

Calculations to determine illustrative working loads for axially loaded piles have been undertaken; each calculation assuming a single pile acting in compression. Indicative capacities are presented in the following table. Available capacities may vary for piles acting in tension.

The soil profile assumed for these calculations has been based on examination of the recovered samples and the results of in-situ and laboratory testing. A modelled ground profile comprising made ground to 1m, underlain by London Clay Formation deposits to 5m, in turn, underlain by Lambeth Group deposits has been adopted. Groundwater has been assumed to be present at a depth of 1.0m below ground level.

In consideration of the high volume change potential of the clay soils and the proximity of existing trees, it has been assumed, for the purpose of the calculation, that the upper 3m of the piles will be sleeved.

Table 10. Indicative Axially Loaded Pile Working Capacities

Working Loads of Piles (kN)			
Length (m)	Size (mm)		
	200	300	450
6	65	110	200
8	100	165	285
10	140	225	370

Notes:

The structural strength of the concrete used in construction may limit the available working loads of the piles. Indicated pile lengths are from existing ground level. A factor of safety of 3.0 has been applied. The benefit of shaft resistance within the upper 3m has been discounted.

Working capacities for pile groups should be assessed when final design details are known, although for preliminary design purposes it is likely that piles spaced at least 3 x pile diameter from other piles in any group will behave as single piles.

Where preliminary and working pile load tests are undertaken it may be appropriate to reduce Safety Factors, although 2.5 may be a minimum local authority requirement. Should testing not be undertaken it is suggested that a factor of safety of at least 3.0 should be adopted.

For all piling options it is recommended that the advice of specialist foundation contractors should be sought at the earliest opportunity and that piling specifications should be obtained with reference to their particular products as this may affect the calculated pile capacity.

8.2 Groundwater

Stabilised standing water depths between 2.0m and 2.5m below ground level were recorded at the site during the monitoring undertaken as part of the previous ground investigation works. During the current phase of works, groundwater seepage was recorded only at a depth of 0.60m in a single borehole, at the boundary of the made ground and London Clay Formation strata.

Where excavations are proposed to extend below the groundwater, groundwater control will be required to maintain adequately dry working conditions and excavation stability. It is expected that pumping from sumps would be sufficient to control groundwater in excavations extending a shallow depth beneath the groundwater table.

8.3 Stability of Excavations

All made ground soils exposed in excavations should be assumed to be unstable, even in the short term. Whilst fine-grained natural soils may remain stable for a short period of time if not subjected to surcharge loads (such as may be imposed by existing foundations, traffic or storage of materials), the stability of these deposits if left unsupported should be assumed to have the potential to deteriorate. Where stable excavations are required, excavations should either be suitably supported or side slopes should be battered back to a safe angle of repose.

All excavations requiring human entry must be shored or battered as necessary to conform to current best practice, as accepted by the Health and Safety Executive (HSE)¹⁰. Current legislation requires that where personnel access is required into any excavation a competent person must inspect excavation supports or battering of slopes at the start of the working shift and at other specified times. No work should take place until the excavation is safe. Excavations should also be inspected after any event that may have affected their stability, such as a significant weather event, changes in surcharge loadings imposed by temporary storage of materials or changes in site traffic plans or alteration of support systems. Inspections should be formally recorded and any faults that are found should be corrected immediately.

8.4 Aggressivity to Concrete

The aggressivity of the soils to concrete has been assessed in accordance with guidance published by the BRE¹¹.

In consideration of the soils encountered beneath the site it is considered that 'natural ground conditions' may be assumed for the purpose of assessing the aggressivity of the chemical environment for concrete classification (ACEC class). Given the noted presence of groundwater, 'mobile groundwater' conditions should be assumed.

Assessment of the chemical analysis of the soil indicates a sulphate content falling into Design Sulfate Class DS-1 of Table C1. The results of the pH tests indicate that the underlying soils are neutral.

In accordance with the digest, a DS-1 Design Sulfate Class and an AC-1 ACEC classification should be assumed as a minimum for the design of concrete in contact with the ground.

8.5 Ground Floors

In view of the variable thickness of made ground and the presence of soils of up to high volume change potential underlying the site, it is recommended that ground floors should be suspended.

Current guidance¹² suggests that ground bearing floor slabs may, however, be considered where made ground soils are not present or are to be removed from beneath building footprints and the depth of foundations required to protect against seasonal soil volume changes close to trees is less than 1.5m. In such circumstances further works should be undertaken to demonstrate, that close to the time of construction, no significant soil desiccation is present. If ground bearing floors are adopted it is recommended that the potential for differential movement, both between the floor slab and walls and across the floor slab itself, should be anticipated. Such floors should

¹⁰ Relevant guidance is given on the HSE website, www.hse.gov.uk

¹¹ BRE Special Digest 1:2005 Concrete in Aggressive Ground.

¹² <http://www.nhbc.co.uk/> : NHBC Standards, Chapter 4.2.

be fully debonded from walls. Formations should be adequately proof rolled and any excessively soft materials excavated and replaced with a suitable, well graded granular fill. The depth of any fill should be limited to a maximum of 600mm unless placed to an engineering specification designed to limit internal settlement of the fill materials to a tolerance to be advised by the designer. The detailing of services through, or under, ground-bearing floors should incorporate flexible connections and, where appropriate, enhanced falls.

8.6 Pavement Design

Cone penetrometer tests undertaken to establish the California bearing ratio (CBR) of the in-situ soils indicated CBR values ranging between 2% and >50% in the underlying soils at the time of the investigation. It is noted that CBR values are, in part, dependent on the moisture content of the tested soils and are consequently subject to seasonal variation.

Equilibrium CBR values¹³ are derived from knowledge of soil classification data (plasticity index for soils exhibiting cohesion (clay type) and particle size distribution for granular soils) and pavement thickness. This guidance document suggests a design equilibrium CBR value of 2.0% to 3.9% would be applicable to the natural soils for the construction of thin pavement (300mm).

Based upon review of the in-situ and laboratory test results and the quoted guidance it is recommended that, for the fine-grained London Clay Formation deposits or derived made ground soil deposits, a CBR value of no greater than 2.5% should be adopted for preliminary pavement design.

All formations should be proof rolled and any excessively large, soft, degradable or otherwise unsuitable materials thus identified should be removed and be replaced with well compacted coarse-grained fill. Prepared subgrades should be protected from severe adverse weather by ensuring they are graded to falls to prevent ponding, and they should be reasonably protected from trafficking during construction.

The subgrade may be assumed not to be susceptible to frost heave.

If new roads are to be adopted the local highway authority should be consulted with reference to the acceptability of the proposed CBR figures prior to designs being finalised and construction undertaken.

8.7 Stormwater Infiltration Systems

In-situ infiltration testing¹⁴ was undertaken in the London Clay Formation deposits encountered in boreholes WS01, WS02 and WS03 as part of the previous ground investigation works. In general, either no or negligible fall in water level was observed over the period of the tests and the London Clay Formation should be considered to possess a negligible permeability.

In addition to the borehole soakage tests, rising head tests were carried out in the deeper boreholes BH01, BH02 and BH03 as part of the previous works. For each of these tests the infiltration rate through the soils and into the borehole was estimated by dividing the volume of water rising during the test by the product of the average surface area of the sides in contact with water during the test period and the test duration in seconds.

¹³ Highways England Design Manual for Roads and Bridges Interim Advice Note 73/06; Draft HD25

¹⁴ Conducted in accordance with The Soakaway Design Guide, published by Kent County Council, July 2000.

The infiltration rates derived from these tests are summarised in the following table.

Exploratory Hole	Groundwater Depth (m)		Depth of Borehole at time of test (m)	Stratum	Response Rate (m/sec)
	Start	Finish			
BH01 (within standpipe)	10.60	2.50	12.00	Lambeth Group	9.8×10^{-7}
BH02 (within standpipe)	4.70	4.47	11.50	Lambeth Group	3.6×10^{-8}
BH03 (within standpipe)	3.70	2.39	10.00	London Clay Formation / Lambeth group	9.6×10^{-6}

The results from the infiltration tests indicate that the Lambeth Group soils also possess negligible to poor infiltration characteristics.

The results from the infiltration tests should be provided to engineers responsible for the design of the drainage system.

To comply with building regulations¹⁵, point discharging infiltration systems (conventional ring or trench soakaways) are required to be constructed a minimum of 5.0m away from proposed or existing buildings.

In the event that discharge to ground via infiltration systems is proposed, it is recommended that designers of the system provide for the prevention of pollution of groundwater. In this regard due consideration should be given to guidance provided within BRE 365 and by the Environment Agency. Attention is drawn to the assessment of risk posed to groundwater discussed under Section 9 of this report which concludes the concentrations of contaminants within the made ground soils pose a negligible risk to groundwater.

Appropriate consideration should also be given to whether there is a need for inclusion of interceptors and oil separators. The Local Authority and/or relevant water company should be consulted in relation to consent for discharge of water from rooftops, areas of hardstanding and roadways to drains.

¹⁵ The Building Regulations 2010; Part H; Drainage and Waste Disposal

9. QUANTITATIVE CONTAMINATION ASSESSMENT

9.1 Assessment Strategy

The design of the ground investigation considered the potential contaminant sources identified by the preliminary ground contamination risk assessment and comprised a series of boreholes across the site. This included exploratory positions within the north of the site, where the potential for made ground associated with historical demolition of buildings and the deposition of imported/waste materials has been identified.

The site covers an area of approximately 6,900m² and the eight sampling positions were spread across the site. Each position is therefore assumed to represent around 860m², which equates to sample positions at approximately 30m centres. Such an approach falls within the upper end of the range recommended for an exploratory investigation provided in BS10175:2011+A2:2017.

9.2 Analysis of Contamination Test Results

The results of the laboratory testing have been compared with soil screening values (SSVs) comprising the 'Suitable For Use Levels' (S4ULs) calculated as a joint project between LQM and CIEH¹⁶. In lieu of an S4UL screening value for lead, the Category 4 Screening Level (C4SL) was used, as published within SP1010¹⁷.

In view of the proposed development the assessment has been made against SSV calculated using the generic "Residential" land use¹⁸. The critical receptor for this land use is considered to be a young female child resident on site from birth to age 6. Exposure routes that are considered include the potential for direct ingestion of the soil, the outdoor and indoor ingestion of dust, the potential inhalation of dust and vapours, ingestion of site grown vegetables and ingestion of soil attached to vegetables.

For the assessment of risk to controlled waters a qualitative assessment has been undertaken based upon the concentrations of contaminants recorded within the soil samples and the information obtained about the sensitivity of the underlying strata or nearby surface water receptors.

9.3 Heavy Metals

The following table summarises the soil screening values along with the maximum and minimum concentrations of the heavy metals tested for.

¹⁶ The LQM/CIEH Suitable 4 Use Levels, 2015.

¹⁷ SP1010: Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination. Final Project Report, published by DEFRA, 2014.

¹⁸ As defined within Science Report SC050021/SR3, January 2009, with the amendments discussed in the LQM/CIEH report.

Table 11. Summary of Test Results for Heavy Metals

Contaminant	SSV (mg/kg)	No. of Samples	Minimum Concentration (mg/kg)	Maximum concentration (mg/kg)	Limit of Detection (mg/kg)	No of exceedances
Arsenic	37	5	12	14.2	<1	0
Cadmium	11	5	<0.5	0.6	<0.5	0
Chromium	910	5	26.2	36.7	<5	0
Copper	2400	5	18.9	89.1	<5	0
Lead	200	5	32.7	2050	<5	1
Mercury	40	5	<0.5	0.6	<0.5	0
Nickel	180	5	16.3	21.5	<5	0
Selenium	250	5	<1	1.3	<1	0
Zinc	3700	5	51.2	460	<5	0
Hexavalent Chromium	6	5	<0.8	<0.8	<0.8	0
Water Soluble Boron	290	5	<0.8	1.3	<0.5	0

One made ground sample, taken from borehole WS105 at 0.20m depth recorded a concentration of lead in excess of the respective SSV, which may pose an unacceptable risk to site end users. It is noted that this borehole was located in the north eastern corner of the site within the general area of the access track formed from imported materials.

At the concentrations recorded, none of the heavy metals would be expected to exhibit any significant mobility and they are not considered to pose an unacceptable risk to controlled waters beneath the site.

9.4 Asbestos

Four samples of the made ground were screened for the presence of asbestos.

No suspected asbestos materials were noted within any of the exploratory holes undertaken at the site. None of the samples recorded the presence of any asbestos materials.

Based on the findings of this investigation, no significant risk to end users is considered to be posed by asbestos materials within soils. However, due to the heterogeneity of made ground, there will always remain the potential for localised asbestos materials to be encountered during construction works. All workers at the site should be made aware of what actions to take in the event that suspected asbestos materials are identified at any time during the development works.

9.5 Organic Contaminants

9.5.1 Polycyclic Aromatic Hydrocarbon (PAH) Compounds

The following table summarises the soil screening values, maximum and minimum concentrations for the PAH compounds tested for.

Table 12. Summary of Test Results for PAH Compounds

Contaminant	SSV (mg/kg)	No. of Samples	Minimum Concentration (mg/kg)	Maximum concentration (mg/kg)	Limit of Detection (mg/kg)	No of exceedances
Naphthalene	2.3	5	<0.1	<0.1	<0.1	0
Acenaphthylene	170	5	<0.1	0.2	<0.1	0
Acenaphthene	210	5	<0.1	0.2	<0.1	0
Fluorene	170	5	<0.1	0.3	<0.1	0
Phenanthrene	95	5	0.1	3.1	<0.1	0
Anthracene	2400	5	<0.1	1.5	<0.1	0
Fluoranthene	280	5	0.6	9.5	<0.1	0
Pyrene	620	5	0.6	8.3	<0.1	0
Benz(a)anthracene	7.2	5	0.4	4.3	<0.1	0
Chrysene	15	5	0.5	5.1	<0.1	0
Benzo(b)fluoranthene	2.6	5	0.6	4.6	<0.1	1
Benzo(k)fluoranthene	77	5	0.6	5	<0.1	0
Benzo(a)pyrene	2.2	5	0.6	5.1	<0.1	1
Indeno(123-cd)pyrene	27	5	0.5	3.5	<0.1	0
Dibenz(ah)anthracene	0.24	5	<0.1	0.7	<0.1	1
Benzo(ghi)perylene	320	5	0.5	3.2	<0.1	0

As was the case of heavy metal contamination, one sample of made ground, again the sample recovered from borehole WS105 at 0.20m depth, recorded concentrations of the PAH compounds Benzo(b)fluoranthene, Benzo(a)pyrene and Dibenz(ah)anthracene in excess of the respective SSVs, which may pose an unacceptable risk to site end users.

At the concentrations recorded, PAH compounds would not be expected to exhibit any significant mobility and are not considered to pose an unacceptable risk to controlled waters beneath the site.

9.5.2 Petroleum Hydrocarbons

Six samples of made ground/natural soil were tested to determine their total concentrations of petroleum hydrocarbons with the results speciated by equivalent carbon weight fractions.

The following table lists the screening values for petroleum hydrocarbon equivalent carbon weight fractions calculated for 1% organic content.

Table 13. Soil Screening Values for petroleum hydrocarbon equivalent carbon weight fractions

Petroleum Hydrocarbon Fraction	SSV (mg/kg)	Petroleum Hydrocarbon Fraction	SSV (mg/kg)
Aliphatic EC 5-6	42	Aromatic EC 5-7	70
Aliphatic EC >6-8	100	Aromatic EC >7-8	130
Aliphatic EC >8-10	27	Aromatic EC >8-10	34
Aliphatic EC >10-12	130	Aromatic EC >10-12	74
Aliphatic EC >12-16	1100	Aromatic EC >12-16	140
Aliphatic EC >16-35	65000	Aromatic EC >16-21	260
Aliphatic EC >35-44	65000	Aromatic EC >21-35	1100
		Aromatic EC >35-44	1100

Full speciation of petroleum hydrocarbons by aromatic and aliphatic fractions was not undertaken. However, the results of the testing undertaken can still be compared with the more stringent of the screening values for the respective equivalent carbon weight fraction and, where the concentration recorded is found to be lower, then it can be concluded that no significant risk is present.

None of the samples tested recorded petroleum hydrocarbons above screening values for a residential land use.

Comparison of the test results with screening criteria for water supply pipes¹⁹ indicates that the protection of water supply services is unlikely to be required. However, it is noted that the testing undertaken to date does not encompass all of the contaminants that may be required by water supply companies for assessment purposes. Notwithstanding the above it is strongly recommended that designers consult with the proposed water supply company to ascertain whether they require further laboratory testing and assessment specific to proposed routes of services.

9.6 Quantitative Contamination Risk Assessment

9.6.1 Contamination Sources Identified

The following sources of contamination have been identified by the quantitative contamination risk assessment:

- Elevated lead and PAH concentrations within made ground soils in northeast part of site.

9.6.2 Quantitative Conceptual Model

The quantitative conceptual model for the proposed development is presented in Appendix H.

¹⁹ Set out within Table 3.1 of the Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites, UK Water Industry Research, 2010.

9.7 Risks to Other Potential Receptors

The following general guidance is given with regard to other potential on site receptors, which may not necessarily be statutory drivers for remedial works.

As a minimum and in accordance with industry best practice all ground-workers should be issued with the appropriate PPE and should be instructed in safe working methods.

As a precautionary measure instruction should be given in the recognition of potentially hazardous materials, including oily and odorous soil and water and discoloured or fibrous substances. Any oil-like substances contacting the skin must be washed off immediately using an appropriate cleanser. Operatives should be warned to avoid contact between hands and mouth before washing. The consumption of food and smoking must be confined to designated clean areas. Suitable welfare (washing) facilities should be provided. These precautions should be taken in addition to anything highlighted by a site-specific risk assessment which should be undertaken by any contractor prior to commencing work.

All site personnel should be appropriately briefed on what actions to take in the event that evidence of significant contamination is identified or suspected.

9.8 Recommendations

The ground investigation has recorded elevated concentrations of lead and PAH compounds within the shallow made ground soils in the north-eastern part of the site, which is likely to be associated with the historical deposition of either crushed surfacing materials or waste materials within this part of the site, as identified by the preliminary risk assessment.

Based upon the findings of the investigation, it is considered likely that some form of remediation will be required to safeguard end users of the site from the recorded soil contamination in this part of the site. However, further sampling and risk assessment, specifically within the northern part of the site, will be required in order to confirm the extent of any contamination present and inform the requirements for remedial measures.

9.9 Handling and Disposal of Waste

9.9.1 Waste Management – Legislative Framework

Waste is defined as “any substance or object which the holder discards or intends to discard”²⁰. Soils excavated during construction works are therefore generally considered to be waste²¹.

If a material is waste then an Environmental Permit²² will be required to lawfully deposit or re-use the material unless it is “uncontaminated soil and other naturally occurring material excavated in the course of construction activities where it is certain that the material will be used for the purposes of construction in its natural state on the site from which it was excavated”. Such materials are excluded from the Waste Framework Directive (WFD).

²⁰ 2008 Waste Framework Directive (Directive 2008/98/EC)

²¹ Guidance on the legal definition of waste and its application, Environment Agency, 2012

<https://www.gov.uk/government/publications/legal-definition-of-waste-guidance/decide-if-a-material-is-waste-or-not>

²² Environmental Permitting (England and Wales) Regulations 2010

Guidance published by CL:AIRE²³ provides a framework for demonstrating how excavated materials arising from development sites may be considered as non-waste and can therefore be re-used on their site of origin, or elsewhere.

Soils and other materials taken for disposal should be handled, transferred and disposed of as controlled waste in accordance with current waste management^{24,25} and duty of care regulations²⁶ and comply with current codes of practice²⁷. Waste transfer notes detailing the site address, the waste type, details of the haulage contractor and full details of the disposal site must be kept by the waste producer.

Specifically, the disposal of any asbestos containing materials should be undertaken by appropriately trained personnel. The disposal of such material and other hazardous waste should be undertaken in accordance with the Hazardous Waste Regulations 2005²⁸.

9.9.2 Waste Classification

It is a legal requirement (as discussed within the Waste Duty of Care Code of Practice) to correctly assess and classify waste. Characterisation of the waste in full accordance with current guidance²⁹ was beyond the scope of this assessment.

However, analysis of the results of the laboratory testing was undertaken using the HazWasteOnline^{TM30} tool.

The HazwasteOnline tool classifies soils in accordance with European Waste Catalogue (2002) following guidance published by the Environment Agency (WM3)³¹.

The output sheets generated by the tool are presented in Appendix J.

The following table summarises the classification of soils tested and the code from the List of Wastes (LoW).

Table 14. Summary of Classification of Samples from HazWasteOnline Analysis

Exploratory Hole Location	Sample Depth (m bgl)	Strata	Classification	Code from LoW
WS102	0.30	Made ground	Non-Hazardous	17-05-04
WS104	0.10	Made ground	Non-Hazardous	17-05-04
WS105	0.20	Made ground	Hazardous	17-05-03*
WS107	0.10	Made ground	Non-Hazardous	17-05-04
WS108	0.20	Made ground	Non-Hazardous	17-05-04

An asterisk (*) at the end of a code means the waste is hazardous.

²³ CL:AIRE, The Definition of Waste: Development Industry Code of Practice, Version 2, March 2011

²⁴ The Waste (England and Wales) Regulation 2011

²⁵ Section 34, Environmental Protection Act 1990

²⁶ The Environmental Protection (Duty of Care) Regulations 1991

²⁷ Waste Duty of Care Code of Practice, Dept. for Environment Food & Rural Affairs, March 2016

²⁸ Hazardous Waste (England and Wales) Regulations 2005

²⁹ As discussed in BS EN 14899:2005 Characterisation of waste

³⁰ <https://www.hazwasteonline.com/>

³¹ Technical Guidance WM3: Waste Classification – Guidance on the assessment of waste, 1st Edition v1.1, May 2018

It is noted that the same sample that recorded elevated levels of lead and PAH has been classified as hazardous waste (WS105 at 0.20m depth).

9.9.3 Waste Acceptance Criteria (WAC) Testing

As specified in WM3: "Landfill WAC analysis (specifically leaching test results) must **not** be used for waste classification and hazardous waste assessment purposes." Environment Agency guidance³² states "Before a waste can be accepted at a landfill site, the operator must be satisfied that the waste meets his (*sic*) permit conditions, the waste acceptance procedures and waste acceptance criteria." Figure 1 and 2 of the guidance show the stages in the assessment of waste for disposal by landfill, including WAC testing.

WAC testing was undertaken on two samples of the made ground soils. The made ground sample from borehole WS108 (0.20m depth) meets the WAC criteria for inert landfill. The total organic carbon and antimony concentrations in the sample from borehole WS105 (0.20m depth) were in excess of the inert WAC limits.

It is noted that the disposal site has the final decision on whether to accept any materials and we would recommend that all the testing and classification information be provided to them at the earliest opportunity.

Ashdown Site Investigation Ltd.

³² Waste acceptance at landfills, November 2010

Land at Arundel Road, Angmering, West Sussex

FIGURES

- Figure 1 Site Location Plan
- Figure 2 Site Plan