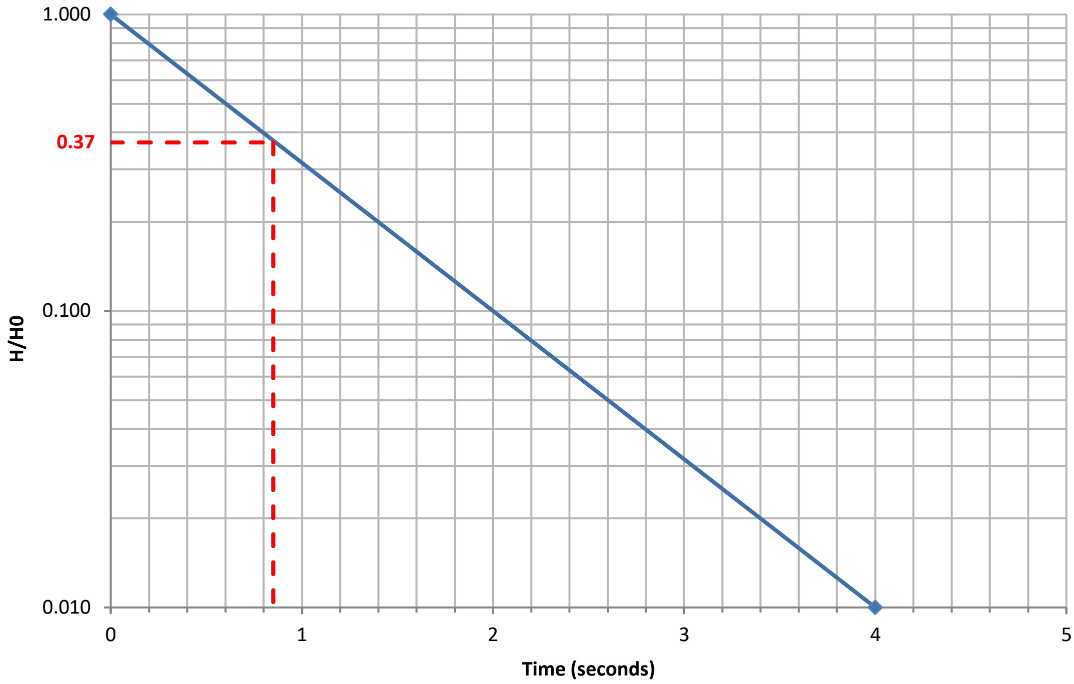


Representation of the time-dependent correct hydraulic head *hcor(t)*, ratio chart

Test observations:

TIME (mins)	DEPTH TO WATER (m)	TIME (mins)	DEPTH TO WATER (m)
0	4.29		
0.06667	4.31		

Calculations:

$$k = \frac{r^2 \cdot \ln\left(L/R\right)}{2 \cdot L \cdot t_o}$$

Test section prepared to Figure 2c/2d in accordance with BS EN ISO 22282-2-2012.

r is the radius of the measuring tube (m) = 0.0315
R is the radius of the test section (m) = 0.0315
L is the length of the test section (m) = 1.69
t_o is the time it takes for the water level to rise or fall to 37 percent of the initial change in head (s) = 0.85

k is the coefficient of permeability (m/s) = 1.38E-03

Groundwater observations
Groundwater encountered at 41m depth, rising to 39.3 on completion.

Geology unit under test
Made Ground

Borehole depth (m)
42

Borehole diameter (m)
0.063

Title
Hvorslev method in accordance with BS EN ISO 22282-2:2012.

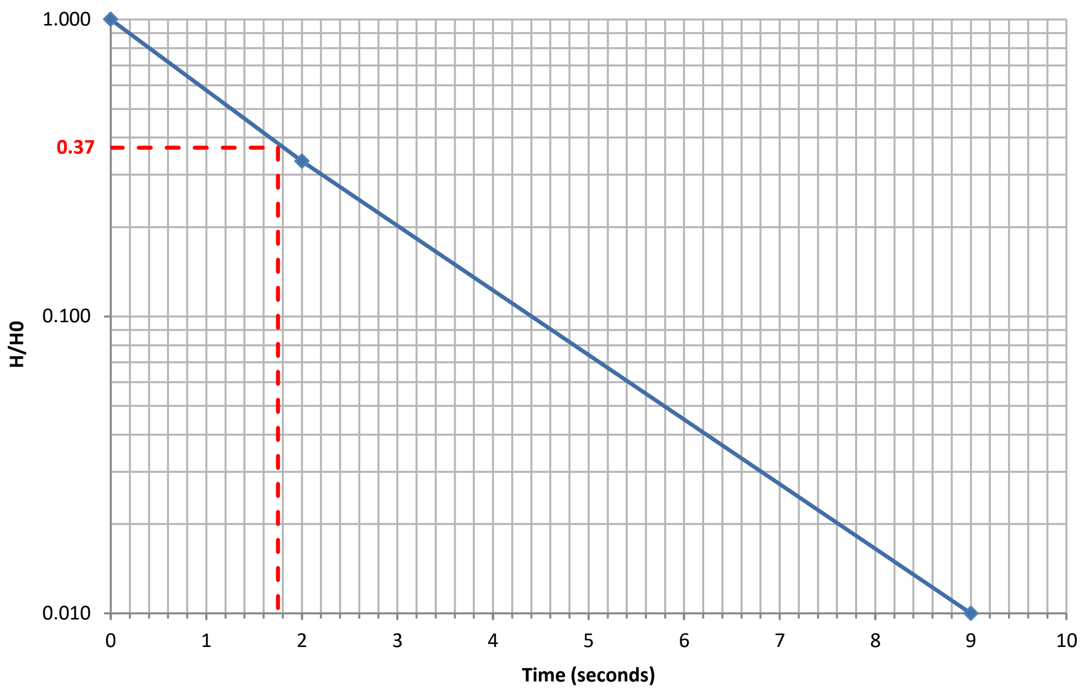
Co-ordinates
-

Cycle number
1

Date
27/02/2019

Ground level
25.50 (m OD)

Borehole number
BH03



Representation of the time-dependent correct hydraulic head *hcor(t)*, ratio chart

Test observations:

TIME (mins)	DEPTH TO WATER (m)	TIME (mins)	DEPTH TO WATER (m)
0	4.28		
0.03333	4.3		
0.15	4.31		

Calculations:

$$k = \frac{r^2 \cdot \ln\left(L/R\right)}{2 \cdot L \cdot t_o}$$

Test section prepared to Figure 2c/2d in accordance with BS EN ISO 22282-2-2012.

r is the radius of the measuring tube (m) = 0.0315

R is the radius of the test section (m) = 0.0315

L is the length of the test section (m) = 1.69

t_o is the time it takes for the water level to rise or fall to 37 percent of the initial change in head (s) = 1.75

k is the coefficient of permeability (m/s) = 6.68E-04

Groundwater observations

Groundwater encountered at 41m depth, rising to 39.3 on completion.

Geology unit under test

Made Ground

Borehole depth (m)

42

Borehole diameter (m)

0.063

Title

Hvorslev method in accordance with BS EN ISO 22282-2:2012.

Co-ordinates

-

Cycle number

2

Date

27/02/2019

Ground level

25.50 (m OD)

Borehole number

BH03

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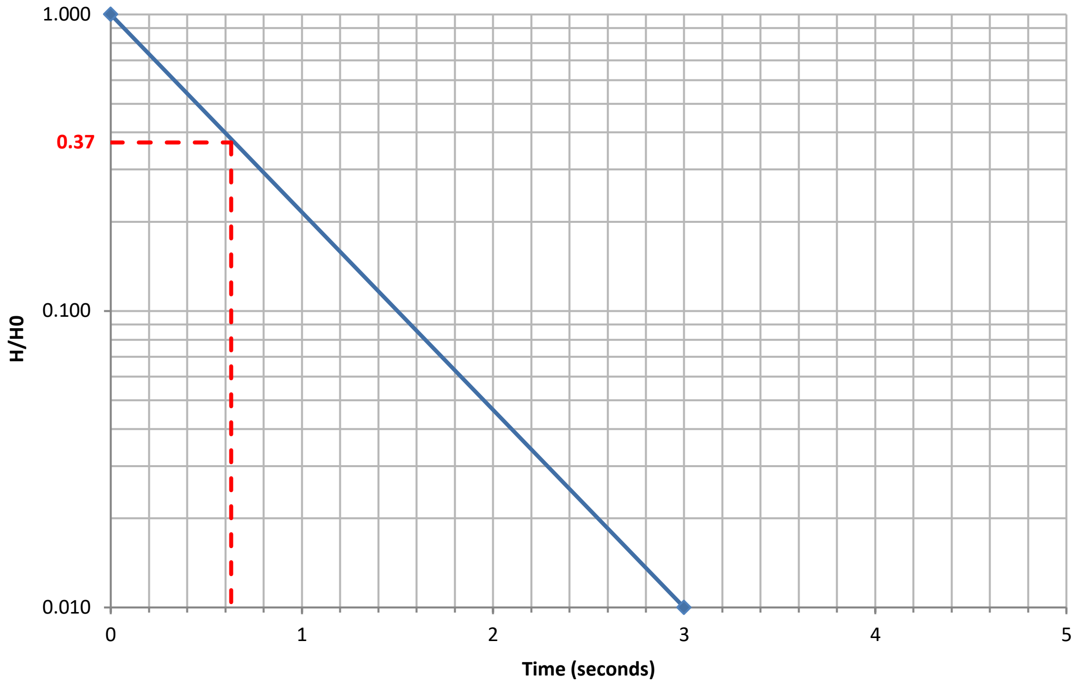

Representation of the time-dependent correct hydraulic head *hcor(t)*, ratio chart

Test observations:

TIME (mins)	DEPTH TO WATER (m)	TIME (mins)	DEPTH TO WATER (m)
0	4.27		
0.05	4.31		

Calculations:

$$k = \frac{r^2 \cdot \ln\left(L/R\right)}{2 \cdot L \cdot t_o}$$

Test section prepared to Figure 2c/2d in accordance with BS EN ISO 22282-2-2012.

r is the radius of the measuring tube (m) = 0.0315
R is the radius of the test section (m) = 0.0315
L is the length of the test section (m) = 1.69
t_o is the time it takes for the water level to rise or fall to 37 percent of the initial change in head (s) = 0.63

k is the coefficient of permeability (m/s) = 1.86E-03

Groundwater observations
Groundwater encountered at 41m depth, rising to 39.3 on completion.

Geology unit under test
Made Ground

Borehole depth (m)
42

Borehole diameter (m)
0.063

Title
Hvorslev method in accordance with BS EN ISO 22282-2:2012.

Co-ordinates
-

Cycle number
3

Date
27/02/2019

Ground level
25.50 (m OD)

Borehole number
BH03

STRATA					WATER STRIKES	IN SITU TESTING		SAMPLING		
DESCRIPTION	DEPTH (m)	REDUCED LVL (m OD)	LEGEND			TYPE / DEPTH (m)	RESULT	FROM (m)	TO (m)	TYPE
Red SCREED. (MADE GROUND)	0.05									
Light grey reinforced CONCRETE comprised of aggregates of flint up to 20mm nominal size. 10mm reinforcement bar located at 110mm depth. Approximately 1.5% air voids. Blue membrane at base. (MADE GROUND)	0.22									
Brown SAND. (MADE GROUND)	0.30									
Brown sandy GRAVEL. Gravel consists of fine to coarse angular brick and flint. (MADE GROUND)	1.05							0.70		ES
								0.80		ES
TRIAL PIT TERMINATED AT 1.05m										

Key

D Small Disturbed Sample
B Bulk Disturbed Sample
ES Environmental Sample
W Water Sample
C Core sample
UT Undisturbed Sample

S Standard Penetration Test
C Standard Penetration Test (solid cone)

PP Pocket Penetrometer test
SV Shear Vane test
PID Photo Ionisation Detector test

Notes

Trial pit sides remained upright and stable upon completion. Drill probe completed at base of excavation to a total depth of 2m below ground level with no obstruction encountered.

Groundwater observations

No groundwater encountered.

Title Trial pit record	**Dimensions (w x l)** 0.30m x 0.30m	
Method Hand tools	**Logged by** DN	**Date(s)** 25/02/2019
Level (m OD) -	**Compiled by** JJ	**Sheet number** Sheet 1 of 1
Co-ordinates -	**Checked by** KB	**TP01A**

Report ref: STR4646-G01 **Revision:** 0

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STRATA				WATER STRIKES	IN SITU TESTING		SAMPLING		
DESCRIPTION	DEPTH (m)	REDUCED LVL (m OD)	LEGEND		TYPE / DEPTH (m)	RESULT	FROM (m)	TO (m)	TYPE
Red SCREED. (MADE GROUND)	0.05								
Light grey reinforced CONCRETE comprised of aggregates of flint up to 20mm nominal size. 10mm reinforcement bar located at 130mm and 168mm depths. Approximately 1.5% air voids. Blue membrane at base. (MADE GROUND)	0.20								
Brown SAND. (MADE GROUND)	0.25						0.30		ES
Brown sandy GRAVEL. Gravel consists of fine to coarse angular brick and flint. (MADE GROUND)	0.37								

TRIAL PIT TERMINATED AT 0.37m

Key

D Small Disturbed Sample
B Bulk Disturbed Sample
ES Environmental Sample
W Water Sample
C Core sample
UT Undisturbed Sample

S Standard Penetration Test
C Standard Penetration Test (solid cone)

PP Pocket Penetrometer test
SV Shear Vane test
PID Photo Ionisation Detector test

Notes

Trial pit sides remained upright and stable upon completion. Trial pit terminated due o competency of materials. Drill probe completed at base of excavation to a total depth of 1.9m below ground level with no obstruction encountered.

Groundwater observations

No groundwater encountered.

Title Trial pit record	**Dimensions (w x l)** 0.30m x 0.30m	
Method Hand tools	**Logged by** DN	**Date(s)** 25/02/2019
Level (m OD) -	**Compiled by** JJ	**Sheet number** Sheet 1 of 1
Co-ordinates -	**Checked by** KB	**TP01B**

Report ref: STR4646-G01 **Revision:** 0

Proposed redevelopment
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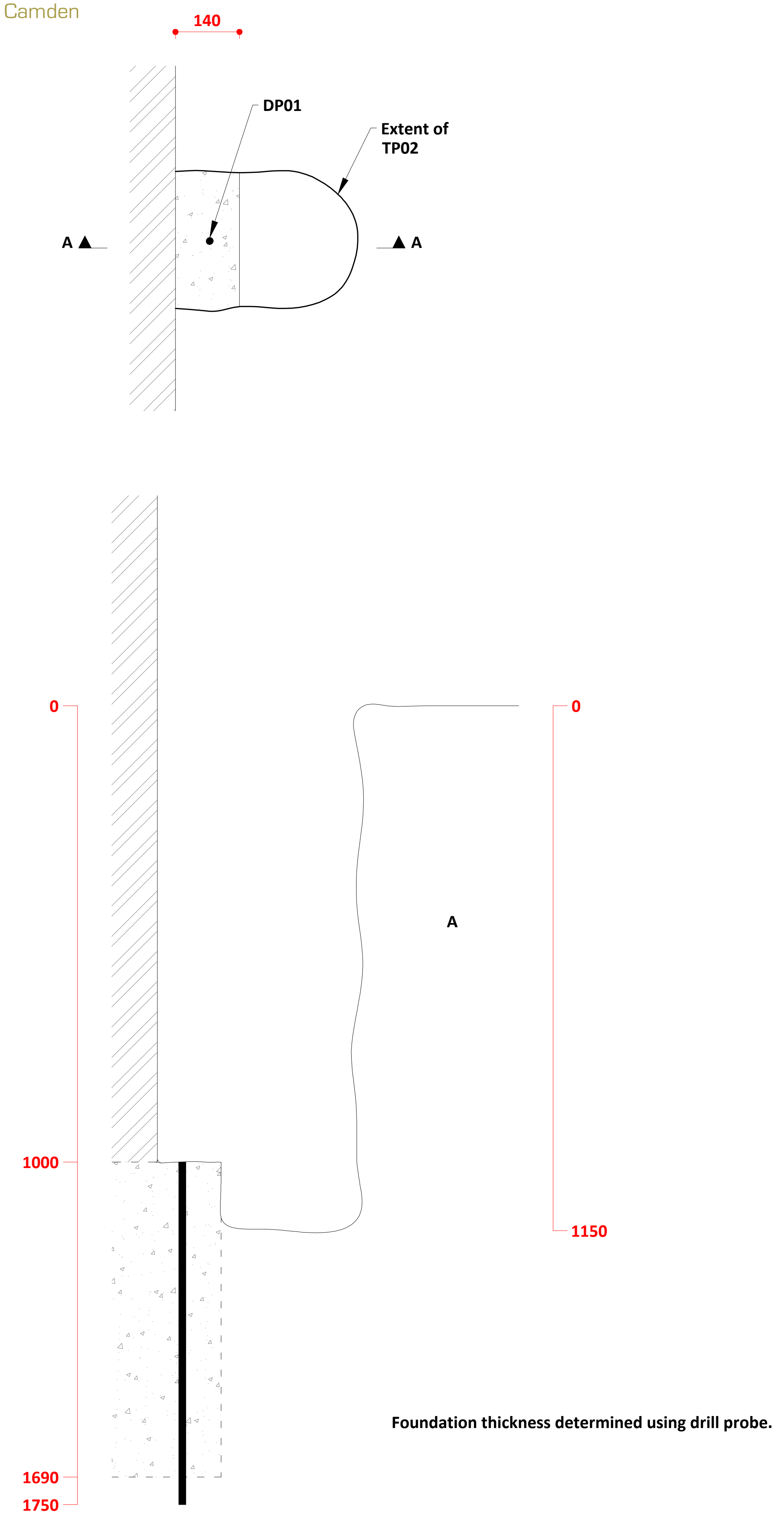

Photographic record

Key

A. Grass onto brownish very gravelly fine to coarse SAND with frequent cobbles of brick and rare boulder of sub-rounded concrete. Gravel consists of fine to coarse brick, concrete, metal, slate, flint, timber and plastic. (MADE GROUND)

Observed features
Assumed features

Notes

1. All dimensions shown in millimeters
2. Disturbed samples taken from 0.2m, 0.6m and 0.9m depths
3. Trial pit sides remained upright and stable

Method of excavation Hand tools		Title Trial pit record	Location reference TP02
Dimensions As shown		Date of works 25.02.2019	Location plan on drawing number 02
Groundwater observations No groundwater encountered		Scale 1:12.5 at A3	Appendix D

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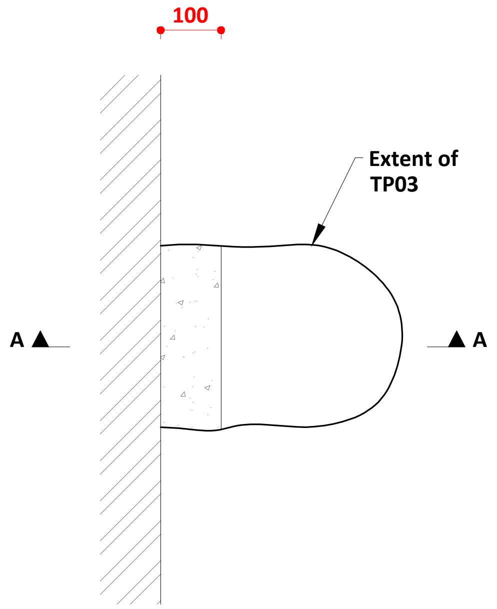
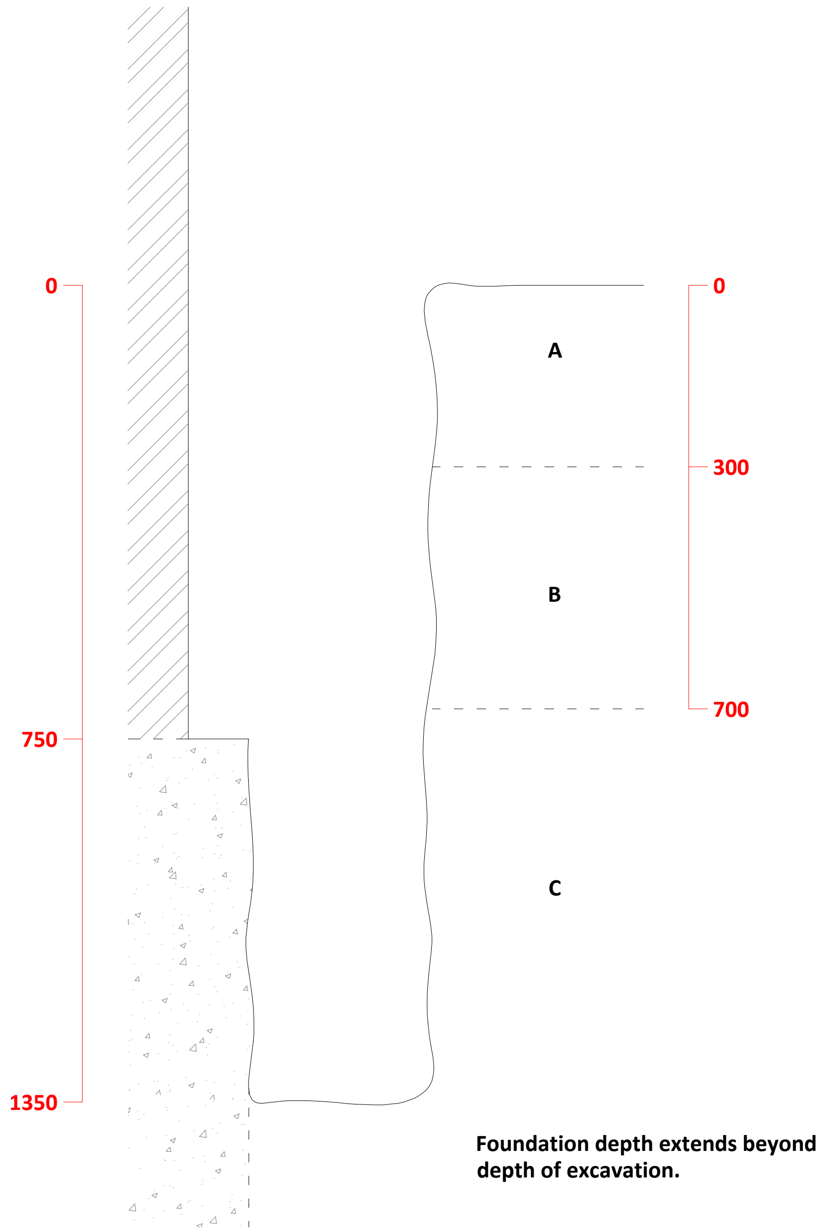
Plan



Section A-A



Photographic records

Key

A. Loose dark greyish brown slightly clayey gravelly SAND with occasional roots up to 10mm diameter. Gravel consists of fine to coarse sub-angular brick, concrete, plastic and glass.
(MADE GROUND)

B. Loose orange brown gravelly fine to medium SAND. Gravel consists of fine to coarse sub-angular brick and concrete.
(MADE GROUND)

C. Loose to medium dark brown gravelly fine to coarse SAND with frequent cobbles of angular brick and concrete. Gravel consists of fine to coarse angular brick, concrete, plastic, clinker and porcelain.
(MADE GROUND)

——— Observed features
– – – – Assumed features

Denotes brickwork **Denotes concrete**

Notes

1. All dimensions shown in millimeters
2. Disturbed samples taken from 0.2m, 0.6m and 0.9m depths
3. Trial pit sides remained upright and stable

Method of excavation Hand tools	Title Trial pit record	Location reference TP03
Dimensions As shown	Date of works 25.02.2019	Location plan on drawing number 02
Groundwater observations No groundwater encountered	Scale 1:12.5 at A3	Appendix D

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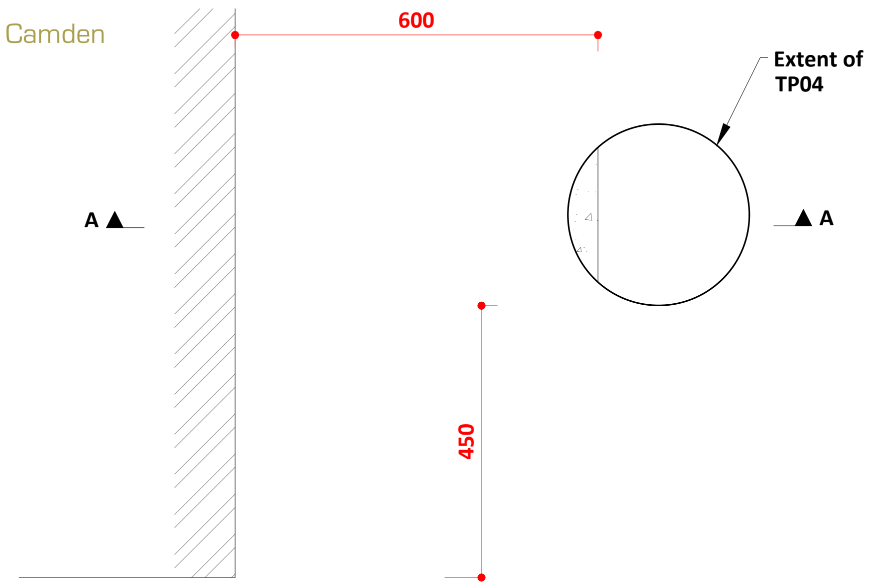
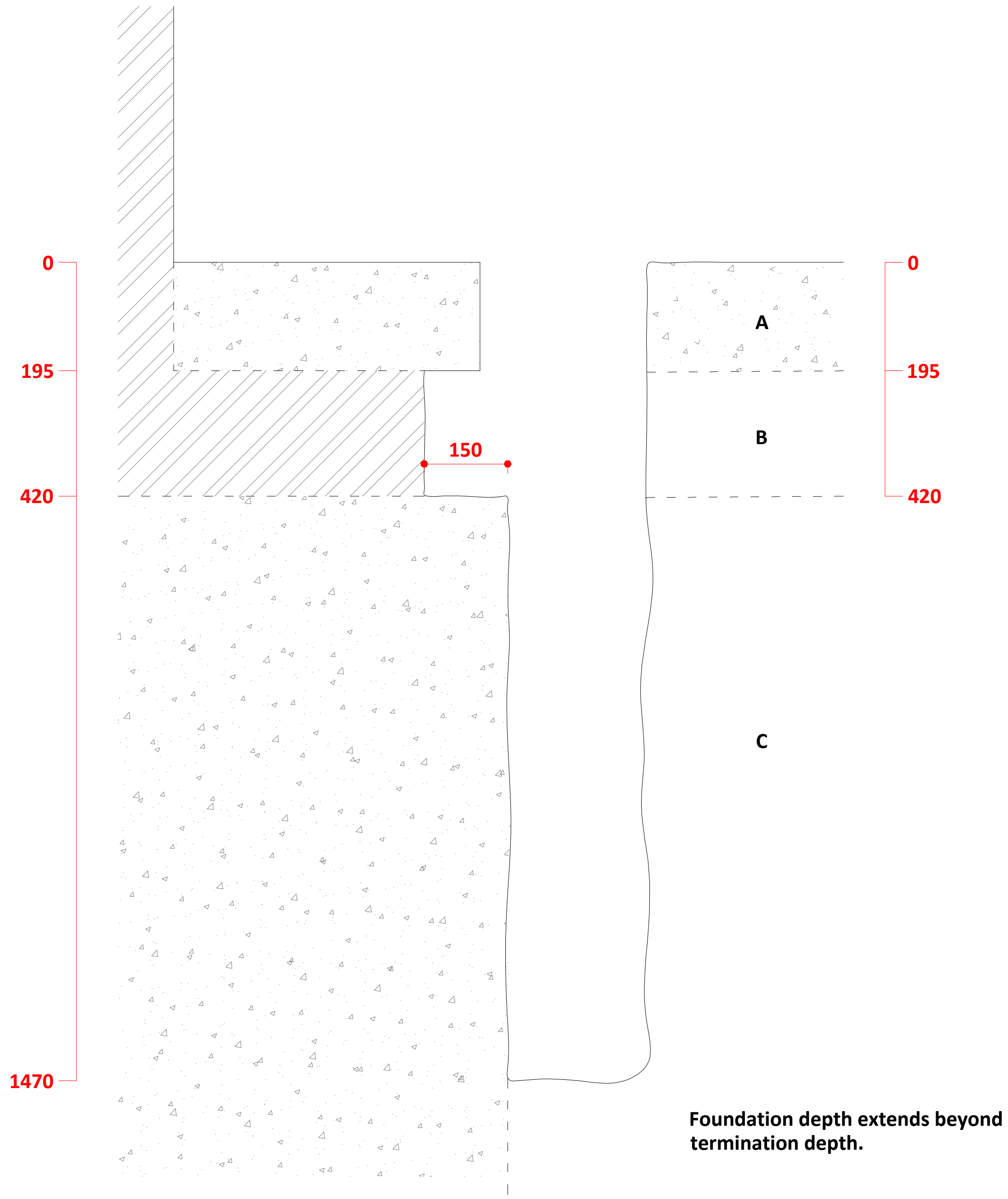
Plan



Section A-A



Photographic records

Key

A. Light grey reinforced CONCRETE comprised of aggregates of flint up to 20mm nominal size. 10mm reinforcement bar located at 72mm depth. Approximately 1% air voids.
(MADE GROUND)

B. Orange brown gravelly SAND. Gravel consists of fine to medium flint.
(MADE GROUND)

C. Loose brown slightly clayey very gravelly SAND. Gravel consists of fine to coarse sub-angular to sub-rounded flint, brick, concrete and sheet metal.
(MADE GROUND)

Observed features
Assumed features

Denotes brickwork
Denotes concrete

Notes

1. All dimensions shown in millimeters
2. Disturbed samples taken from 0.2m, 0.6m and 0.9m depths
3. Trial pit sides remained upright and stable

Method of excavation		Title	Location reference
Hand tools		Trial pit record	TP04
Dimensions		Date of works	Location plan on drawing number
As shown		25.02.2019	02
Groundwater observations		Scale	Appendix
No groundwater encountered		1:12.5 at A3	D