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Site Investigation, Land Contamination Assessment and Remediation Strategy

October 2018

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Proposed redevelopment
Melliss Avenue
Richmond
London

Ground Investigation Report
Revision 01

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GROUND INVESTIGATION REPORT

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Registered to:
ISO 9001 • ISO 14001 • OHSAS 18001

Aerial photograph of site

The approximate site boundaries are highlighted in magenta

Amendments made to the previous version of this report is indicated with a black vertical line in the left-hand margin.

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Report status and format

Report section	Principal coverage	Report status	
		Revision	Comments
1	Executive summary	01	Following comments from the client
2	Introduction		
3	Desk study information and site observations	01	Following comments from the client
4	Fieldwork	01	
5	Laboratory testing	01	
6	Ground conditions encountered	01	
7	Geotechnical Appraisal	01	
8	Chemical contamination	01	
9	Gaseous contamination	01	
10	Effects of ground conditions on building materials		
11	Classification of waste soils under the Waste Acceptance Criteria	01	Following comments from the client
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 undrained shear strength derived from insitu density testing and laboratory test results in the London Clay.	01	Following comments from the client
05	Section showing construction of standpipes installed in boreholes BH01, BH03, BH04 and BH06.		

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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			
C	Details of insitu testing in boreholes			
D	Trial pit records (hand excavated)			
E	Borehole records (Cable and tool percussion drilling and driven tube sampling)			
F	TRL probe records			
G	Copies of laboratory test result certificates (Soil Engineering)	Soil classification testing		
		Triaxial testing		
		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 (soil)			
J	Analysis and summary of test data in relation to concentrations of chemical contaminants (concrete)			
K	Conceptual models for chemical contamination			
L	Record of in-situ gas monitoring results		01	
M	Landfill waste acceptance criteria – Primary classification			
N	Landfill waste acceptance criteria – Secondary classification			
O	Landfill waste acceptance criteria – Basic categorisation schedules			
P	Copy of drawing showing location of services across the site			
Q	Copy of desk study information produced by Envirocheck			

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1 Executive summary

General

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

Site description, history and development proposals

The site comprises a disused Biothane plant located off Melliss Avenue, Richmond, London. The nearest watercourse is the River Thames, the channel of which lies some 18m to the east of the site. At the time of the investigation, the tank structures and infrastructure associated with the former biothane plant remained on site, although were fully decommissioned. The central area of the site contained the main structures and was surfaced in concrete, which extended to the site access to the south. The surrounding areas were generally laid to grass. The levels on site slope from the northern, southern and western boundaries, toward the centre of the site. A bund, approximately 2m high, is located along the eastern boundary.

Inspection of historical maps dating back to 1868 indicate the site was occupied by filter beds associated with an adjacent drainage works from the 1930s until the biothane plant was recorded on site in the 1990s.

We understand the scheme will comprise the construction of a 5-6 storey residential care home with access roads and landscaped garden. No basement is proposed as part of the development.

Ground conditions encountered

The exploratory excavations encountered Made Ground to depths between 1.7m and 4.4m, with such soils generally deepening towards the south. Where shallower Made Ground was encountered, Alluvium was present beneath and extended to a depth of between 2.6m and 2.9m. Beneath the Made Ground/Alluvium, Kempton Park Gravel extended to depths of around 6m with the London Clay at depth. Groundwater was encountered, generally within the Kempton Park Gravel at depths between 2-5m.

Foundation solution

Based on the depth and variable nature of the Made Ground and Alluvium, a piled foundation solution is recommended. Should a basement be required then a raft foundation may be possible however a settlement check will need to be completed using a proposed load per m^2 provided by the Structural Engineers. The potential significant inflow of groundwater beyond 2.5m depth would also need to be considered as this may make construction of a basement difficult.

Proposed hardstanding areas will be located at or about existing ground levels with formation located on Made Ground soils. A CBR design value of 10% has been derived from DCP testing.

Chemical and gaseous contamination

Elevated concentrations of metals and PAH have been identified within near surface Made Ground soils. In addition, asbestos fibres/clumps have been identified in one location. On this basis, we recommend introduction of a capping layer within all proposed garden/landscaped areas.

Potential sources of landfill gas have been identified on and close to the site. We have implemented a gas monitoring regime with results suggesting the site can be classified as characteristic situation 2 and traffic light colour Amber 1. On this basis, gas protection measures are required to achieve a '*gas protection score'* of 3.5.

Given the depth of Made Ground and the presence of contamination, it is considered likely that barrier water pipes will need to be installed. We recommend Thames Water are consulted on this to determine their requirements.

Landfill classification

Comparison of test data with landfill waste acceptance criteria indicates that Made Ground soils *not containing asbestos fibres* are suitable for disposal as stable non-reactive hazardous waste in non-hazardous landfill.

Wastes containing greater than 0.1% free and dispersed asbestos fibres are classified as hazardous waste with the code 17 05 03*. At this stage, we have not undertaken asbestos quantification. However, given only one of the twelve samples screened produced a positive identification, we would recommend additional sampling and testing for asbestos, including quantification if identified, be undertaken within the proposed garden area to further refine the classification of Made Ground for off-site disposal.

Natural soils can be classified as inert waste.

Unexploded Ordnance

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. According to their response, we understand that the area was subject to bombing during WWII and at least three bombs struck the site footprint. 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
2.2	Status of this report
2.3	Client instructions and confidentiality
2.4	Site location and scheme proposals
2.5	Report format and investigation standards
2.6	Report distribution

2.1 Objectives

2.1.1 This report describes a ground investigation carried out for the proposed redevelopment of a former Biothane plant off Melliss Avenue, Richmond, London, TW9 4BD.

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 sections 120 and 121.

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 March 2018 and was reported in May 2018 acting on instructions received from AKT II on behalf of our client, Melliss Ave Devco Ltd.

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 email to AKT II, dated 5th February 2018 and were generally in accordance with their briefing document ref.3859 dated January 2018. The investigation generally followed our original investigation proposals. The investigation process was also determined to maintain as far as possible the original investigation budget costs.

2.4 Site location and scheme proposals

2.4.1 The National Grid reference for the site is 519780, 176920. 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 a 5-6 storey residential care home with access roads and landscaped garden. No basement is proposed as part of the development.

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 This investigation integrates both contamination and geotechnical aspects. The investigation was 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*'. Sections 2 to 6 form a Ground Investigation Report as set out in BS EN 1997:2 2007 '*Eurocode 7 – Geotechnical Design – Part 2: Ground Investigation and Testing*'.

2.5.3 The investigation process also followed the principles of BS10175: 2011 *'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

2.5.4 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.

2.5.5 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, 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

3 Desk study information and site observations

3.1	General
3.2	Description of the site
3.3	Injurious and invasive weeds and asbestos
3.4	History of the site
3.5	Geology and geohydrology of the area
3.6	Landfill and infilled ground
3.7	Radon
3.8	Flood risk
3.9	Enquiries with statutory undertakers
3.10	Enquiries with Local Authority Building Control and Environmental Health Officers
3.11	Unexploded Ordnance (UXO) Risk

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 1866 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 including:

- Ordnance Survey
- Environment Agency
- Scottish Environment Protection Agency
- The Coal Authority
- British Geological Survey
- Centre for Ecology and Hydrology
- Countryside Council for Wales
- Scottish Natural Heritage
- Natural England
- Health Protection Agency

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 Q. 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 a disused Biothane plant located off Melliss Avenue, Richmond, London. The nearest watercourse is the River Thames, the channel of which lies some 18m to the east of the site. Local topography is relatively flat with a slight slope towards the River Thames.

3.2.2 Melliss Avenue borders the site to the west and partially to the south, beyond which lies residential housing. The remainder of the southern boundary is bordered by disused land. Trees/vegetation and a footpath borders the site to the east, beyond which lies the River Thames. A Media Control Centre, inlet tank and storm tank for a large 2440mm diameter Thames Water sewer is located to the north of the site.

3.2.3 At the time of the investigation, the tank structures and infrastructure associated with the former biothane plant remained on site, although were fully decommissioned (see photographs 01 and 02). The central area of the site contained the main structures and was surfaced in concrete, which extended to the site access to the south. The surrounding areas were generally laid to grass with some concrete pathways and ancillary structures present.

Photograph 01 - View of the site looking north-west.

Photograph 02 - View of the site looking north.

3.2.4 In the central part of the site, four large above ground tanks were located to the north and west, while the base of a gas holder and Biothane Generator (which had already been removed) were present toward the south-east (see photograph 03). Former hydrochloric acid and sodium hydroxide tanks were located to the east of the central area. A metal framed structure was located in the south western corner of the site which housed a number of large pipes and presumed storage tanks on the top of the structure (see photograph 04).

Photograph 03 - View of the former gas holder base in south eastern corner of the site. View looking north.

Photograph 04 - View of the metal framed building in the south-western corner of the site. View looking west.

3.2.5 The levels on site slope from the northern, southern and western boundaries, toward the centre of the site. A bund, approximately 2m high, is located along the eastern boundary (see photograph 05). Levels beyond the bund slope down towards the footpath to the east.

Photograph 05 –

View of the bund along the eastern boundary of the site. View looking north.

3.2.6 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 your 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, however, we recommend specialists in the identification and procedures to deal with injurious and invasive weeds are appointed prior to commencement of any works on site.

3.3.2 Asbestos

3.3.2.1 Our investigations exclude surveys to identify the presence or indeed absence of asbestos on site. It should be noted however, that where intrusive investigations were undertaken we did not observe any obvious evidence of potential asbestos containing materials. This information does not constitute a site-specific risk assessment and we recommend specialists in the identification and control/disposal of asbestos are appointed prior to commencement of any works on 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
1868 to 1874	The site is undeveloped and recorded as marsh/osiers with trees/brushwood present. The site and surrounding areas are split into several small plots.	The bank of the River Thames is located immediately adjacent to the eastern boundary of the site. The surrounding area is predominantly undeveloped.
1896 to 1898	The site is still largely undeveloped but no longer recorded as marsh/osiers or split into smaller plots. The south of the site is covered with hardstanding associated with the adjacent site. Sluices are recorded to the north of the site. Embankments or cutting slopes are recorded along the eastern boundary and across the southern half of the site.	The site immediately south is recorded as a Main Drainage Works with multiple filter beds, a pumping room and precipitation tanks. Significant residential development has occurred some 500m to the west and some development has also occurred on the eastern bank of the River Thames.
1913 to 1920	Embankments are recorded to the north, east and west of the site, falling in towards the centre of the site. Sluices are no longer recorded. Adjacent allotments encroach the site to the west. A site access appears to be present in the south-western corner from the adjacent drainage works.	Allotments are recorded to the west of the site. Residential development now within 250m of the site in a westerly direction and further development has occurred to the east of the river.
1933 to 1935	The site is now developed as part of the Main Drainage Works. Four filter beds are recorded on site. The majority of the former embankments are no longer recorded.	The allotments to the west are also part of the Main Drainage Works. Significant development has occurred in the surrounding area. A large building recorded as a claims and record office is recorded approximately 120m to the north. A motor works is located approximately 170m to the west of the site.
1940 to 1949	No significant change	The motor works to the west of the site has been extended.

Summary description of site history from Ordnance Survey maps		
Date	**Onsite**	**Offsite**
1960 to 1967	Embankments are recorded around the filter beds, with levels falling into the site. Two small structures are located along the southern boundary.	A number of rectangular features (possible filter beds) are recorded on the adjacent site to the west.
1974 to 1985	No significant change.	Sludge beds are recorded to the north of the site. Some of the rectangular features to the west are no longer recorded.
1988	No significant change.	Sludge beds recorded on land to the west. Former motor works to the west now recorded as warehouses.
1991	No significant change.	The warehouse buildings to the west have been demolished.
1999	The site has been redeveloped, concurrent with existing layout of the site.	The sludge beds to the north and west are no longer recorded. A shopping centre has been developed in the area of the former warehouses to the west. The office buildings to the north have been redeveloped.
2006 to 2018	The site is recorded as a sewage works	The surrounding land associated with the Main Drainage Works has been redeveloped for predominantly residential housing.
Table 3.4.1		

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 Q). 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**
Made Ground	N/A	Unknown	Unknown	Unknown	N/A
Alluvium	Superficial	2-3m	Clay, silt, sands and gravels	Variably permeable	Secondary undifferentiated
Kempton Park Gravel	Superficial	4m	Sand and gravel	Moderately permeable	Secondary A
London Clay	Bedrock	50m	Clays	Impermeable	Unproductive strata
Table 3.5.1.1					

3.5.1.2 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.

3.5.1.3 Secondary undifferentiated aquifer is a designation used when it is not possible to attribute fully one of either Secondary A or Secondary B, due to the variable nature of the soils. The unit will therefore be a mix of both, which are defined as follows:

- Secondary A can be defined as: Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.
- Secondary B can be defined as: layers which may store limited amounts of ground water. These groundwater stores are generally the water bearing parts of former aquifers.

3.5.1.4 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.

3.5.1.5 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.

3.5.2 Water abstractions

3.5.2.1 Three active ground water abstraction points are located within 1000m of the site. The closest groundwater abstraction point lies 366m to the north west of the site with water abstracted for industrial/commercial/public services use (evaporating cooling). There are no active surface water abstractions within 1000m of the site.

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 Coal mining and brine extraction

3.5.3.1 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).

3.5.4 Shallow mining and natural subsidence hazards

3.5.4.1 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	No hazard
Potential for compressible ground stability hazard	Very low
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 3.5.4

3.5.4.2 The potential for shrinking or swelling clay is recorded by Envirocheck as a moderate risk on site. This is considered to be associated with the Alluvial deposits and potentially the London Clay Formation at depth, which are likely to be cohesive in nature and potentially compressible.

3.5.5 Borehole records

3.5.5.1 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 Q. We do not normally obtain copies of these records but can do on further instructions. There is normally a charge made by the BGS for retrieving and copying these records.

3.6 Landfill and infilled ground

3.6.1 A number of historic landfill sites are recorded in the area. The following table summarises these landfill sites:

Summary of Landfill sites

Landfill name	Type	Location	Waste authorised	Last input date
Cubitts Basin	Historical	201m SE	Inert and industrial	Not supplied
Ibis Rowing Club	Historical	460m SE	Not supplied	Not supplied
Hartington Road Sports Ground	Historical	499m SE	Inert and industrial	1934
Hartington Road Sports Ground	Historical	616m SE	Not supplied	1935
Staveley Road	Historical	698m NE	Inert waste	1951
Dukes Meadow	Historical	712m SE	Not supplied	1950

Table 3.6.1

3.6.2 In addition to the above, Envirocheck records four areas of potentially infilled land (non-water) within 1000m of the site. Three of these areas are associated with the landfills detailed in table 3.6.1. The fourth is located 987m to the north of the site. Envirocheck also record one BGS mineral site within 1000m of the site. The former quarry is located 803m to the north-east of the site, within the area of the Staveley Road landfill.

3.6.3 Inspection of geological maps indicates the site is located within a large area of Made Ground, which follows the channel of the River Thames.

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 "*Radon: guidance on protective measures for new buildings*" (2007), 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 located within an area at risk of flooding (Zone 3) but the site and surrounding area benefits from flood defences. The site is generally not recorded to be at risk of surface water flooding with the exception of the centre of the site, which is recorded to be at a low risk. The site is also recorded to be in an area where there is a potential for groundwater flooding to occur at surface.

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 Statutory undertakers records have been provided by the client. Copies of the service plans, together with a topographic and service plan drawing, are presented in Appendix P.

3.9.2 It should be noted that there are multiple services which cross the site. We are not aware that the supply to such services is capped off and as such they should be treated as live until further information indicates otherwise.

3.10 Enquiries with Local Authority building control and environmental health officers

3.10.1 We have contacted Local Authority Building Control with regard to any information they can provide about the local area. They have suggested that fill/Made Ground is present in the area and does contain contamination. They have also stated that piling is a common foundation solution as is provision of a gas membrane system.

3.10.2 We have contacted Local Authority Environmental Health Officers however we are yet to receive a response. We can follow this up, if required, on further instruction.

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 at least three bombs struck within the site boundaries during WWII. 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, no metallic objects were detected on the seven 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.

4 Fieldwork

4.1	General
4.2	Site restrictions
4.3	Exploratory trial pits
4.4	Light cable percussion boring
4.5	Driven tube sampling
4.6	Diamond coring
4.7	TRL dynamic cone penetration testing
4.8	Measurement of landfill type gases in gas monitoring standpipes
4.9	Sampling strategies

4.1 General

4.1.1 Fieldwork was undertaken between the 12th and 15th March 2018 and comprised the following activities:

- Excavation of seven exploratory trial pits.
- Excavation of three exploratory boreholes using cable and tool percussion drilling techniques.
- Excavation of four exploratory boreholes formed using driven tube sampling equipment.
- Concrete coring in four positions.
- Eight TRL-DCP probes for CBR analysis.

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 and Client's Engineer.

4.1.4 Exploratory points were positioned to avoid known locations of underground services and to provide a reasonable coverage of the site. 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 Although the site was disused at the time of investigation, it was situated within a gated residential community and as such, the hours of work were limited to 8am-5.30pm to reduce the affect of noise on the neighbouring properties. Restrictions on site were limited by the presence of services and existing infrastructure on site. Some areas of the site were inaccessible for both the shell and auger rig and the driven tube rig, due to the presence of tanks, pits and other obstructions. In addition to this, a bund was present along the eastern boundary of the site which was relatively steep and as such, also inaccessible for the rigs.

4.3 Exploratory trial pits

4.3.1 Trial pits TP01 to TP07 were excavated using hand tools to a maximum depth of 1.2m. Where necessary, an electrically-powered breaker was used to loosen surface concrete prior to excavation.

4.3.2 Trial pits exposed foundation arrangements to existing tanks within the site. Sampling and logging was carried out as trial pit excavations proceeded. The density of granular soils encountered in excavations was gauged by the ease of excavation.

4.3.4 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.

4.3.4 Trial pit records are presented in Appendix D.

4.4 Light cable and tool percussion boring

4.4.1 Boreholes BH01, BH03 and BH06 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.

4.4.2 On completion of excavations the boreholes were backfilled with excavated soils and cement bentonite grout where standpipes were installed.

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. A sub sample was obtained discarding soil, which would have been in contact with the drilling rig cutting shoe. Samples were 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 Bulk soil samples for identification or subsequent 'classification' laboratory testing were taken from borehole cutting equipment. The samples were placed in plastic bags 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).

4.4.5 '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.

4.4.6 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 C. The drive rods were type AW up to 20m depth and type BW for depths in excess of 20m. 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.

4.4.7 A graphical summary of standard penetration test results is presented on Drawing 04.

4.4.8 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 C. An average of measurements taken at a specific depth are recorded on borehole records. The pocket penetrometer is not covered by British Standards.

4.4.9 A graphical summary of pocket penetrometer measurements is presented on Drawing 04.

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, BH03 and BH06. 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 installations 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.

4.5 Boreholes formed using driven tube sampling techniques

4.5.1 Boreholes BH02, BH04, BH05 and BH07 were formed using driven tube sampling equipment. Driven tube sampling comprises driving 1m long steel sample tubes which are screw coupled together or coupled to extension rods and fitted with a screw on cutting edge. The sample tubes are of various diameters, generally commencing with 100mm and reducing, with depth, to 50mm and include a disposable plastic liner which is changed between sampling locations in order to limit the risk of cross contamination. On completion of excavation the liner containing the sample is cut open and the soil sample logged by a geo-environmental engineer. The sample tubes are considered thick walled with reference to BS EN ISO 22475-1:2006 clause 3.3.11.

4.5.2 Samples for determination concentration of chemical contaminants are taken from samples obtained in the disposable tubes as sub-samples.

4.5.3 Soil samples for subsequent laboratory 'classification' testing were taken from samples obtained in the disposable tubes. The samples were placed in plastic bags and subsequently sealed and labelled. Samples for determination of water content were placed in sealable tubs and appropriately labelled. These samples were obtained with a view to achieve category B sampling methods to meet quality class 3 (for fine grained soils only) as described in BS EN ISO 22475-1: 2006 (table 3). Sample sizes were appropriate for the laboratory test being considered.

4.5.4 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 C. A summary of standard penetration testing is recorded on borehole logs.

4.5.5 A graphical summary of standard penetration test results is presented on Drawing 04.

4.5.6 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 C. An average of measurements taken at a specific depth are recorded on borehole records. The pocket penetrometer is not covered by British Standards.

4.5.7 A graphical summary of pocket penetrometer measurements is presented on Drawing 04.

4.5.8 A combined gas and groundwater monitoring standpipe was installed in borehole BH04. The standpipe was 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.

4.5.9 The water level in the standpipe has 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 level is measured from ground level at the borehole position. Records of water levels are presented in Section 6.

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

4.5.11 Records of boreholes formed using driven tube sampling techniques are presented in Appendix E.

4.6 Diamond coring

4.6.1 Diamond coring was undertaken through the existing concrete hardstandings in four locations in order to determine the thickness and quality of the concrete.

4.6.2 Coring was carried out using thin wall steel barrels with a diamond tipped cutting edge at a 100mm diameter. The barrel is rotated using an electrically powered motor and when cutting, was lubricated with water and powered by 110 Volt electricity supply. Coreholes were reinstated with concrete on completion.

4.6.3 Core records are presented in Appendix E.

4.7 TRL dynamic cone penetration testing

4.7.1 Transport Research Laboratory Dynamic Cone Penetration (TRL DCP) testing was carried out in five 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.

4.7.2 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 the rate of penetration, and then calculates an equivalent CBR (California Bearing Ratio) value for the layer from the rate of penetration in blows/mm using the following equation:

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

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

4.7.3 It should be noted that TRL DCP testing is not a test defined by British Standards. It is however, widely used and accepted in the industry for determination of equivalent CBR values.

4.7.4 Results and analysis of dynamic cone penetration test data is presented in Appendix F.

4.8 Measurement of landfill type gases in gas monitoring standpipes

4.8.1 The concentrations of landfill type gases collected within gas monitoring standpipes installed in boreholes BH01, BH03, BH04 and BH06 were measured using a portable infra-red gas analyser (model 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.

4.8.2 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)

4.8.3 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.

4.8.4 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.

4.8.5 Records of gas monitoring data are presented in Appendix L.

4.9 Sampling strategies

4.9.1 Geotechnical

4.9.1.1 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

4.9.2 Environmental

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

4.9.3 Sample retention

4.9.3.1 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
5.2	Chemical testing

5.1 Classification and physical testing

5.1.1 Laboratory testing was carried out on samples retrieved from site. The method of testing is recorded on the laboratory test certificate. The following table summarises the classification and physical testing scheduled;

Table summarising classification and physical testing

Exploratory point	Depth (m)	Strata	Soil type	Testing scheduled (determination of)
BH01	0.5-1	Made Ground	Granular	Particle size distribution (by wet sieving)
BH06	0.3-0.8			
BH01	3-3.5	Kempton Park Gravels	Granular	Particle size distribution (by wet sieving)
BH03	3-3.5			
BH06	5-5.45			
BH01	1.8	Made Ground	Cohesive	Water contents and the plastic and liquid limits and plasticity index.
BH06	1.2-1.65			
BH06	3-3.45			
BH01	9	London Clay Formation	Cohesive	Water contents and the plastic and liquid limits and plasticity index.
BH03	6			
BH03	12			
BH05	1.4			
BH06	6.5			
BH07	0.8-1.1			
BH01	5	London Clay Formation	Cohesive	Water contents and the plastic and liquid limits and plasticity index. One-dimensional consolidation Undrained shear strength in triaxial compression without measurement of pore pressure.
BH01	17	London Clay Formation	Cohesive	Water contents and the plastic and liquid limits and plasticity index. Undrained shear strength in triaxial compression without measurement of pore pressure.
BH03	20			
BH01	7	London Clay Formation	Cohesive	Undrained shear strength in triaxial compression without measurement of pore pressure.
BH01	13			
BH01	23			
BH01	27			
BH03	10			
BH03	13			
BH03	16			
BH03	26			
BH06	9-9.45			
BH06	14-14.45			
BH06	18-18.45			
BH06	24-24.45			
BH06	27-27.45			

Table 5.1.1

5.1.2 Laboratory test certificates are presented in Appendix G.

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)	Strata	Soil type	Testing scheduled (Refer to Appendix B for details).
BH01	0.5	Made Ground	Granular	Asbestos screening
BH02	0.3			
BH03	0.5-1			
BH06	0.3-0.8			
TP05	0.2			
TP06	0.1			
TP07	0.6			
TP01	0.3		Cohesive	
TP02	0.2			
BH04	0.1	Made Ground	Granular	Asbestos screening Suite 17
BH05	0.3			
BH07	0.2			
BH01	0.8	Made Ground	Granular	Suite 17
CS01	0-0.25	Concrete	-	Suite 17
CS02	0-0.22			Suite 17
CS04	0-0.22			Suite 17
BH01	3.61	Water	-	Suite 17
BH03	3.42			
CS03	0-0.24	Made Ground	Concrete	Suite 17 Suite 13
BH04	2.6-2.8	Made Ground	Cohesive	Suite 17 (Leachate)
BH07	0.8-1.1			
BH06	7.39	Water	-	Suite 17 Suite 9
BH01	1	Made Ground	Granular	Suite 8
BH05	0.5-1			
TP03	1.1			
BH03	3	Kempton Park Gravels	Granular	
BH06	4-4.45			
BH01	4.7	London Clay Formation	Cohesive	
BH03	16			
BH06	9-9.45			
CS1	-	Made Ground	Granular	Full two-stage WAC Suite 13

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
6.2	Topsoil
6.3	Groundwater
6.4	Evidence of contamination
6.5	Obstructions and instability
6.6	Existing foundation arrangements

6.1 Soils/Rocks

6.1.1 The exploratory excavations encountered the following geological profile, in order of superposition:

- Made Ground
- Alluvium
- Kempton Park Gravel
- London Clay Formation

6.1.2 Made Ground

6.1.2.1 Made Ground extended to depths between 1.7m and 4.4m, with the thickness increasing towards the south. The Made Ground generally comprised medium dense brown slightly to very clayey slightly to very gravelly sand, dark brown to orange brown slightly to very sandy slightly to very gravelly clay. The gravel consisted of flint, brick, clinker, concrete, ash, plastic, pottery, glass, timber and slag. Within boreholes BH04, BH06 and BH07, soils at depth comprised soft to firm very low to low strength dark grey and blue grey slightly gravelly clay with the gravel consisting of flint.

6.1.3 Alluvium

6.1.3.1 Alluvium was encountered beneath the shallower Made Ground in BH01 and BH02. The Alluvium extended to depths of 2.9m and 2.9m respectively. The Alluvium generally comprised soft to firm very low to low strength grey and brown/orange brown slightly gravelly clay. The gravel consisted of flint.

6.1.3.2 The following table summarises test data in the Alluvium.

Table summarising soil testing and derived geotechnical parameters					
Geotechnical parameter	**Method**	**Value range**	**Characteristic value**	**Comments**	**Notes**
Weight density (above water table)	Soil descriptions	15-18	17	Derived from BS 8004 figure 1. Most onerous value to be used in structural design	-
Plasticity index	Laboratory testing	71	70	-	1
Plasticity index (modified)		65	65	-	1
Water content (%)		59	59	-	1
Consistency index		0.72	0.72 (firm)	-	1
Undrained Shear strength (kN/m²)	Insitu testing	13	13	-	2
Table 6.1.3.2					

1. Laboratory testing presented in Appendix G
2. Presented on Drawing 04

6.1.4 Kempton Park Gravel

6.1.4.1 The Kempton Park Gravel was encountered in each borehole and extended to between 4.7m and 6.2m depth where the full depth was proven. The Kempton Park Gravel generally comprised medium dense to very dense grey and orange brown sand and gravel. The gravel consisted of flint.

6.1.4.2 The following table summarises test data in the Kempton Park Gravel.

Table summarising soil testing and derived geotechnical parameters					
Geotechnical parameter	**Method**	**Value range**	**Characteristic value**	**Comments**	**Notes**
Weight density (above water table)	Soil descriptions	18-21	18	Derived from BS 8004 figure 1. Most onerous value to be used in structural design	-
Standard Penetration testing (SPT) (uncorrected)	Insitu testing	17->50	40	Mean of results	2
Uniformity coefficient from particle size distributions	Laboratory testing	11-110	44	Mean of results	1
Table 6.1.4.2					

1. Laboratory testing presented in Appendix G
2. Presented in Appendix C

6.1.5 London Clay Formation

6.1.5.1 The London Clay Formation extended beyond the termination depth of the cable percussive boreholes (>30m). The London Clay Formation generally comprised stiff becoming very stiff high becoming very high brown and orange brown becoming grey/dark grey clay with occasional gravel of shells at depth.

6.1.5.2 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 (above water table)	Soil descriptions	18-22	18	Derived from BS 8004 figure 1. Most onerous value to be used in structural design	-
Plasticity index	Laboratory testing	41-51	45	Mean of results	1
Plasticity index (modified)		38-51	44	Mean of results	1
Water content (%)		27-31	29	Mean of results	1
Consistency index		0.95-1.16	1.06 (very stiff)	-	1
Undrained Shear strength (kN/m^2)	Triaxial testing	85-296	75 at 5m to 190 at 30m	Increases linearly	1
	Insitu testing	75-190	75 at 5m to 190 at 30m	Excluding anomalous (localised soft spots) Increases linearly	2
Standard Penetration testing (SPT) (uncorrected)	Insitu testing	13-50			3
Coefficient of volume compressibility (m^2/MN)	Laboratory testing	0.2	-	Based on laboratory testing	1
Eu/cu Ratio		425	-	Taken from CIRIA C580 report	-
E’	E’ = Eu x 0.75	319	-	Taken from Burland et al (*Building Response to Tunnelling*)	-
Friction Angle in London Clay		24-28	-		-

Table 6.1.5.2

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

6.1.6 Summary

6.1.6.1 The following table summarises the geology encountered:

Table summarising soil types				
Strata	**Depth to top (m)**	**Depth to bottom (m)**	**Thickness (m)**	**Summary description**
Made Ground	0.0	1.7-4.4	1.7-4.4	Brown, dark brown and orange brown clayey gravelly sand/sandy gravelly clay. Gravel includes flint, brick, clinker, concrete and ash.
Alluvium (where encountered)	1.7-1.8	2.6-2.9	0.8-1.2	Grey brown slightly gravelly clay. Gravel consists of flint.
Kempton Park Gravel	2.6-4.4	4.7-6.2	2.1-2.6	Grey and orange brown sand and gravel
London Clay Formation	4.7-5.3	>30	Not proven	Grey brown clay
Table 6.1.6.1				

6.1.6.2 The investigation generally confirmed published geological records.

6.2 Groundwater

6.2.1 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	10.04.18	3.58	Standing level measured during monitoring visit
	28.03.18	3.77	
	25.04.18	3.64	
	09.05.18	3.69	
BH02	14.03.18	3.54	Measured 30 minutes after completion
BH03	12.03.18	4.8m	Rose to 4.1m. Sealed out at 6.0m
	10.04.18	3.62	Standing level measured during monitoring
	28.03.18	2.53	
	25.04.18	3.7	
	09.05.18	3.88	
BH04	14.03.18	2.3m	Measured 10 minutes after completion
	10.04.18	2.41	Standing level measured during monitoring visit
	28.03.18	2.34	
BH06 (shallow)	10.04.18	4.74	Standing level measured during monitoring visit
	28.03.18	4.66	
	25.04.18	5.06	
	09.05.18	5.09	
BH06 (deep)	10.04.18	4.95	Standing level measured during monitoring visit
	28.03.18	4.67	
	09.05.18	5.1	
BH07	14.03.18	4.4m	Measured 15 minutes after completion
Table 6.2.1			

6.2.2 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.

6.3 Evidence of contamination

6.3.1 During the excavation of our exploratory points, evidence of potential contamination was identified. A summary of these observations is presented below;

Table summarising contamination observations

Exploratory point	Depth of contamination	Strata	Description
BH01	0.72-1.8m	Made Ground	Slight hydrocarbon odour
BH01 to BH07	0.0-4.4m	Made Ground	Gravels including ash, brick, slag, glass, timber.

Table 6.3.1

6.4 Obstructions and instability

6.4.1 No in-ground obstructions or significant instability were encountered during our site investigations.

6.5 Existing foundation arrangements

6.5.1 Foundations were exposed in exploratory pits TP01 to TP07. 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 tank wall	Founding strata
TP01	350mm	755mm	Made Ground
TP02	350mm	760mm	Made Ground
TP03	1550mm	~3080mm	Made Ground
TP04	330mm	400mm	Made Ground
TP05	570mm	1275mm	Made Ground
TP06	70mm	80mm 160mm	Made Ground
TP07	550mm	1420mm	Made Ground

Table 6.5.1

6.5.2 Based on the above, and our understanding of ground conditions it is considered likely that the existing tanks/tank bases and biothane plant buildings are potentially piled.

7 Geotechnical Appraisal

7.1	General description of the development
7.2	Building regulations and this report section
7.3	The geological model
7.4	Building foundation solution
7.5	Determination of pile bearing resistance to BS EN1997-1:2004 (Eurocode 7)
7.6	Influence of trees and other major vegetation
7.7	Ground floor construction
7.8	Service trench excavations
7.9	Infiltration potential
7.10	Pavement foundations
7.11	Reuse of excavated soils from the site

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 The project will comprise the construction of a 5-6 storey residential care home with access roads and landscaped garden. No basement is currently proposed as part of the development, however, should a basement be later included in the proposals, a raft foundation is considered possible however we would require a proposed load per m^2 to be able to assess the potential settlement. It should however be noted that groundwater was recorded within the boreholes from approximately 2.5m depth and due to the close proximity to The River Thames, it is likely that substantial water inflows will be encountered in excavations extending beyond 2.5m depth. A full viability assessment of a raft foundation would therefore be required should a basement be considered.

7.1.3 It should be noted that there is a potential that the existing tanks/tank bases and biothane plant buildings are potentially piled.

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

7.2.2.1 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.

7.3 The geological model

7.3.1 Seven boreholes were formed at the site and ranged in depth between 3.6m and 30m. Each borehole encountered a reasonably consistent 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	Brown, dark brown and orange brown clayey gravelly sand and sandy gravelly clay. Gravel includes flint, brick, clinker, concrete and ash.	1.7-4.4	4	None	-
Alluvium	Grey brown slightly gravelly clay. Gravel consists of flint.	2.6-2.9 (but locally absent)	2.8	None	-
Kempton Park Gravels	Grey and orange brown sand and gravel	4.7-6.2	6	3.5-4.8	3.5
London Clays	Grey brown clay	>30m	30	None	-
Table 7.3.1					

7.4 Building foundation solution

7.4.1 As the proposed building is some 5-6 storeys in height and will generate high internal columns loads, in combination with 4m depth of weak/loose Made Ground and Alluvium, a piled foundation solution will be appropriate.

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. 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 contact 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.

7.5.3.2 Piled foundations would transmit super structural loads down through the Made Ground and Alluvium, to obtain shaft adhesion in the Kempton Park Gravel and London Clay Formation with end bearing support in the London Clay Formation. We recommend any support from the Made Ground and Alluvium 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 ground levels.

7.5.5.2 The ultimate shaft adhesion for piles in London Clay Formation 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			
Kempton Park Gravel (kN/m³) above water	18-21	18	Figure 1 BS 2004:2015 Note a superior value should be used when a high value is unfavourable and an inferior value when a low value is unfavourable.
Kempton Park Gravel (kN/m³) Below water	19-21	19	
London Clay (kN/m³)	18.2-20.4	20	From laboratory measurements (triaxial testing)
Shaft resistance parameters in the Kempton Park Gravels			
Characteristic constant volume effective angle of shearing resistance(ϕ_{cv}°)	37°	37°	From table 1 of BS8004:2015 using particle size distribution data and for fines content ,15%
Soil pile friction angle (δ)	-	37°	From 6.4.1.2.2 of BS 8004:2015 (ϕ_{cv}= δ)
Earth pressure coefficient K_δ	Bored piles	0.7	From table 8 of BS 8004:2015
	CFA Piles	0.9	
Groundwater level (m)		3.5	Based on the geological model and from monitoring
Undrained shear strength in London Clay soils			
London Clay (kN/m²)	75-190	75-190	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.

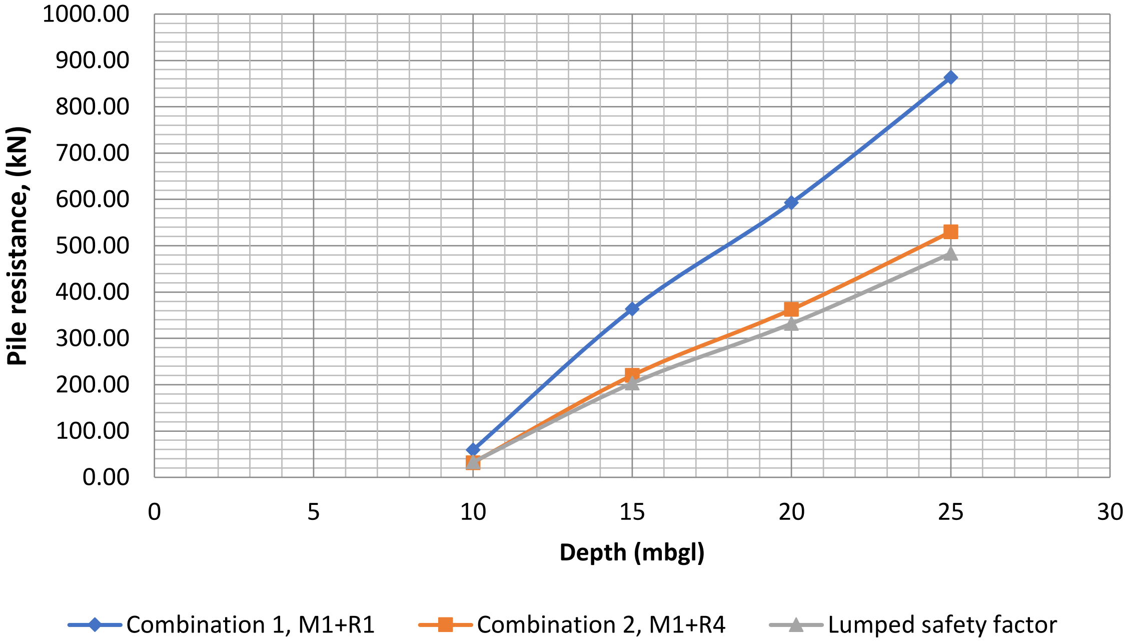
7.5.8 Pile resistances

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.

Chart showing pile resistance by depth for a bored and CFA piles of 300mm diameter



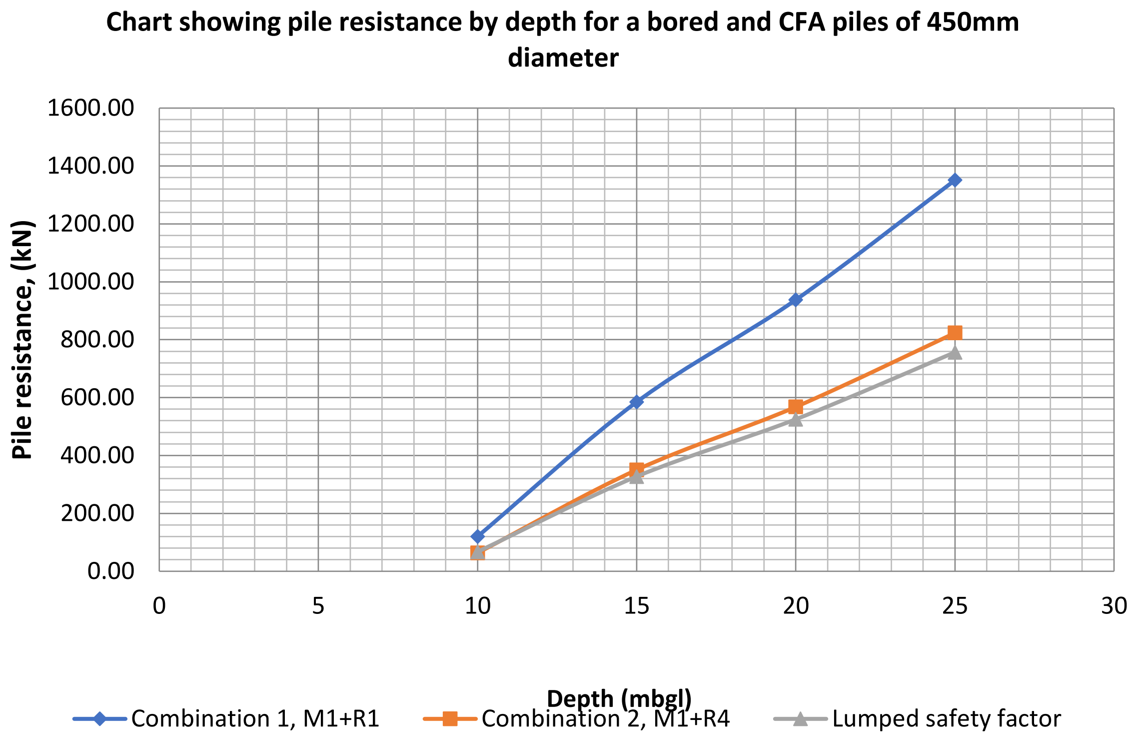


Chart showing pile resistance by depth for a bored and CFA piles of 450mm diameter
Pile resistance, (kN)
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
0
5
10
15
20
25
30
Depth (mbgl)
Combination 1, M1+R1
Combination 2, M1+R4
Lumped safety factor

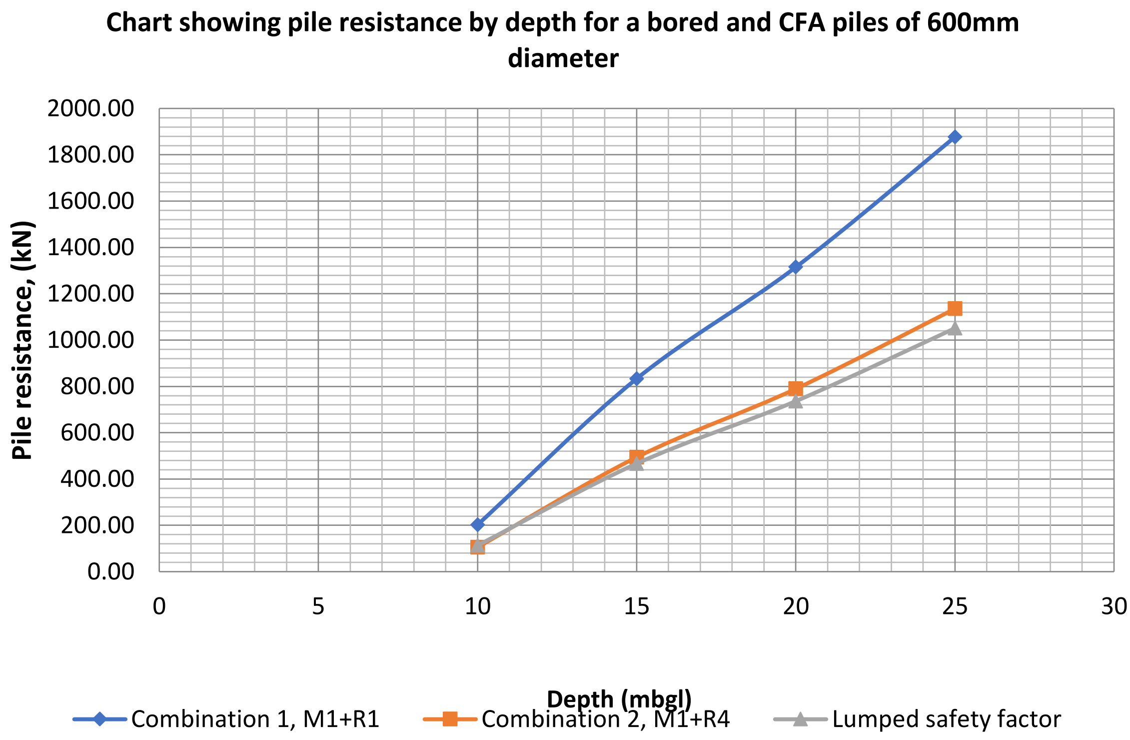


Chart showing pile resistance by depth for a bored and CFA piles of 600mm diameter
Pile resistance, (kN)
2000.00
1800.00
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
0
5
10
15
20
25
30
Depth (mbgl)
Combination 1, M1+R1
Combination 2, M1+R4
Lumped safety factor

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 exploratory excavations encountered granular Kempton Park Gravel deposits which were observed in a dense/very dense state in places. Furthermore, London Clay Formation deposits at depth were also encountered in a very stiff state, and in one location, a localised layer of mudstone rock, 0.3m in thickness, was encountered. 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. Water strikes were encountered in basal deposits of Kempton Park Gravel Formation during excavation of boreholes, with inflows sealed with casing within upper horizons of the London Clay Formation. Groundwater levels measured from standpipes during return monitoring visits have been measured between depths of 2.34m and 5.1m across the site.

7.6 Influence of trees and other major vegetation

7.6.1.1 The results of plastic and liquid limit determinations performed on samples of the Alluvium and London Clay Formation indicate these deposits are soils of high volume change potential when classified in accordance with National House Building Council (NHBC) Standards, Chapter 4.2. Given a piled foundation is recommend, no further consideration of trees and other major vegetation is considered necessary.

7.7 Ground Floor Construction

7.7.1 In view of the thickness of Made Ground at the site, we recommend a suspended ground floor is adopted, supported off piled foundations.

7.8 Service Trench Excavations

7.8.1 It is difficult to predict the stability of trench sides from borehole investigations. Generally, we would anticipate a risk of some over break/instability in the Made Ground deposits.

7.8.2 Excavations extending to depths greater than 2m are at an increasing risk of encountering water inflows, which will promote progressive instability in trench sides, potentially requiring continuous trench sheet shoring to maintain an open excavation. We anticipate water will be controlled with nominal pumping techniques.

7.8.3 Based on trial pit excavations it is considered unlikely that groundwater will be encountered in excavation trenches.

7.8.4 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).

7.9 Infiltration Potential

7.9.1 It is possible that the predominantly granular deposits of the Kempton Park Gravel soils could dispose of storm water using infiltration systems. If such a system is considered as a drainage option, we recommend soil infiltration tests be carried out in accordance with Building Research Establishment Digest 365 (2016) "*soakaway design*" to allow the design of infiltration systems. We would be pleased to carry out such testing on further instructions.

7.10 Pavement Foundations

7.10.1 Criteria for design of the pavement foundation.

7.10.1.1 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). i.e. 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).

7.10.1.2 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).

7.10.2 Methods of determination of CBR values

7.10.2.1 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 7.10.2

7.10.2.2 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.

7.10.2.3 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).

7.10.3 Location of the pavement formation

7.10.3.1 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.

7.10.4 Determination of subgrade CBR using the Dynamic Cone Penetrometer

7.10.4.1 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° 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.

7.10.4.2 These results are input into a standard computer programme developed by the Transport Research Laboratory (TRL) and results are presented in Appendix F with the location of probe positions shown on Drawing 02.

7.10.4.3 For formation at surface onto Made Ground soils, based on the DCP results, utilising an average but discounting significantly low/high values, a subgrade **CBR of 10%** at a depth can be deduced.

7.10.5 Settlement

7.10.5.1 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 15mm 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.

7.10.6 Treatment of formation

7.10.6.1 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.

7.10.7 Subgrade frost susceptibility

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

7.10.8 Moisture susceptibility

7.10.8.1 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.

7.11 Reuse of excavated soils from the site

7.11.1 Generally soils excavated from the site could be reused as bulk filling, if reused at their natural moisture content. We recommend soils be classified and compacted in accordance with the current Highways Agency '*Specification for Highway Works'* (600 series) – table 6/1 (refer www.dft.gov.uk/ha/standards/mchw/vol1).

8 Chemical contamination

8.1	Contaminated land, regulations and liabilities
8.2	Objectives and procedures
8.3	Development characterisation and identified receptors
8.4	Identification of pathways
8.5	Assessment of sources of contamination
8.6	Initial conceptual model
8.7	Laboratory testing
8.8	Updated conceptual model
8.9	Remedial action
8.10	Risk assessment in relation to infiltration systems
8.11	Risk assessment summary and recommendations
8.12	Final conceptual model
8.13	Statement with respect to National Planning Policy Framework
8.14	On site monitoring

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. The investigations were carried out to support a planning application for the site by satisfying National Planning Policies Framework sections 120 and 121. 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	Site comprises a disused biothane plant.
Future land use	Advice	Residential care home with associated landscaped gardens.
Site history	Desk study	The site was undeveloped until it was incorporated into an adjacent drainage works in the 1930s and filter beds were recorded on site. The layout of the site changed to that of present day in the late 1990s and we understand comprised a biothane plant.
Geology	Desk study Site investigation	Made Ground over Alluvium, Kempton Park Gravel and London Clay Formation.
Ground water	Aquifer potential	Secondary (undifferentiated) aquifer in Alluvium and secondary A aquifer in the Kempton Park Gravels. London Clay is recorded as unproductive strata.
	Abstractions	Nearest groundwater abstraction point is 366m north-west with water abstracted for industrial use.
	Source protection zone	Site not within source protection zone
Surface waters	Location	River Thames lies some 18m to the east of the site.
	Abstractions	None within 2000m of the site

Table 8.3.1.1

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 site is disused and secure against public access, we have not considered current site users further. Following completion of the residential care home, although the site will be occupied by adults, it will be accessible to visitors, which may include children. On this basis, the critical site user (receptor) is considered to be a child under the age of 6 years. This criterion has been used in the conceptual model for future site use. Our assessment 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 Vegetation is currently present on site, particularly along site boundaries and the development proposals include areas of soft landscaping. On this basis, both current and proposed vegetation is considered to be a potentially viable receptor.

8.3.5 Water receptors

8.3.5.1 The site is situated on deposits of Alluvium (secondary (undifferentiated) aquifer) and Kempton Park Gravel (secondary A aquifer). On this basis, groundwater is likely to be present beneath the site and is considered to be a potentially sensitive receptor.

8.3.5.2 The nearest surface water feature is the River Thames, located some 18m to the east of the site. Given its close proximity to the site, the River Thames is considered to be a potentially sensitive 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	No	Site disused and secure	-
	End user of the developed site	Yes	Residential care home	Child
	Construction operatives and other site investigators	Yes	To be redeveloped	Adult
Vegetation	Current site	Yes	Vegetation on site	Vegetation
	Developed site	Yes	Vegetation proposed	Vegetation
Controlled waters	Surface waters (Rivers, streams, ponds and above ground reservoirs)	Yes	Site 18m from the River Thames	Surface waters
	Ground waters (used for abstraction or feeding rivers/ streams etc.)	Yes	Site over secondary undifferentiated and secondary A aquifers	Groundwater
Building materials	Materials in contact with the ground	Yes	Assessed in report section 10	Building materials

Table 8.3.6.1

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 8.4.1.1

8.4.1.2 The site will be redeveloped as a residential care home, which will include some landscaped garden areas. There is considered to be a possibility that vegetables could be grown at the site and therefore we consider all the above pathways to be potentially viable.

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

8.4.1.4 A summary of our pathway assessment is presented in Section 8.4.4.

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 A number of pathways exist for the transport of soil contamination to controlled waters. A summary of these pathways is presented below:

- Percolation of water through contaminated soils.
- Near-surface water run-off through contaminated soils.
- Saturation of contaminated soils by flood waters.

8.4.3.2 The near surface soils at the site comprised both coarse and fine soils and therefore percolation of water and near surface water run-off through contaminated soils are both considered potentially viable pathways.

8.4.3.3 The site is located in an area at risk of flooding by rivers but which benefits from flood defences. On this basis, the risk of saturation of contaminated soils by flood waters is considered unlikely.

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
Proposed site users	Child	Ingestion of air-borne dusts
		Ingestion of soil
		Ingestion of soil attached to vegetables
		Ingestion of home grown vegetables
		Inhalation air-borne dusts
		Inhalation of vapours
		Dermal contact with dust
		Dermal contact with soil
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
Vegetation		Root uptake, deposition to shoots and foliage contact.
Controlled waters	Groundwater	Percolation of water through contaminated soils
	Surface water	Near-surface water run-off through contaminated soils

Table 8.4.4.1

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 historically part of a drainage works/sewage works, which extended onto the site to the south. By 1999 the site had been redeveloped into a biothane plant.

8.5.2.3 This former site usage as a sewage works/drainage works is included in *'Sewage works and sewage farms'* published by the department of the Environment, which provides an indication of the type of chemical contaminants likely to be used by the industry. Typical contaminants include organic and inorganic contaminants, hydrocarbons, micro-organisms and potentially asbestos. Clearly, the possibility of potential soil contamination from this former land use would be dependent upon the management of the potential contaminants within this former industry.

8.5.2.4 The former site use as a biothane plant is not included in any of the Department of Environment industry profiles however information available online suggests that likely contaminants include common organic and inorganic contaminants, ammonia and asbestos.

8.5.2.5 Based on the above, potential sources of contamination have been identified from historical on-site activities.

8.5.2.6 In addition to the drainage works to the south, a motor works was recorded some 90m to the west of the site until the 1990s when it was demolished and redeveloped as a retail park. This former site use is included in '*Engineering works – vehicle manufacturing works'* published by the department of the Environment, which suggests that common chemical contaminants associated with this industry include inorganic and organic contaminants, TPHs, solvents and asbestos. However, given the distance from the site, it is considered unlikely of being a significant source of contamination 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 Q), there are two pollution incidents recorded within 100m of the site. The incidents are recorded 29m to the north and 75m to the south and both are classified as category 3 (minor) incidents. The pollutants are recorded as oils (unknown) and unknown sewage respectively. Given their distance and position relative to the site (neither are up-gradient), it is considered unlikely contamination would feasibly migrate from these potential sources to the subject site.

8.5.3.3 Based on the Envirocheck data (refer Appendix Q) there is one historic landfill site located within 250m of the site. The landfill is recorded 201m to the south-east of the site and was licensed to receive inert and industrial waste. Given the distance from the site, it is considered unlikely significant contamination would migrate from this potential source to the subject site. In addition, the site is recorded within an area of Made Ground. The depth and nature of the Made Ground is unknown and is therefore considered to be a potential source of contamination.

8.5.3.4 Envirocheck records one trading activity within 100m of the site. The activity comprises a domestic cleaning service and is not considered to be a source 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 There were a number of disused tanks, pits and structures observed on site, associated with the former Biothane Plant. However, there was no obvious evidence of contamination associated with any of these structures or evidence of ongoing contamination at the site.

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 Made Ground, Alluvium, Kempton Park Gravel and London Clay Formation. Typically, and in our experience, the natural deposits do not exhibit any abnormal concentrations of naturally occurring chemical contaminants. The nature of the Made Ground is unknown and could contain elevated concentrations of chemical contaminants.

8.5.6 Source assessment - Fieldwork observations

8.5.6.1 During excavation of the boreholes and trial pits, we did observe Made Ground extending up to 3.9m depth which included anthropogenic materials such as brick, concrete, slag and ash. These materials are considered potential sources of contaminants such as PAHs and metals.

8.5.6.2 We obtained samples of the potentially chemically impacted soils for subsequent laboratory testing.

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 sewage works/drainage works	Desk Study	Organic, inorganic, TPHs, micro-organisms and asbestos	Likely	Site wide
Former biothane plant	Desk Study and site reconnaissance	Organic, inorganic, ammonia and asbestos	Likely	Site wide
Made Ground	Ground investigation	Organic, inorganic and asbestos	Likely	Site wide
Hydrocarbon odour in BH01	Ground investigation	Hydrocarbons	Likely	Local to BH01
Adjacent sites				
Adjacent sewage works/drainage works	Desk Study	Organic, inorganic, TPHs, micro-organisms and asbestos	Low-likelihood	Local to southern boundary

Table 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 K.

8.6.2 Based on the conceptual model there are risks to site users, construction operatives and water receptors, which exceed the low category therefore further investigation by laboratory testing of soil samples has been undertaken 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) we have evidence to identify past or recent uses of the site, which may have generated contamination. On this basis, in order to carry out an assessment, we have scheduled testing to measure the concentration of commonly occurring inorganic and organic contaminants. We have also scheduled Made Ground samples for asbestos screening.

8.7.1.2 We understand it is proposed to crush and reuse the remaining concrete tanks and therefore samples of concrete have also been tested for commonly occurring inorganic and organic contaminants, to determine their suitability.

8.7.1.3 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 for suite descriptions)**	**Rationale**
BH01	0.5	Made Ground	No	Asbestos screening	General site coverage
BH02	0.3				
BH03	0.5-1				
BH06	0.3-0.8				
TP05	0.2				
TP06	0.1				
TP07	0.6				
TP01	0.3				
TP02	0.2				
BH04	0.1	Made Ground	No	Asbestos screening Suite 17	General site coverage
BH05	0.3				
BH07	0.2				
BH01	0.8	Made Ground	No	Suite 17	General site coverage
BH04	2.6-2.8	Made Ground	No	Suite 17 (Leachate)	General site coverage
BH07	0.8-1.1				
BH01	3.61	Water	No	Suite 17	General coverage
BH03	3.42				
BH06	7.39				
CS01	0-0.25	Concrete	Yes	Suite 17	Contamination in existing tanks
CS02	0-0.22				
CS04	0-0.22				
CS03	0-0.24	Concrete	Yes	Suite 17 Suite 13	Contamination in existing tanks

Table 8.7.1.3

8.7.1.4 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. Guideline values are not available for all SVOCs/VOCs. Where there are published guideline values, concentrations have been compared directly. Where there are no guideline values, we have assumed a potential risk if concentrations are above detectable limits.

8.7.2.5 Measured concentrations of metals, PAH and TPH contaminants have been compared directly with the relevant guideline values.

8.7.2.6 We have adopted a residential land use for proposed end users of the site. In the absence of guidelines, we have adopted industrial guideline values for assessment of construction operatives.

8.7.3 Criteria for assessment of test data – Vegetation

8.7.3.1 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.

8.7.4 Criteria for assessment of test data – Controlled waters

8.7.4.1 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).

8.7.4.2 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 calcium carbonate concentrations of 263mg/l. Although not an insitu groundwater measurement, such results are likely to be similar to those that would be measured in groundwater in the local area.

8.7.4.3 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.

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

8.7.4.5 Following our receptor assessment (outlined in Section 8.3), we have adopted EQS values in preference to alternative guidelines where possible.

8.7.5 Evaluation of test data – Human receptors

8.7.5.1 Inorganics, PAH and TPH in soil

8.7.5.1.1 Concentrations of commonly occurring organic and inorganic contaminants have been tested in four soil samples

8.7.5.1.2 Tables summarising and analysing test data in the soil samples 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, 2 & 6	Proposed site users	Child	Residential	Refer to paragraphs below	Refer to paragraphs below
3, 4 & 7	Construction operatives	Adult	Industrial/ commercial	No exceedances	No exceedances

Table 8.7.5.2

8.7.5.1.3 With reference to Tables 1, 2 and 6 in Appendix I, analysis of chemical test data with respect to critical (child) receptors for future site uses, indicates all measured concentrations of selected contaminants are below relevant adopted guideline values with the exception of lead, mercury, benzo(a)pyrene, benzo(b)fluoranthene and dibenzo(a,h)anthracene. With reference to Tables 3, 4 and 7 in Appendix I, all measured concentrations fall below the guideline values for construction operatives.

8.7.5.1.4 Concentrations of lead are above the lower C4SL value of 82mg/kg in all of the soil samples although they are below the higher C4SL value of 210mg/kg. The measured concentrations ranged from 110mg/kg to 210mg/kg.

8.7.5.1.5 An elevated concentration of mercury was measured in one of the four soil samples. The measured concentrations ranged from 0.3mg/kg to 3.4mg/kg compared to a guideline value of 1.2mg/kg. The mean value of mercury was calculated at 1.2mg/kg, which does not exceed the guideline value.

8.7.5.1.6 The measured concentrations of benzo(a)pyrene were between 1.1mg/kg and 7.4mg/kg, with three of the concentrations exceeding the guideline value of 2.2mg/kg.

8.7.5.1.7 The measured concentrations of benzo(b)fluoranthene were between 1.5mg/kg and 9.1mg/kg, with two of the concentrations exceeding the guideline value of 2.6mg/kg.

8.7.5.1.8 The measured concentrations of dibenzo(a,h)anthracene were between 0.3mg/kg and 1.9mg/kg, with all of the concentrations exceeding the guideline value of 0.24mg/kg.

8.7.5.2 VOCs and SVOCs in soil

8.7.5.2.1 In addition to the testing summarised in the tables above, four samples of Made Ground were scheduled for testing of volatile organic compounds (VOC) and semi-volatile organic compounds (sVOC). One of the four samples tested resulted in concentrations above detectable limits. The following table summarises the contaminants and concentrations recorded. A SGV is available for dibenzofuran and concentrations have been compared to the residential guideline value for human health. There are currently no guideline values available for 2-methylnaphthalene and carbazole.

Summary of VOCs and SVOCs detected (µg/kg)

Contaminant	Guideline value	BH01
		0.8m
2-Methylnaphthalene	-	0.088
Dibenzofuran	8*	0.22
Carbazole	-	0.54

Table 8.7.5.2

*This value was derived from the sum of dioxins (PCDDs), furans (PCDFs), and dioxin-like polychlorinated biphenyls (PCBs).

8.7.5.2.2 Based on the above, concentrations of dibenzofuran are well below the residential guideline value and therefore pose a low risk. As no guideline values are available, we must assume the remaining contaminants pose a potential risk to human receptors although given the extremely low concentrations, the risk is considered low-likelihood.

8.7.5.3 Asbestos in soil

8.7.5.3.1 In addition to the above, twelve soil samples were screened for the presence of asbestos fibres. Asbestos (identified as chrysotile fibres/clumps) was identified in one of the samples taken from TP02 at 0.2m depth.

8.7.5.4 Summary

8.7.5.4.1 Based on the above evaluation, we are of the opinion that the near surface soils are likely to exhibit contamination from a perspective of human receptors.

8.7.5.5 Evaluation of test data in concrete core samples

8.7.5.5.1 Concentrations of commonly occurring organic and inorganic contaminants have been tested in four concrete samples. The tests were undertaken to determine whether the tanks could be crushed and re-used on site.

8.7.5.5.2 Tables summarising and analysing test data in the soil samples are presented in Appendix J. 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, 2 & 3	Proposed site users	Child	Residential	No exceedances	No exceedances

Table 8.7.5.5

8.7.5.5.3 In addition to the above, all concentrations VOCs and SVOCs were recorded below detectable limits.

8.7.5.6 Summary

8.7.5.6.1 Based on the above none of the measured concentrations of potential contaminants within the concrete tanks exceed the guideline values for residential end use. .

8.7.6 Evaluation of test data – Vegetation

8.7.6.1 Comparison of test data with guideline values is presented on Tables 4 and 5 in Appendix I. None of the measured concentrations exceed the adopted guideline values with the exception of copper.

8.7.6.2 Concentrations of copper were recorded between 41mg/kg and 1000mg/kg, with two of the four concentrations exceeding the guideline value of 130mg/kg. The mean was calculated as 172.9mg/kg, which also exceeds the guideline value.

8.7.6.3 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.

8.7.7 Evaluation of test data – Controlled waters

8.7.7.1 Inorganic contaminants

8.7.7.1.1 With reference to Table 8 in Appendix I, none of the measured concentrations of inorganic contaminants exceed the relevant guideline outlined in Section 8.7.5.

8.7.7.2 Organic contaminants (polycyclic aromatic hydrocarbons)

8.7.7.2.1 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

8.7.7.2.2 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.

8.7.7.3 Organic contaminants (total petroleum hydrocarbons)

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

8.7.7.4 Organic contaminants (VOCs and SVOCs)

8.7.7.4.1 In addition to the above, leachable VOCs and SVOCs were tested in two samples. All recorded results were below detectable limits.

8.7.7.5 Summary

8.7.7.5.1 Based on the above evaluation, we are of the opinion that the near surface soils are unlikely to exhibit significant contamination with respect to water resources.

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 K.

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 the Made Ground exhibits a degree of contamination, which potentially poses a risk to end users. On this basis, we recommend provision of a capping in garden and soft landscaping areas. Due to the nature of the contamination (including asbestos fibres in one location) and the type of development, we recommend a minimum capping layer of 600mm be adopted. Details of this remediation (in the form of a statement/specification) is provided in Section 13.

8.9.2 In addition to the above, the near surface Made Ground in BH01 exhibited hydrocarbon contamination, which although below guideline values may be a potential source of vapours given the total concentration recorded (700mg/kg). There is also a possibility that further hotspots of hydrocarbon contamination may be present. On this basis, we recommend the hydrocarbon impacted soils are removed from the location of BH01 to reduce the risk from vapour nuisance. Should any other hydrocarbon impacted soils be identified during the site strip/construction works, we recommend these are also removed.

8.10 Risk assessment summary and recommendations

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

8.10.2 End users

8.10.2.1 Contamination has been identified within the Made Ground on site, which potentially poses a risk to end users. Providing remedial action is implemented as detailed in Section 8.9, in our opinion, the site will pose a low risk to human receptors based on the current development proposals.

8.10.3 Construction operatives and other site investigators

8.10.3.1 The risk of damage to health of construction operatives and other site investigators is, in our opinion, moderate. We therefore recommend that adequate hygiene precautions are adopted 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.

8.10.3.2 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).

8.10.3.3 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.

8.10.3.4 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.

8.10.4 Controlled waters

8.12.4.1 Based on laboratory testing, we are of the opinion that the site represents a low risk of causing harm to water receptors

8.10.5 Vegetation

8.10.5.1 Elevated concentrations of copper have been identified within the Made Ground. We recommend that the test results presented in this report are passed to a landscape architect for the selection of suitable planting.

8.11 Final conceptual model

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

8.12 Statement with respect to National Planning Policy Framework

8.12.1 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 121, and compliant with the Building Regulations Part C, '*Site preparation and resistance to contaminants and moisture*'

8.13 On Site Monitoring

8.13.1 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
9.2	General
9.3	Assessment of source of gases
9.4	Gas migration
9.5	Conceptual model
9.6	Development categorisation
9.7	Monitoring observations
9.8	Classification of site characteristic gas situation
9.9	Gas protective measures – new buildings
9.10	Flammability
9.11	Gas protective measures - construction operatives
9.12	Statement with respect to National Planning Policy Framework

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). 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 and 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 A number of historic landfill sites are recorded in the area, with three located within 500m. The following table summarises these landfill sites:

Summary of Landfill sites				
Landfill name	**Type**	**Location**	**Waste authorised**	**Last input date**
Cubitts Basin	Historical	201m SE	Inert and industrial	Not supplied
Ibis Rowing Club	Historical	460m SE	Not supplied	Not supplied
Hartington Road Sports Ground	Historical	499m SE	Inert and industrial	1934
Hartington Road Sports Ground	Historical	616m SE	Not supplied	1935
Staveley Road	Historical	698m NE	Inert waste	1951
Dukes Meadow	Historical	712m SE	Not supplied	1950

Table 9.3.2.2

9.3.2.3 Given the age of the landfills and the nature of the waste, with reference to BS8576:2013, we would consider them to be sources with a low potential for producing landfill gas.

9.3.2.4 In addition to the above, inspection of geological maps indicates the site is located within a large area of Made Ground, which borders the River Thames. The nature and vertical extent of this Made Ground is not known and it is therefore we would also consider an initial assessment of low generation potential.

9.3.2.5 Based on the above, there are potential sources of landfill gas in the area, which could pose a risk to the subject site.

9.3.3 Soil conditions

9.3.3.1 Geological maps indicate the presence of Alluvium at the site and in the surrounding area. Such soils can contain significant quantities of organic matter and can be a source of landfill gas. Alluvium was encountered in a number of boreholes with the thickness of the deposit ranging from 0.8-1.5m. These soils did not contain any obvious evidence of organic matter, although an organic odour was noted within BH04. With reference to BS8576:2013, Alluvium is considered to have a very low potential of being a source of landfill gas.

9.3.3.2 Made Ground across the site ranged between depths of 1.8m to 4.4m. Laboratory testing indicates that the Made Ground soils beneath the site contain between 2.1% and 4.7% of organic matter, with an average content of 3.2%. In addition, our excavations did not encounter significant concentrations of decomposable materials such as wood, fabric or paper. Based on the above, and with reference to BS8576:2013, such Made Ground would be classified as having very low potential of being a source of landfill gas.

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/generation potential**	**Evidence**
Landfills	Low	Desk study information Historic inert and industrial waste landfills located within 500m of the subject site.
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	Made Ground up to 3.9m thickness with TOC <5%
Soils / rocks	Very low	Alluvium present on site.

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 coarse and fine-grained Made Ground overlying fine-grained Alluvium and coarse-grained Kempton Park Gravel Formation to depths of around 5-6m overlying fine-grained London Clay Formation. The Made Ground is likely to exhibit variable permeability and as it was encountered at surface, it is considered possible for any landfill gases generated from the Made Ground and Alluvium to migrate vertically to the surface of the site.

9.4.2 The landfill sites are located in excess of 200m from the site. The River Thames lies between the site and the historical landfill sites and surrounding Alluvium is recorded at crop. Given the depth of the River Thames, the impermeability of the Alluvium and London Clay in the surrounding area and the relatively shallow permeable soils at the site, it is considered unlikely that a significant pathway exists between the site and these former landfill sites.

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. 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 and Alluvium	Via sands and gravels	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 Five standpipes have been installed at the site in accordance with BS8576:2013, 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 low risk of generation potential of source ideally requiring six monitoring visits over a three-month period. This initial assessment will be reviewed pending the results of further monitoring observations.

9.7.2 We have returned to site for all six of the proposed monitoring visits to obtain measurements of landfill type gases at atmospheric conditions in the range of 1000mb to 1017mb and temperatures in the range of 6°C to 14°C. Essentially, we detected concentrations of methane in the range of 0.0 to 1.0% and concentrations of carbon dioxide measured in the range of 0.0 to 8.5%. 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 L.

9.8 Classification of site characteristic gas situation

9.7.1 Using test data obtained to date, and with reference to Table 2 of BS8485:2015, the site would be classified as characteristic gas situation two and traffic light colour Amber 1 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 = (8.5/100) x 1.8 = 0.15l/hr Characteristic situation CS2 (maximum limit is 0.7l/hr)
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 39%v/v to move into the next band i.e. would need to increase 4.5 times. This is not considered feasible.
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 8.2l/hr to move into the next risk band, i.e. to needs to increase 4.5 times. This is not considered feasible.
Is the increase in gas concentration feasible given the known source of the gas?	No It is not considered likely that the gas concentration will exceed 39%v/v based on the nature of the source (Made Ground and organic soils)
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 It is not considered likely that the flow rate will exceed 8.25l/hr based on the nature of the source (Made Ground and organic soils)
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 observations to date, 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 requires gas protective measures which would achieve a '*gas protection score'* of 3.5. Lists of protective measures which each produce a score value are produced in Tables 5, 6 and 7 of BS8485:2015. We recommend the project designer chooses protection elements from Tables 5, 6 and 7 appropriate for the development and to achieve the required gas protection score value.

9.9.2 With the site being classified as Amber 1, then following NHBC report No 10627-R01(04) table 14.2, the following 'low level' gas protection measures are required.

a) Installation of a suitable gas resistant membrane

b) Ventilated subfloor to facilitate a minimum of one complete volume change per 24 hours.

b) Gas protective measures shall be as presented in Building Research Establishment Report 414

9.10 Flammability

9.10.1 Methane is a flammable gas. When the concentrations of methane in air (oxygen 20.9% by volume) are between the limits of 5% and 15% by volume, then an explosive mixture is formed. The lower explosive limit (LEL) of methane is 5% which is equivalent to 100% LEL. The 15% limit is known as the upper explosive limit (UEL), but concentrations above this level cannot be assumed to represent safe concentrations. The flammability of gas mixtures is affected by their composition, presence of an ignition source, temperature, pressure and nature of the surroundings. The explosive hazard of a flammable mixture arises from the speed of propagation of the flame in a confined space and the ability of the container to absorb the associated shock wave. The flammability range can vary depending upon differing circumstances, for example:

- When carbon dioxide concentrations of greater than 25% are present, methane is rendered non-flammable, and
- If the oxygen concentration is reduced, the limits of flammability are reduced. For example, at 13.45% oxygen the LEL and UEL for methane are altered to 6.5% and 7% respectively, whilst at 13.25% oxygen the mixture is incapable of propagating a flame (refer CIRIA report 130)

9.10.2 From measurements taken to date, none of the air, methane and carbon dioxide mixtures are potentially explosive.

9.11 Gas protective measures - construction operatives

9.11.1 Areas near landfill sites, underground coal strata or in carbonate rich deposits (such as limestone and chalk) have the potential to generate both harmfully low oxygen levels and high carbon dioxide levels in confined spaces. The assessment for such situations may therefore require using gas monitors to warn of significant leaks of gas into confined spaces to minimise the risks associated with an oxygen-deficient atmosphere which could lead to asphyxiation, and/or a toxic atmosphere due to high levels of carbon dioxide.

9.11.2 During construction, we recommend any excavations/confined spaces are well ventilated and human entry is avoided. The Workplace Exposure Limits (WELs) for carbon dioxide are 5000 parts per million (ppm by volume), which is equivalent to 0.5%, for the 8-hour time-weighted average (TWA); and 15000 ppm (1.5%) for the 15-minute short-term exposure limit (STEL). Typically, oxygen deficiency alarms on gas detectors are set at 19% volume ratio (v/v). Normal air contains 20.9% oxygen. Therefore, should human entry be necessary then we recommend excavations/confined spaces are monitored over short- and long-term exposure periods for both oxygen and carbon dioxide gases prior to entry to ensure levels are within acceptable concentrations or suitable breathing equipment adopted.

9.11.3 We recommend further reference is made to the following documents to minimise the risks to construction workers from ground gases:

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

- *"A Guide to Safer Working on Contaminated Sites"* (CIRIA Report 132)

- Health and Safety Executive Publication EH40/2005 *''Workplace Exposure Limits''*

9.12 Statement with respect to National Planning Policy Framework

9.12.1 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 121, 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
10.2	Reference documents
10.3	Hazard identification and assessment
10.4	Provision of test data to specifiers/manufacturers/installers
10.5	Risk assessments for individual building materials
10.6	Concrete – general mechanisms of attack
10.7	Concrete – sulphate attack
10.8	Concrete – chloride attack
10.9	Concrete – acid attack
10.10	Concrete – magnesium attack
10.11	Concrete – ammonium attack
10.12	Concrete blocks
10.13	Clay bricks/pipes
10.14	Mortar
10.15	Metals – general
10.16	Metals – cast iron
10.17	Metals – steel piles
10.18	Metals – stainless steel
10.19	Metals – galvanised steel
10.20	Metals – copper
10.21	Metals – lead
10.22	Plastics – general
10.23	Plastic membranes and geotextiles
10.24	Plastic pipes
10.25	Electrical cables
10.26	Rubbers

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, with other items considered outside our brief and scope of investigations.

10.1.3 In aggressive ground conditions, the potential for contaminant attack depends on the following:

- The presence of water as a carrier of chemical contaminants, (except free phase organic contamination).
- The availability of the contaminant in terms of solubility, concentration and replenishment rate.
- Contact between the contaminant and the building material.
- The nature of the building materials and its capability of being attacked by contaminants.

10.1.4 In general the thicker the building material the less likelihood there is for contaminant attack to cause damage to the integrity of the structure.

10.2 Reference documents

10.2.1 Following the Environment Agency publication *'Model Procedures for the Management of Land Contamination'* (Contaminated Land Report 11) the following documents have been referred to in production of the following report paragraphs.

- *'Performance of Building Materials in Contaminated Land'* report BR255 (Building Research Establishment 1994).
- *'Risks of Contaminated Land to Buildings, Building Materials and Services. A Literature Review'* - Technical Report P331 (Environment Agency 2000).
- *'Guidance on assessing and managing risks to buildings from land contamination'* - Technical Report P5 035/TR/01).
- Building Regulations Approved document C - site preparation and resistance to contaminants and moisture (Office of the Deputy Prime Minister, 2004).
- *'Concrete in aggressive ground'* Special Digest 1: 2005 (Building Research Establishment).

10.3 Hazard identification and assessment

10.3.1 The identification of hazards is based on the findings of this investigation primarily relating to former land uses (potential for chemical contamination, and likely type of contamination) and laboratory determination of concentration of chemical contaminants. Clearly, the scope of laboratory testing is determined with respect to former land uses, contaminants which may cause harm to human health and water resources.

10.3.2 Based on the above, the scope of our testing regime is described in Section 8. We have utilised this test data in production of the following risk assessments in relation to building materials, in conjunction with test data targeting the effects of chemical attack on concrete in contact with the ground, as described in BRE Special Digest 1.

10.3.3 The identification of hazards from contamination and subsequent assessment of risks is based on the following:

- The contaminants present on site.
- The nature of the contaminant (i.e. calcium sulphate is much less soluble than sodium or magnesium sulphate and is, therefore, less of a concern with regards sulphate attack).
- The concentration of contaminants - in general the higher the concentration the greater the hazard.
- The solubility of the contaminants - contaminants which are not soluble will not generally react with materials.
- The permeability of the soils - i.e. ease by which fluids can transport contaminants to the building.

10.3.4 The process of risk assessment for building materials is concerned with identification of the hazard (contaminants at the site - a source) and subsequently how the contaminants can reach the building (pathway) and how they can react with the building (receptor). Thus the risk assessment is produced based on the source - pathway - receptor model.

10.4 Provision of test data to specifiers/manufacturer/installer

10.4.1 The following risk assessments are based on current published data. We strongly recommend, however, that information gained from this investigation are provided to specifiers/manufacturers/installers of building materials/service ducts/apparatus who may have more up to date research to confirm the ability of the product to resist the effects of chemical contaminants at the site for the desired lifespan of the product.

10.5 Risks assessments for individual building materials

10.5.1 The following/typical Sections contain risk assessments for various building materials likely to be incorporated in developments. Other materials which we are not aware of may also be used in developments and be in contact with the ground. We therefore recommend the suppliers are consulted with respect to ground conditions at this site and their opinion sought as to the ability of the product to resist chemical conditions determined at the site.

10.6 Concrete - General mechanisms of attack

10.6.1 There are a number of mechanisms by which contaminants attack concrete including the following:

- Hydrolysis of the hardened concrete.
- Degradation as a result of exchange reactions between calcium in calcium hydroxide (free lime hydrate) and ions in aggressive solutions.
- Expansive reactions as a result of chemical reaction or salt crystallisation.

10.7 Concrete - Sulphate attack

10.7.1 Hazard

10.7.1.1 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 alluminate and sulphite ions.
- Thaumasite formation as a result of reactions between calcium silicate hydrates, carbonate ions (from aggregates) and sulphate ions.

10.7.2 Assessment

10.7.2.1 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.

10.7.3 Desk Study Information

10.7.3.1 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 10.7.3

10.7.3.2 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.

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

10.7.4 Assessment of Design Sulphate Class

10.7.4.1 The sulphate concentration in a 2:1 water/soil extract was measured in three samples of Made Ground, two samples of Kempton Park Gravel and three samples of London Clay Formation. The highest test result has been used as the characteristic value (refer to table 10.7.7). The measured values are not considered to be significantly variable.

10.7.4.2 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. We have therefore assessed the potentially pyritic strata underlying the site in disturbed and undisturbed states.

10.7.4.3 Following the recommendations of SD1: 2005, we have scheduled additional testing on the same soil samples to include:

- Determination of total sulphate content (% SO_4)
- Determination of total sulphate present (% S)

10.7.4.4 Using this test data we have calculated the total potential sulphate content (TPS, % SO_4) and the amount of oxidisable sulfides (OS % SO_4), again following the procedures described in SD1: 2005. As the amount of oxidisable sulfides exceeds 0.3% SO_4, pyrite is probably present.

10.7.4.5 The characteristic total potential sulphate content has been based on the highest TPS value for each soil type (rounded to 0.1% SO_4, refer to table 10.7.7). With reference to table C1 of SD1: 2005, the design sulphate class has been based on considering both the initial characteristic value, and characteristic total potential sulphate content, and adopting the more onerous of these two values.

10.7.4.6 The concentration of sulphate was measured at less than 3000mg/l and thus the concentration of magnesium was not measured.

10.7.4.7 If excavations are to be formed for foundations in potentially pyritic ground, and total potential sulfates (TPS) are not used, any backfill with pyritic material should not be placed in proximity to foundations.

10.7.5 Assessment of groundwater mobility

10.7.5.1 With reference to SD1: 2005, Section C3.1, we are of the opinion that soils at the site generally have a low permeability and thus 'static' groundwater conditions are considered characteristic of the site.

10.7.5.2 With reference to SD1: 2005, Section C3.2, we are of the opinion that ground and site characteristics suggest 'mobile groundwater' conditions are characteristic of the Made Ground and Kempton Park Gravel. With reference to SD1: 2005, Section C3.1, we are of the opinion that the London Clay Formation at the site generally has a low permeability and thus 'static' groundwater conditions are considered characteristic.

10.7.6 Assessment of pH

10.7.6.1 Following SD1: 2005, Section C5.1.1 (step 4) only a 'small number' of samples have been tested and thus the characteristic value for pH within Made Ground, Kempton Park Gravel and London Clay Formation equates to the lowest measured values of 9.1, 8.6 and 8.2 respectively.

10.7.6.2 None of the measured pH values were below 5.5, thus the concentration of chlorides and nitrates was not measured.

10.7.7 Assessment of aggressive chemical environment for concrete (ACEC)

10.7.7.1 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 10.7.2 below.

Summary of concrete classification

Soil type	No. of samples	Characteristic pH	Groundwater mobility	Characteristic TPS	Characteristic sulphate (mg/l)	DS class	ACEC class
Made Ground	3	9.1	Mobile	0.63	820	DS-2	AC-2
Kempton Park Gravel	2	8.6	Mobile	N/A	53	DS-1	AC-1
London Clay Formation	3	8.2	Static	2.04	120	DS-4	AC-3s
Groundwater	3	8.0	N/A	N/A	120	DS-1	AC-1

Table reference 10.7.7

10.7.7.2 As more than one soil/groundwater source has been tested at the subject site, the more onerous of design sulphate class and ACEC class should be adopted.

10.8 Concrete - Chloride attack

10.8.1 Hazards

10.8.1.1 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.

10.8.2 Risk assessment

10.8.2.1 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.

10.8.2.2 In view of the past use of the site we consider the likelihood of elevated concentrations of chlorides in the ground to be low and on this basis have not specifically measured concentrations of chlorides.

10.9 Concrete - Acid attack

10.9.1 Hazards

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

10.9.2 Risk assessment

10.9.2.1 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

10.9.2.2 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.

10.9.2.3 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.

10.10 Concrete - Magnesium attack

10.10.1 Hazards

10.10.1.1 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.

10.10.2 Risk assessment

10.10.2.1 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.

10.10.2.2 We are not aware the site has been subject to any manufacturing processes which would have included magnesium containing compounds, and in addition sulphate concentrations did not exceed 3000mg/l. On this basis we have not measured the concentration of magnesium in soils at the site, and would consider the risk of soils at the site promoting attack on concrete to be low.

10.11 Concrete - Ammonium attack

10.11.1 Hazards

10.11.1.1 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.

10.11.2 Risk assessment

10.11.2.1 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.

10.11.2.2 The site has no history which provides evidence of the uses of ammonia on site, and therefore the risk of concrete being affected by ammonia is considered low.

10.12 Concrete blocks

10.12.1 Hazards

10.12.1.1 Precast aggregate concrete blocks and autoclaved aerated concrete blocks are commonly used in the construction of shallow foundations. Concrete blocks are potentially attacked by the same contaminants and ground conditions which affect dense concrete.

10.12.2 Risk Assessment

10.12.2.1 In general, the mechanism of attack on concrete blocks is the same for hardened concrete. We recommend parameters for ground conditions for concrete described in the preceding paragraphs for concrete blockwork in contact with the ground/groundwater and the blockwork manufacturers confirmation sought for applicability of their product.

10.13 Clay Bricks/Pipes

10.13.1 Clay Bricks are highly durable materials which have been used in buildings for many centuries. Fire clay pipe material can also be considered similarly resistant to contaminants.

10.13.2 Hazards

10.13.2.1 Dissolution of clay brick is a potentially serious cause of deterioration. The extent of dissolution depends upon the solubility of the glassy material (produced by firing of the clay) contained in the brick. The acidic nature of the glass phase will produce low solubility in a neutral and acidic environment, but can be soluble in a basic environment.

10.13.2.2 A potentially more serious hazard for brickwork is the crystallisation of soluble salts within the brick pore structure. Salts are transported by water to the interior of the brick originating from the external environment or by rehydration. However, such processes are only likely to occur when there is a gradient from a wet interior to a drying surface. The potential for salt crystallisation in the ground is, therefore, low.

10.13.3 Risk Assessment

10.13.3.1 There seems to be little published information as regards the resistance to clay bricks/pipes in aggressive ground conditions, however, clay bricks are generally considered very durable. We recommend manufacturers' advices are sought with respect to their resistance to ground conditions encountered at this site.

10.13.3.2 Some basic guidance is provided in BS5628-3: 2005 '*Code of Practice for the Use of Masonry - Part 3: Materials and components, design and workmanship*' with regards to resistance of masonry to resist the effects of sulphate attack.

10.14 Mortar

10.14.1 Mortars are based on building sands mixed with cement and/or lime as a binder. In the UK Portland cements and masonry cement are commonly used. Masonry cements are a mixture of Portland Cements and fine mineral filler (i.e. limestone) with an air entraining agent.

10.14.2 Hazards

10.14.2.1 Mortar is subject to the same agents for deterioration as concrete with the major cause of deterioration being sulphate attack.

10.14.3 Risk assessment

10.14.3.1 Sulphates can originate from soils/groundwater or from the bricks themselves. Calcium, magnesium, sodium and potassium sulphates are present in almost all fired-clay bricks. Water can dissolve a fraction of these sulphates and transport them to the mortar.

10.14.3.2 Currently, we are not aware of any guidance on the resistance of mortars to sulphate attack. The Building Research Establishment report that the sulphate resistance of mortar was improved by the use of sulphate resisting Portland cements and lime. Some guidance is also provided in BS5628-3: 2005 '*Code of Practice for the use of Masonry - Part 3: Materials and components, design and workmanship*'.

10.14.3.3 Based on ground conditions determined at the site the risk of significant sulphate attack on mortars (Based on testing/analysis of sulphates in relation to concrete - refer Section 10.7) is considered low.

10.15 Metals - general

10.15.1 There are a number of metals which are used in buildings either as piles, services, non structural and, indeed, structural components. The most common metals used in buildings are steel, stainless steel, copper, lead, zinc, aluminium and cast iron. All these metals can deteriorate through corrosion processes. Corrosion can affect metals in a variety of ways depending upon the nature of the metal and the environment to which it is subjected. The most common forms of corrosion are:

- Electrochemical - the most common form of corrosion in an aqueous solution.
- Chemical corrosion - occurs when there is a direct charge transfer between the metal and the attacking medium (examples are oxidation, attack by acids, alkalis and organic solvents).
- Microbial induced corrosion.

10.16 Metals - Cast iron

10.16.1 Cast iron is a term to describe ferrous metals containing more than 1.7% carbon and is used extensively in the manufacture of pipes.

10.16.2 Hazards

10.16.2.1 Generally, cast iron has a good resistance to corrosion by soils, however, corrosion can occur due to the following mechanisms:

1) Generation of large scale galvanic cells caused by differences in salt concentrations, oxygen availability or presence of stray electrical currents.

2) Hydrochloric acid will cause corrosion at any concentration and temperature. Dilute sulphuric, nitric and phosphoric acids are also aggressive as also are well aerated organic acids.

10.16.3 Risk assessment

10.16.3.1 Testing can be carried out on site to measure the resistivity and redox potential of soils which can assist in deriving recommendations for protection of cast iron components using coatings, burial trenches, or isolation techniques. Currently, however, there is no specific guidance and we recommend advice is sought from manufacturers.

10.16.3.2 Guidelines produced by the Water Research Centre (WRc) on the use of ductile iron pipes, state that highly acidic soils (pH <5) are corrosive to cast iron pipe even when protected by a zinc coating or polythene sleeving. WRc also indicate that groundwater containing >300ppm chloride may corrode even protected cast iron pipes.

10.16.3.3 On the basis that the pH of soils at the site are not less than 5, and groundwater is unlikely to be in contact with cast iron elements, then the risk of ductile cast iron pipes being affected by acid/chloride attack is considered low. We have not carried out any redox/resistivity testing (considered outside our brief) and thus we cannot comment further with regards to the risks of galvanic action.

10.17 Metals - Steel piles

10.17.1 Hazards

10.17.1.1 The corrosion of steel requires the presence of both oxygen and water. In undisturbed natural soils the amount of corrosion of driven steel piles is generally small. In disturbed soils (Made Ground) however, corrosion rates can be high and normally twice as high as those for undisturbed natural soils.

10.17.2 Risk Assessment

10.17.2.1 Guidance on the use of steel piles in different environments is provided in British Steel's piling handbook which includes calculating the effective life of steel piles. There is no specific guidance, however, for contaminated soils in this publication. Coatings can be provided to the pile surface but experience has shown that some coatings can be damaged during driving, particularly in ground which can contain hard materials such as brick/concrete/stone.

10.18 Metals - Stainless steel

10.18.1 Hazards

10.18.1.1 Stainless steel is used in a number of building components including services, pipework, reinforcement bars and wall ties. There is little knowledge, however, of the performance of stainless steel in aggressive environments.

10.18.2 Risk assessment

10.18.2.1 Stainless steel can withstand pH of 6.5 to 8.5, but the chlorine content of a soil increases the risk of corrosion. At concentrations of 200mg/l type 304 stainless steel can be used, but for concentrations of 200 to 1000mg/l type 316 should be used in preference to type 304, but for concentrations greater than 1000mg/l type 316 should always be used.

10.18.2.2 At this site the pH of the soils was between 8.2 and 10.3. We recommend manufacturers' advices are sought with respect to their resistance to ground conditions encountered at this site.

10.19 Metals - Galvanised steel

10.19.1 Hazards

10.19.1.1 Galvanising steel is a means of protecting steel from aggressive environments; however, zinc galvanising can be corroded by salts and acids.

10.19.2 Risk assessment/remedial action

10.19.2.1 There is no current specific guidance on the effects of aggressive ground conditions on galvanised steel, however, some research indicates zinc alloys are generally more resistant than pure zinc coatings in aggressive conditions.

10.20 Metals - Copper

10.20.1 Hazards

10.20.1.1 Copper is commonly used for gas and water supplies. Copper is generally resistant to corrosion in most natural environments, but in contaminated ground copper can be subject to corrosion by acids, sulphates, chlorides and ground containing cinders/ash. Wet peat (pH 4.6) and acid clays (pH 4.2) are considered aggressive conditions to promote corrosion to copper.

10.20.2 Risk assessment

10.20.2.1 There is no specific published guidance on what constitutes aggressive conditions to copper except very acid/peaty conditions.

10.20.2.2 There are no significantly acidic or peaty conditions in near surface soils at the site or, indeed, significant concentrations of ash/cinders. On this basis the risk of significant corrosion to copper in contact with the ground is considered low.

10.21 Metals - Lead

10.21.1 Hazards

10.21.1.1 Lead is used in tanking, flashings, damp proof courses, etc. Lead is a durable material which is resistant to corrosion in most environments. Lead damp proof courses can be subject to attach from the lime released by Portland Cement based mortar and concrete. In the presence of moisture, a slow corrosive attack is initiated on lead sheet. In such cases a thick coat of bitumen should be used to protect the lead damp proof course.

10.21.2 Risk assessment

10.21.2.1 There is no current guidance on the performance of lead in contact with contaminated soils, however, acids and alkalis (lime) could be aggressive towards lead.

10.21.2.2 At the site pH conditions are not considered significantly extreme and this it is considered unlikely that ground conditions at the site would significantly affect lead.

10.22 Plastics - General

10.22.1 The range of plastics in construction is wide and increasing. The deterioration of plastics varies with the individual material and the environment to which it is exposed. In general, plastics deteriorate through degradation of their polymer constituent, but loss of plasticizer and other additives can render plastics ultimately unserviceable.

10.23 Plastic membranes and geotextiles

10.23.1 Plastic membranes and textiles are used in the construction industry as damp proof courses, gas resistant membranes, cover systems and liners. They are typically used to restrict the movement of gas or water into buildings, building materials or components or to separate differing soil types. Typically materials used for membranes are polyethylene (PE) and poly vinyl chloride (PVC).

10.23.2 Hazards

10.23.2.1 Membranes of PE and PVC are attacked by a variety of acids and solvents. PE has a poor corrosion resistance to oxidising acids (nitric and sulphuric) at high concentrations. Hydrochloric acid (HCl) does not chemically attack PE but can have a detrimental effect on its mechanical properties. Alkalis, basic salts, ammonia solutions and bleaching chemicals such as chlorine will cause deterioration of PE. PE is resistant to non-oxidising salt solutions.

10.23.2.2 PVC is degraded by the action of oxidising acids. Nitric acid is particularly aggressive towards PVC. PVC does not deteriorate under the action of neutral or alkaline solutions.

10.23.3 Risk assessment

10.23.3.1 There is no published guidance on quantitative assessment of the risks to PE or PVC although there is a lot of advice on how contaminants react with these plastics. In general, the more concentrated the contamination the greater the risk to plastic membranes/geotextiles.

10.23.3.2 Based on the investigatory data obtained to date, and in consideration of the hazards described above, there is no evidence of significant concentrations of acids or alkalis, indicating the risks of ground conditions at the site affecting PE and PVC materials are low.

10.24 Plastic Pipes

10.24.1 Hazards

10.24.1.1 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.

10.24.1.2 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.

10.24.2 Assessment

10.24.2.1 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.

10.24.2.2 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'

10.24.2.3 The subject site has previously been developed and on this basis could potentially be considered brownfield in accordance with the UKWIR document. Following the preliminary risk assessment procedures described in the UKWIR document however, (paragraph 2.4.2) there is no evidence to indicate that chemicals have ever been used or stored on site.

10.24.2.4 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) 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 contaminants forming part of the PAH suite exceeds the trigger value of 0.125mg/kg. In addition, the Made Ground does exhibit some localised hydrocarbon contamination. 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.

10.25 Electrical cables

10.25.1 Hazards

10.25.1.1 Electrical cables are generally protected by plastic sleeves. These sleeves are potentially subject to chemical and permeation in similar modes as plastic pipes. Medium and low voltage cables are often laid directly into the ground and are thus at risk of attack by contaminants. High voltage cables tend to be laid in trenches backfilled with 'clean' materials.

10.25.2 Risk assessment/remedial action

10.25.2.1 The selection of appropriate sheathing material is important to provide resistance to ground conditions at the site and we recommend manufacturers' advices are sought.

10.26 Rubbers

10.26.1 Hazards

10.26.1.1 Rubbers are cross-linked polymeric materials containing a number of additives such as carbon black, fillers, antioxidant and vulcanising agents. The corrosion resistance of rubber is dependent upon the polymeric constituent. The mechanisms by which rubbers deteriorate when placed in aggressive chemical environments are similar to those described for plastics. Oxidation is the principal form of degradation. Whilst rubbers are resistant to strong acids and alkalis, they are rapidly attacked by oxidising agents such as nitric acid and oxidising salts such as copper, manganese and iron.

10.26.1.2 Rubber is also susceptible to attack by certain hydrocarbons and oils. The absorption of these liquids causes the rubber to smell.

10.26.2 Risk assessment/remedial action

10.26.2.1 Information on the effect of a range of chemicals on the physical properties of various rubbers has been produced by the Rubber and Plastics Research Association. This was based on observations carried out following immersion tests using undiluted chemicals, but this has limitations such as the effects of combined chemicals and the effects of dilution.

10.26.2.2 We recommend manufacturers of the rubber materials likely to be in contact with the ground at the site are consulted to confirm, or otherwise, the applicability of their product.