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GEO-ENVIRONMENTAL & GEOTECHNICAL ASSESSMENT (GROUND INVESTIGATION) REPORT

Folder's Lane (Eastern Plot), Burgess Hill, RH15 0DX



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EXECUTIVE SUMMARY

Site Details	Site Address	Folders Lane (Eastern Plot), Burgess Hill, RH15 0DX
	National Grid	533000, 118000
	Site Area	0.50Ha (approx.)
	Proposed Development	It is understood that the proposed development will comprise the construction of residential dwellings with some communal/amenity soft landscaping, private gardens and associated roadways.
Encountered Conditions	Scope of Works	The assessment incorporated a desk study to determine the site's setting to inform a preliminary risk assessment followed by an intrusive investigation to confirm the ground and groundwater conditions and support the development of a geotechnical and geo-environmental assessment.
	Ground Conditions	The ground conditions encountered broadly consistent with those anticipated, and comprised Topsoil/Made Ground, to depths of up to 0.90m, underlain by sandy clay/sand of the Weald Clay Formation to the base of the boreholes (maximum depth of 4.00m).
	Groundwater	Groundwater seepages were encountered within WS4 and WS13 at depths of between 3.0m and 4.0mbgl during the intrusive investigation. In addition, combined groundwater and ground gas monitoring wells were installed within WS2, WS12, and WS17 to a maximum depth of 3.69mbgl which were monitored on 4No occasions in February 2024. Water was recorded between depths of 0.00m (ground level) -3.43mbgl during the return visits.
Geo-environmental Assessment Summary and Recommendations		Following generic risk assessments, elevated concentrations of lead were detected in soils in excess of generic assessment criteria for the protection of human health within a residential with plant uptake end-use scenario. These elevated concentrations were localised within an area proposed to contain communal landscaping only, and therefore is considered appropriate to utilise less stringent assessment criteria and therefore these soils are considered suitable to remain provided no private gardens are proposed within this area of site. No asbestos containing materials or fibres were detected in the Made Ground samples analysed in the laboratory. A significant risk to plant growth has not been identified. The risk to controlled waters from soils is considered negligible. Based on the calculated GSVs, and in consideration of the conceptual site model, the site is classified as Characteristic Situation 1 (CS1) and no formal gas protection measures are considered to be necessary. Upgraded potable water supply pipe materials are unlikely to be required. The water supply pipe requirements for this site should be discussed at an early stage with the relevant utility provider. Based on the existing proposed development plan, no formal remedial measures are considered necessary. This is on the basis that only communal soft landscaping is proposed within the north of the site, in the area as shown on Figure 5. If the proposed development changes, this assessment should be revised accordingly. As with any ground investigation, the presence of further hotspots between sampling points cannot be ruled out. Should any contamination be encountered, a suitably qualified environmental consultant should be informed immediately, so that adequate measures may be recommended. The above conclusions are made subject to approval by the statutory regulatory bodies.

Geotechnical Considerations	Foundations	Based on the ground and groundwater conditions encountered, traditional strip/trench-fill foundations up to 1m wide may be formed within the underlying Weald Clay Formation at a minimum depth of 2.0m for an allowable bearing capacity of 100kPa.
	Sulphates	Buried concrete for foundations should be designed to Class DS-1 (AC1).
	Ground Floor Slabs	Given the presence of shrinkable soils, it is recommended that suspended floor slabs are used with an adequate void designed according to NHBC Standards. As a guide, initial modelling indicates a requirement for a sub-floor void of at least 300mm due to the presence of shrinkable soils of “high” volume change potential.
	Excavations	Temporary excavations are unlikely to remain stable and some form of temporary support or battering back to a safe angle and dewatering are likely to be required. Subject to seasonal variations, surface water/groundwater encountered during site works could likely be dealt with by conventional pumping from a sump used to collate waters.
	Road Pavements	Preliminary CBR design values of 1% and 2.5% are recommended for pavements constructed within the Made Ground/near surface deposits of Weald Clay and the deeper Weald Clay Formation, respectively.
	Surface Water Drainage	Based on the results of in-situ testing, and ground conditions encountered, conventional soakaways are not likely to be suitable and an alternative drainage solution should be sought.
Recommended Further Work		The following works are recommended: • Submit chemical testing results to appropriate waste facility to confirm waste classification. • Seek approval of the Generic Quantitative Risk Assessment and Soil Gas Assessment from the Local Authority, NHBC and other relevant stakeholders. • Should the proposed development plan alter to include private soft landscaping in the north of the site, a Remediation Method Statement (RMS) should be prepared. • Seek confirmation of the water supply pipe requirements by the appropriate service provider.
<i>This Executive Summary is intended to provide a brief summary of the main findings and conclusions of the investigation. For detailed information, the reader is referred to the main report ref. P1215J553b.</i>		

1 INTRODUCTION

1.1 Terms of Reference

- 1.1.1 Jones Homes (Southern) Limited ("The Client") has commissioned Jomas Associates Ltd ('Jomas') to undertake an investigation of the geotechnical and geo-environmental factors pertaining to the proposed development at a site referred to as Folders Lane (Eastern Plot), Burgess Hill, RH15 0DX (herein referred to as 'the site'). The site's location is presented in Figure 1.
- 1.1.2 A Phase 1 Desk Study has been produced for the site and issued separately (detailed in Table 1.1 below), followed by an intrusive investigation (detailed in this report).
- 1.1.3 An intrusive investigation has been undertaken in accordance with Jomas' proposal dated 18th October 2023.

1.2 Proposed Development

- 1.2.1 The proposed development is to comprise the construction of a new residential scheme comprising 40No plots with private and communal gardens and associated roadways and infrastructure.
- 1.2.2 For the purpose of geo-environmental assessment and selection of generic assessment criteria, the development is considered "residential with plant uptake" as a conservative approach. Less sensitive areas may be zoned separately as part of the later assessments if necessary.
- 1.2.3 A plan of the proposed development is provided as Figure 4.
- 1.2.4 For the purpose of geotechnical assessment, it is considered that the project could be considered as a Geotechnical Category (GC) 2 site in accordance with BS EN 1997.

1.3 Objectives

- 1.3.1 The objectives of Jomas' investigation are as follows:
- To undertake an intrusive investigation, to determine the ground and groundwater conditions as well as to assess the nature and extent of contaminants (if any) potentially present at the site;
 - To establish the presence of significant pollutant linkages, in accordance with the procedures set out within Part IIA of the Environmental Protection Act 1990, associated statutory guidance and current best practice including the EA land contamination risk management (LCRM); and,
 - To determine soil properties to inform the preliminary geotechnical assessment for foundations, drainage, excavation stability, pavement design and buried concrete and recommendations for further action (if required).

1.4 Scope of Works

- 1.4.1 The following tasks were undertaken to achieve the objectives listed above:

- Intrusive ground investigation to determine shallow ground conditions, and potential for contamination to be present at the site;
- Undertaking of laboratory chemical and geotechnical testing upon samples obtained;
- Return ground gas/groundwater monitoring.
- The compilation of this report, which collects and discusses the above data, and presents an assessment of the site conditions, conclusions and recommendations.

1.5 Supplied Documentation

- 1.5.1 A number of relevant reports prepared by or supplied to Jomas Associates prior to the commencement of this investigation are detailed in Table 1.1:

Table 1.1: Previous/Supplied Reports

Title	Author	Reference	Date
Geo-environmental Desk Study /Preliminary Risk Assessment Report for Folders Lane (Eastern Plot)	Jomas Associates	P1215J553b	8 th February 2018

1.6 Limitations

- 1.6.1 Jomas has prepared this report for the sole use of Jones Homes (Southern) Limited, in accordance with the generally accepted consulting practices and for the intended purposes as stated in the agreement under which this work was completed. This report may not be relied upon by any other party without the explicit written agreement of Jomas. No other third party warranty, expressed or implied, is made as to the professional advice included in this report. This report must be used in its entirety.
- 1.6.2 The records search was limited to information available from public sources; this information is changing continually and frequently incomplete. Unless Jomas has actual knowledge to the contrary, information obtained from public sources or provided to Jomas by site personnel and other information sources, have been assumed to be correct. Jomas does not assume any liability for the misinterpretation of information or for items not visible, accessible or present on the subject property at the time of this study.
- 1.6.3 Whilst every effort has been made to ensure the accuracy of the data supplied, and any analysis derived from it, there may be conditions at the site that have not been disclosed by the investigation, and could not therefore be taken into account. As with any site, there may be differences in soil conditions between exploratory hole positions. Furthermore, it should be noted that groundwater conditions may vary due to seasonal and other effects and may at times be significantly different from those measured by the investigation. No liability can be accepted for any such variations in these conditions.
- 1.6.4 Any reports provided to Jomas have been reviewed in good faith. Jomas cannot be held liable for any errors or omissions in these reports, or for any incorrect interpretation contained within them.

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- 1.6.5 This investigation and report has been carried out in accordance with the relevant standards and guidance in place at the time of the works. Future changes to these may require a re-assessment of the recommendations made within this report.
- 1.6.6 **This report is not an engineering design and the figures and calculations contained in the report should be used by the Structural Engineer, taking note that variations may apply, depending on variations in design loading, in techniques used, and in site conditions. Our recommendations should therefore not supersede the Engineer's design.**

2 DESK STUDY SUMMARY

2.1 Site Information

2.1.1 The site location plan is appended to this report in Figure 1, Appendix 1.

Table 2.1: Site Information

Name of Site	Folders Lane (Eastern Plot)
Address of Site	Folders Lane Burgess Hill RH15 0DR
Approx. National Grid Ref.	533000 118000
Site Area (Approx)	0.50ha
Site Occupation	Undeveloped land/agricultural
Local Authority	Mid Sussex District Council
Proposed Site Use	Residential with private gardens and associated roadways

2.2 Site Walkover

2.2.1 A site walkover survey was undertaken by Jomas on the 26th January 2024.

Table 2.2: Site Description

Area	Item	Details
On-site:	Current Uses:	Site consists of a medium-sized agricultural field currently kept as grass pasture. No structures were observed on site. There is a public footpath adjacent to the western site boundary.
	Evidence of historic uses:	There was no evidence of historic uses of the site.
	Surfaces:	All of site is grass covered.
	Vegetation:	No trees are located within the site boundary, however numerous mature trees (oak, ash and birch) are located along the perimeter of the site. Site entirely covered by grass. All vegetation observed on site appeared in healthy condition, exhibiting no evidence of distress.
	Topography/Slope Stability:	A slight downward slope to the south was observed.
	Drainage:	The ground appears to be slow draining, several boggy areas with standing water observed at the surface.
	Services:	No services observed on site.
	Controlled waters:	No controlled waters were noted on site.
	Tanks:	No tanks observed on site.

Area	Item	Details
Neighbouring land:	North:	Residential
	East:	Agricultural land
	South:	Residential and Winery
	West:	Agricultural land

2.2.2 Site photographs taken during the site walkover can be found as Figure 2, in Appendix 1.

2.3 Summary of Preliminary Risk Assessment (Desk Study)

2.3.1 As detailed in Table 1.1, a Phase 1 Desk Study report has been produced for the site and issued separately (Jomas Associates – P1215J553b – February 2018). The findings of the Phase 1 Desk Study are presented in the following section. Reference should be made to the original reports and documents for further details. Comments made in the following section regarding possible ground conditions on the site and within the surrounding area are based purely on the desk study. Where appropriate, this information will be used in the later sections of this report as supplementary information to assist in the evaluation of the ground conditions and aid the identification of geotechnical and geochemical constraints and hazards that could impact on the scheme.

2.3.2 A review of historical Ordnance Survey maps indicates that the site originally (1870) comprised undeveloped potentially agricultural land, with trees located along its perimeter. Other than two small buildings located in the northwest corner of the site developed around 1937 and removed by 1974, the site is in its current configuration.

2.3.3 The surrounding area was predominantly agricultural land with small associated farmhouses from the earliest maps. A rail track is shown, located 200m northeast of site orientated northwest to southeast, this feature is in the same present-day configuration. Industrial buildings area located directly NE of site is noted in 1937 as a textile factory, changing to a workshop in 1954 and a chapel in 1984. The surrounding area shows consistent minor residential development within 500m, with more larger scale developments noted in 1984 and 2010.

2.3.4 Information provided by the British Geological Survey indicates that the site is directly underlain by solid deposits of the Weald Clay Formation. A band of sandstone is reported across the south of the site, also part of the Weald Clay Formation.

2.3.5 The sandstone deposit underlying the south of the site is a Secondary (A) aquifer.

2.3.6 A review of the Envirolnsight report indicates that there are no Source Protection Zones within 500m of the site.

2.3.7 There are no groundwater or potable water abstractions reported within 1km of the site.

2.3.8 The nearest active surface water abstraction is reported 350m west of the site.

2.3.9 There are no Environment Agency Zone 2 or Zone 3 floodplains reported within 250m of the site.

- 2.3.10 A ground investigation was recommended comprising of a series of window sampler holes or trial pits. Gas/groundwater monitoring well installations were recommended if a significant thickness of made ground was encountered to allow for ground gases to be monitored.
- 2.3.11 The conceptual site model is reproduced in Table 2.3 overleaf.

Table 2.3: Preliminary Risk Assessment for the Site

Sources	Pathways (P)	Receptors	Consequence of Impact	Probability of Impact	Risk Estimation	Hazard Assessment
- Potential for Made Ground associated with previous development operations – on site (S1) - Current and previous industrial use – off site (S2)	- Ingestion and dermal contact with contaminated soil (P1) - Inhalation or contact with potentially contaminated dust and vapours (P2) - Permeation of water pipes and attack on concrete foundations by aggressive soil conditions (P6)	- Construction workers (R1) - Maintenance workers (R2) - Neighbouring site users (R3) - Future site users (R4) - Building foundations and on site buried services (water mains, electricity and sewer) (R5)	Medium	Low likelihood	Moderate	GI – Ground Investigation
			Severe for Asbestos	Low for Asbestos	Moderate for Asebestos	
	Accumulation and migration of soil gases (P5)		Severe	Unlikely	Low	
	- Leaching through permeable soils, migration within the vadose zone (i.e., unsaturated soil above the water table) and/or lateral migration within surface water, as a result of cracked hardstanding or via service pipe/corridors and surface water runoff (P3) - Horizontal and vertical migration of contaminants within groundwater (P4)	- Neighbouring site users (R3) - Building foundations and on site buried services (water mains, electricity and sewer) (R5) - Controlled Waters (Aquifer) (R6)	Medium	Unlikely	Low	

3 PREVIOUS GROUND INVESTIGATIONS

- 3.1.1 Jomas is not aware of any previous intrusive investigation works that have been undertaken on the site.

4 GROUND INVESTIGATION

4.1 Scope of Works

- 4.1.1 A ground investigation was undertaken on the 30th 31st January & 1st & 2nd February 2024.
- 4.1.2 A summary of the fieldwork carried out at the site, with justifications for exploratory hole positions, is presented in Table 4.1 below.

Table 4.1: Scope of Intrusive Investigation

Investigation Type	Number of Exploratory Holes Achieved	Exploratory Hole Designation	Depth Achieved	Justification
Windowless Sample Boreholes	20	WS1-20	Up to 5mbgl	Obtain shallow samples for laboratory chemical and geotechnical testing. To allow in-situ geotechnical testing. Boreholes were positioned across the site to provide a non-targeted sampling strategy, with consideration to physical constraints on the site.

- 4.1.3 The ground investigation was undertaken in accordance with British Standard BS5930:2015+A1:2020 "Code of practice for ground investigations", British Standard BS10175:2011+A2:2017 "Investigation of potentially contaminated sites - code of practice", NHBC Standards, Chapter 4.1 and AGS Guidelines for Good Practice in Site Investigations.

- 4.1.4 Exploratory hole positions are shown on the exploratory hole location plan presented in Figure 2, Appendix 1. The exploratory hole records are included in Appendix 2.

- 4.1.5 Where monitoring wells were not installed, the exploratory holes were backfilled with the arisings (in the reverse order in which they were drilled) and the ground surface was reinstated so that no depression was left.

4.2 In-situ Geotechnical Testing

- 4.2.1 In-situ geotechnical testing included Standard Penetration Tests. The determined 'N' values have been used to determine the relative density of granular materials and have been used with standard correlations to infer various other derived geotechnical parameters including the undrained shear strength of the cohesive strata. The results of the individual tests are on the appropriate exploratory hole logs in Appendix 2.

- 4.2.2 In-situ California Bearing Ratios (CBRs) were determined using a TRL dynamic cone penetrometer (DCP) and the methodology laid out in IAN 73/06. The CBR values have then been calculated using the methodology laid out in both IAN 73/06 and TRL 587. Copies of the test results and calculations are provided in Appendix 7.

- 4.2.3 The determination of permeability of the underlying ground was undertaken by carrying out in-situ falling head tests. These were carried out to conform with the methodology for falling head permeability test formerly outlined in BS: 5930 (1999) and recently in BS EN ISO 22282-2. Copies of the results and calculations are provided in Appendix 8.

4.3 Laboratory Analysis

4.3.1 A programme of laboratory testing, scheduled by Jomas Associates Limited, was carried out on selected samples of Made Ground and natural strata.

Chemical Testing

4.3.2 Chemical testing of soils was undertaken by Derwentside Environmental Testing Services Ltd (DETS), which holds UKAS and MCERTS accreditations for a wide range of determinands.

4.3.3 The samples were analysed for a wide range of contaminants as shown in Table 4.2 below:

Table 4.2: Chemical Tests Scheduled

Test Suite	No. of tests	
	Made Ground / Topsoil	Natural
Basic Suite 3	20	-
Waste Acceptance Criteria Testing	2	-
Total Organic Carbon	10	-
Jomas Modified BRE SD-1 Suite	4	8
Asbestos Screen & ID	15	-

4.3.4 The determinands contained in the Basic Suite 3 are as detailed in Table 4.3 below.

Table 4.3: Basic Suite of Determinands

DETERMINAND	LIMIT OF DETECTION (mg/kg)	UKAS ACCREDITATION	TECHNIQUE
Arsenic	2	Y (MCERTS)	ICP-EOS
Cadmium	0.2	Y (MCERTS)	ICP-EOS
Chromium	2	Y (MCERTS)	ICP-EOS
Chromium (Hexavalent)	4	N	ICP-EOS
Lead	3	Y (MCERTS)	ICP-EOS
Mercury	1	Y (MCERTS)	ICP-EOS
Nickel	3	Y (MCERTS)	ICP-EOS
Selenium	2	Y (MCERTS)	ICP-EOS
Copper	4	Y (MCERTS)	ICP-EOS
Zinc	3	Y (MCERTS)	ICP-EOS
Boron (Water Soluble)	0.1	N	ICP-EOS
pH Value	0.1 units	Y (MCERTS)	Electrometric Measurement
Sulphate (Water Soluble)	0.01g/l	Y (MCERTS)	Ion Chromatography/ICP-EOS
Total Cyanide	1	N	Distillation followed by Chromatography
Speciated/Total PAH	0.10/1.6	Y (MCERTS)	GC-MS
Phenols	2	N	Distillation followed by Colorimetry
Total Petroleum Hydrocarbons (banded)	6	N	GC-FID/Headspace GS-MS

4.3.5 To support the selection of appropriate tier 1 screening values, 10No. samples were analysed for total organic carbon.

4.3.6 The laboratory test results are included in Appendix 3.

Geotechnical Laboratory Testing

4.3.7 In addition to the contamination assessment, soil samples were submitted to the UKAS Accredited laboratory of K4 Soils Laboratory for a series of geotechnical analyses.

4.3.8 This testing was designed to classify the samples and to obtain parameters (either directly or sufficient to allow relevant correlations to be used) relevant to the technical objectives of the investigation.

4.3.9 The following laboratory geotechnical testing was carried out:

Table 4.4: Laboratory Geotechnical Analysis

Methodology	Test Description	Number of tests
BS1377:1990	Moisture Content Determination	18
BS1377:1990	Liquid and Plastic Limit Determination (Atterberg Limits)	18

4.3.10 In addition, 12No. soil samples were analysed by DETS for a modified BRE Special Digest 1 suite (acid and water soluble sulphate, total sulphur and pH) to assist with the ACEC classification for buried concrete.

4.3.11 The laboratory test results are included in Appendix 4.

5 GROUND CONDITIONS ENCOUNTERED

5.1 General

5.1.1 A factual record of the conditions encountered during the physical investigation of the site is presented in the following section.

5.2 Ground Conditions

5.2.1 The ground conditions encountered were broadly consistent with those anticipated, i.e. a thickness of Made Ground overlying Weald Clay Formation and are summarised in Table 5.1 below.

Table 5.1: Ground Conditions Encountered

Stratum and Description	Encountered from (mbgl)	Base of strata (mbgl)	Thickness range (m)
Grass over brown slightly sandy slightly gravelly clay. Sand is fine to coarse. Gravel consists of fine to medium sub-angular to sub-rounded flint. (MADE GROUND – TOPSOIL)	GL	0.10 – 0.90	0.10 – 0.90
Grass over brown slightly sandy slightly gravelly clay. Sand is fine to coarse. Gravel consists of fine to medium sub-angular to sub-rounded flint and occasional brick. (MADE GROUND) Only encountered in WS2 – WS9 inclusive	GL	0.20 – 0.50	0.20 – 0.50
Soft becoming firm to very stiff** consistency Orangish/reddish/yellowish brown mottled grey/purple sandy CLAY. Sand is fine to coarse. (WEALD CLAY FORMATION – COHESIVE)	0.10 - 0.90	>2.00 – >4.20	>1.65 – >3.70
Medium dense becoming very dense brownish yellow SAND. Sand is fine to coarse. (WEALD CLAY FORMATION – SANDSTONE) Only encountered in WS5, WS6 & WS9	2.90 – 3.00	>3.00 – >4.00	>0.10 – >1.00

**** Consistency estimated using semi-empirical correlations with SPT N Values, plasticity indices and published literature.**

5.2.2 Made Ground with gravel containing evidence of anthropogenic material was found to only be present in the northern half of site.

5.3 Groundwater

5.3.1 Recorded groundwater strikes are summarised below.

Table 5.2: Groundwater Strikes During Investigation

Exploratory Hole ID	Depth Encountered (mbgl)	Depth After 20mins (mbgl)	Stratum
WS4	3.0 – 4.0	-	Weald Clay Formation
WS13	3.1	-	Weald Clay Formation

- 5.3.2 4 No. Return groundwater monitoring visits were undertaken between the 9th and 28th Februsry 2024, the results are presented in Appendix 5 and are summarised below.

Table 5.3: Groundwater Monitoring Summary

Exploratory Hole ID	Depth Encountered (mbgl)	Well Response Zone as installed (top/bottom mbgl)	Depth to Base of Well – as gauged (mbgl)	Strata targeted by response zone
WS2	0.00 – 0.18	1.00 – 3.10	2.90 – 2.97	Weald Clay Formation
WS12	2.38 – 3.43	1.00 – 3.40	3.60 – 3.69	Weald Clay Formation
WS17	0.29 – 0.63	1.00 – 2.60	1.57 – 1.62	Weald Clay Formation

- 5.3.3 It should be noted that changes in groundwater levels can occur for a number of reasons including seasonal effects and variations in drainage. Such fluctuations may only be recorded by the measurement of the groundwater level within a standpipe or piezometer installed within appropriate response zones. Changes in groundwater level can have a direct effect on excavation stability and dewatering requirements, and cohesive soils can soften under rising or high groundwater levels.

5.4 Physical and Olfactory Evidence of Contamination

- 5.4.1 No visual or olfactory evidence of potential contamination was identified within the investigation positions.

5.5 Limitations

- 5.5.1 During the intrusive ground investigation, all of the boreholes were terminated prior to 5mbgl due to refusal of the sample barrel in hard natural ground, which was interpreted to be interbedded sandstone and mudstone of the Weald Clay Formation.

6 RISK ASSESSMENT – ANALYTICAL FRAMEWORK

6.1 Context and Objectives

6.1.1 This section seeks to evaluate the level of chronic risk pertaining to human health and the environment which may result from both the existing use and proposed future use of the site. It makes use of the ground investigation findings, as described in the previous sections, to evaluate further the potential pollutant linkages identified in the desk study. A combination of qualitative and quantitative techniques is used, as described below.

6.1.2 The purpose of generic quantitative risk assessment is to compare concentrations of contaminants found on site against generic assessment criteria (GAC) to establish whether there are actual or potential unacceptable risks. It also determines whether further detailed assessment is required. The approaches detailed all broadly fit within a tiered assessment structure in line with the framework set out in the Department of Environment, Food and Rural Affairs (DEFRA), EA and Institute for Environment and Health Publication, Guidelines for Environmental Risk Assessment and Management.

6.2 Analytical Framework – Soils

6.2.1 There is no single methodology that covers all the various aspects of the assessment of potentially contaminated land and groundwater. Therefore, the analytical framework adopted for this investigation is made up of a number of procedures, which are outlined below. All of these are based on a Risk Assessment methodology centred on the identification and analysis of Source – Pathway – Receptor linkages.

6.2.2 The soil analytical test results have been compared to Suitable 4 Use Levels (S4UL) published by the Chartered Institute of Environmental Health in order to assess the potential long-term risks to human health posed by contaminants in the soils. S4UL'S have been derived for a range of land uses and Soil Organic Matter contents. They represent the minimal or tolerable risk, above which further assessment of the risks or remedial action may be required.

6.2.3 In the absence of a S4UL recommended concentration, other available general assessment criteria (GAC), including the Category 4 Screening Levels (C4SL) published by DEFRA have been used. Site-specific assessments are undertaken wherever possible and/or applicable. All assessments are carried out in accordance with the CLEA protocol.

6.2.4 The assessment criteria used for the screening of determinands within soils are identified within Table 6.1.

Table 6.1: Selected Assessment Criteria - Contaminants in Soils

Substance Group	Determinand(s)	Assessment Criteria Selected
<u>Organic Substances</u>		
Non-halogenated Hydrocarbons	Total Petroleum Hydrocarbons (TPHCWG banded)	S4UL
	Total Phenols	S4UL
Polycyclic Aromatic Hydrocarbons (PAH-16)	Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Indeno(123-cd)pyrene, Dibenzo(ah)anthracene, Benzo(ghi)perylene	S4UL
Volatile Organic Compounds (VOCs/sVOCs).	Toluene, Ethylbenzene, Benzene, Xylenes	S4UL
<u>Inorganic Substances</u>		
Heavy Metals and Metalloids	Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Zinc	S4UL
	Copper, Zinc, Nickel	BS: 3882 (2015).
Cyanides	Free Cyanide	CLEA v1.06
Sulphates	Water Soluble Sulphate	BRE Special Digest 1:2005

- 6.2.5 It is understood that the site is to be converted to provide residential units with private gardens. As a result, the site has been assessed with regards to a “residential with plant uptake” end use scenario.
- 6.2.6 GAC have been selected with consideration to the Soil Organic Matter (SOM) content of the soil. From the soils analytical results, the average value for Total Organic Carbon for the Made Ground is 1.8 %, which gives an equivalent SOM of 3.1 %. Published GAC have been selected as those derived assuming a SOM of 1% to give a conservative assessment.
- 6.3 BRE**
- 6.3.1 The BRE Special Digest 1:2005, ‘Concrete in Aggressive Ground’ is used with soluble sulphate and pH results to assess the aggressive chemical environment of future underground concrete structures at the site.

7 GENERIC QUANTITATIVE RISK ASSESSMENT – SOIL DATA

7.1 Screening of Soil Chemical Analysis Results – Human Health Risk Assessment

7.1.1 Laboratory analysis for soils is summarised in Table 7.1 to 7.4. Raw laboratory data is included in Appendix 3.

7.1.2 Results have been screened against generic assessment criteria for a “residential with home grown produce” end use, assuming 1% soil organic matter.

Table 7.1: Soil Laboratory Test Results - Metals, Metalloids, Phenol, Cyanide

Determinand	Unit	No. samples tested	Screening Criteria	Min	Max	No. Exceeding
Arsenic	mg/kg	19	S4UL 37	10.0	18.0	0
Cadmium	mg/kg	19	S4UL 11	<0.2	<0.2	0
Chromium	mg/kg	19	S4UL 910	13.0	32.0	0
Lead	mg/kg	19	C4SL 200	13	264	2No: WS1@0.05mbgl, WS3@0.20mbgl.
Mercury	mg/kg	19	S4UL 40	<1	<1	0
Nickel	mg/kg	19	S4UL 180	4.0	12.0	0
Copper	mg/kg	19	S4UL 2400	9	27	0
Zinc	mg/kg	19	S4UL 3700	21	112	0
Total Cyanide ^A	mg/kg	19	CLEA v 1.06 33	<1	<1	0
Selenium	mg/kg	19	S4UL 250	<2	<2	0
Boron Water Soluble	mg/kg	19	S4UL 290	<1	<1	0
Phenols	mg/kg	19	S4UL 120	<2	<2	0

Notes: ^AGeneric assessment criteria derived for free inorganic cyanide.

Table 7.2: Soil Laboratory Test Results - Polycyclic Aromatic Hydrocarbons (PAHs)

Determinand	Unit	No. Samples Tested	Screening Criteria	Min	Max	No. Exceeding
Acenaphthene	mg/kg	19	S4UL 210	<0.1	<0.1	0
Acenaphthylene	mg/kg	19	S4UL 170	<0.1	<0.1	0
Anthracene	mg/kg	19	S4UL 2400	<0.1	<0.1	0
Benzo(a)anthracene	mg/kg	19	S4UL 7.2	<0.1	0.15	0
Benzo(a)pyrene	mg/kg	19	S4UL 2.2	<0.1	0.19	0
Benzo(b)fluoranthene	mg/kg	19	S4UL 2.6	<0.1	0.28	0
Benzo(ghi)perylene	mg/kg	19	S4UL 320	<0.1	<0.1	0

Determinand	Unit	No. Samples Tested	Screening Criteria		Min	Max	No. Exceeding
Benzo(k)fluoranthene	mg/kg	19	S4UL	77	<0.1	<0.1	0
Chrysene	mg/kg	19	S4UL	15	<0.1	0.25	0
Dibenzo(ah)anthracene	mg/kg	19	S4UL	0.24	<0.1	<0.1	0
Fluoranthene	mg/kg	19	S4UL	280	<0.1	0.5	0
Fluorene	mg/kg	19	S4UL	170	<0.1	<0.1	0
Indeno(123-cd)pyrene	mg/kg	19	S4UL	27	<0.1	<0.1	0
Naphthalene	mg/kg	19	S4UL	2.3	<0.1	<0.1	0
Phenanthrene	mg/kg	19	S4UL	95	<0.1	0.21	0
Pyrene	mg/kg	19	S4UL	620	<0.1	0.42	0
Total PAH	mg/kg	19	-	-	<1.6	2	-

Table 7.3: Soil Laboratory Test Results - Total Petroleum Hydrocarbons (TPH)

TPH Band	Unit	No. Samples Tested	Screening Criteria		Min	Max	No. Exceeding
C ₈ -C ₁₀	mg/kg	19	S4UL	27	<1	<1	0
>C ₁₀ -C ₁₂	mg/kg	19	S4UL	74	<1	<1	0
>C ₁₂ -C ₁₆	mg/kg	19	S4UL	330	<1	<1	0
>C ₁₆ -C ₂₁	mg/kg	19	S4UL	540	<1	<1	0
>C ₂₁ -C ₃₅	mg/kg	19	S4UL	1500	<6	<6	0
Total TPH	mg/kg	19	-	-	<6	<6	-

Note: *The lower value of guidelines for Aromatic/Aliphatics has been selected

7.2 Asbestos in Soil

7.2.1 14No samples of the Made Ground were screened in the laboratory for the presence of asbestos.

7.2.2 No asbestos containing materials (ACM) or fibres were reported in samples analysed in the laboratory.

7.3 Vapour Risk Assessment from a Soil Source

7.3.1 As outlined in Table 7.2 and Table 7.3, none of the polyaromatic hydrocarbons nor petroleum hydrocarbon fractions have been found in excess of their generic screening criteria for the protection of human health within a 'residential with homegrown produce' end-use scenario. The generic screening criteria considers all possible pathways between the source and the receptor, including vapour inhalation.

7.3.2 On this basis, a significant vapour risk is not considered to exist.

7.4 Discussion of Soil Analytical Results

- 7.4.1 As outlined above, 2No soil samples have been found to contain concentrations of lead above the threshold of 200mg/kg for use within a “residential with plant uptake” end use within WS1 and WS3. Both of these exploratory locations are found within the far north of the site, within an area understood to be proposed for development as flats with communal soft landscaping and no private soft landscaping. On this basis, it is considered appropriate to consider the results from this area against generic assessment criteria protective of human health within an “residential *without* plant uptake” end use which allows for lead concentrations up to 310mg/kg.
- 7.4.2 On the basis that the maximum lead concentration recorded in this area is 264mg/kg, the soils are considered suitable for use within this area of site, provided the end use does include private gardens.
- 7.4.3 A plan showing the site “zoning” is provided as Figure 5 in Appendix 1, showing the areas of site where private gardens can be accommodated without remedial measures.

7.5 Summary of Human Health Generic Quantitative Risk Assessment

- 7.5.1 In summary, concentrations of lead in excess of the GAC have been recorded in samples of Made Ground but not natural soils.
- 7.5.2 These elevated concentrations were localised within an area proposed to contain communal landscaping only, and therefore is considered appropriate to utilise less stringent assessment criteria and therefore these soils are considered suitable to remain provided no private gardens are proposed within this area of site.

7.6 Screening of Soil Chemical Analysis Results – Potential Risks to Plant Growth

- 7.6.1 Zinc, copper and nickel are phytotoxins and could therefore inhibit plant growth in soft landscaped areas. Concentrations measured in soil for these determinands have been compared with the pH dependent values given in BS:3882 (2015). This does not constitute a full BS:3882 topsoil test.
- 7.6.2 Table 7.4 shows the soil analytical results compared with the relevant screening values, adopting a pH value of greater than 7, as indicated by the results of the laboratory analysis.

Table 7.4: Soil Laboratory Analysis Results - Phytotoxic Determinands

Determinand	Threshold level (mg/kg)	Min (mg/kg)	Max (mg/kg)	No. Exceeding
Nickel	110	4	12	0
Copper	200	9	27	0
Zinc	300	21	112	0

- 7.6.3 None of the samples exceeded the threshold levels and a significant risk to plant growth has not been identified.

7.7 Screening for Water Pipes Materials

- 7.7.1 The results of the analysis have been assessed for potential impact upon water supply pipes. Table 7.5 below summarises the findings of the assessment:

Table 7.5: Screening Guide for Water Pipes

Determinand	No. of tests	Threshold for Polyethylene Pipes* (mg/kg)	Value for site data (mg/kg)		No of Exceedances
			Min	Max	
Total VOCs	0	0.5	N/A	N/A	N/A
BTEX	0	0.1	N/A	N/A	N/A
MTBE	0	0.1	N/A	N/A	N/A
EC5-EC10	19	1	<1	<1	0
EC10-EC16	19	10	<2	<2	0
EC16-EC40	19	500	<7	<7	0
Naphthalene	19	5	<0.1	<0.1	0
Phenols	19	2	<2	<2	0

* UK Water Industry Research (2010) Source Guidance for Selection of Water Supply Pipes to be Used in Brownfield Sites. Report No. 10/WM/03/21.

- 7.7.2 Determinands marked “N/A” were not analysed for as no evidence of their presence was obtained from the Desk Study.
- 7.7.3 The above suggests that upgraded pipe work is unlikely to be required.
- 7.7.4 The water supply pipe requirements for this site should be discussed at an early stage with the relevant utility provider.
- 7.8 Assessment of Soil Analytical Data with Respect to Controlled Waters**
- 7.8.1 At the Preliminary Risk Assessment (Desk Study) stage, risks to controlled waters were considered low.
- 7.8.2 The following controlled waters receptors were identified:
- Secondary A aquifer located in the southern area of site – associated with sandstone band within the Weald Clay Formation;
 - Surface waters – tertiary river located along the northern and southern boundary of site.
- 7.8.3 Pathways for migration of leachable/mobile contamination were considered to be potentially present within the underlying sandstone of Weald Clay Formation in the south of site.
- 7.8.4 Pathways for migration of leachable leachable/mobile contamination were not considered to be present within the underlying, relatively impermeable mudstone in the north of site.
- 7.8.5 The falling head tests undertaken in 8No boreholes across site to depths of 1.2mbgl indicated no drainage within the underlying Weald Clay Formation, indicating that potential pathways for migration of leachable/mobile contamination are not present. These tests are discussed in more detail in Section 11.7.

7.8.6 Reported concentration of polyaromatic and petroleum hydrocarbons were generally very low and commonly below laboratory detection limit. No evidence of potentially mobile contamination was encountered.

7.8.7 A pollutant linkage to controlled waters is not considered to exist and therefore, the risk to controlled waters is considered to be negligible.

7.9 Waste Characterisation

7.9.1 Waste soil must be classified using the characterisation assessment and analysis described by the WM3 technical guidance to determine whether soils may be treated as hazardous or non-hazardous prior to removal from site.

7.9.2 Preliminary waste classification has been carried out (see Appendix 6) and has resulted in the following:

- Made Ground is provisionally classified as non-hazardous waste.
- Made Ground - Topsoil is provisionally classified as non-hazardous waste.

7.9.3 Waste Acceptance Criteria testing results are summarised in Table 7.6 below.

Table 7.6: Waste Acceptance Criteria Testing Summary

Sample	Material Type	Exceeds "Inert Waste Landfill" Thresholds?	Notes
WS4 - 0.30m	Made Ground	X	Does not exceed thresholds for inert waste landfill.
WS14 - 0.15m	Made Ground – Topsoil	X	Does not exceed thresholds for inert waste landfill.

7.9.4 Waste Acceptance Criteria (WAC) testing indicates that the soils on site are likely to be suitable for disposal as "inert" waste.

7.9.5 Additional testing will be required by the landfill operator to confirm the above preliminary assessment during construction. Surplus Made Ground and natural soils should be segregated on excavation and placed in separate stockpiles underlain by polythene sheeting (to prevent potential cross-contamination of underlying soils) before further testing is carried out.

7.9.6 Any soils containing >0.1% asbestos or visible asbestos containing materials would be considered hazardous waste.

7.9.7 The above comments are given as guidance and should be confirmed by the waste disposal facility accepting the waste. The waste disposal facility may have their own classification methodology and are under no obligation to honour the comments given above.

7.9.8 Alternatively, if Made Ground soils are to be excavated and re-used on site, a Materials Management Plan (MMP) must be produced in accordance with CL:AIRE Definition of Waste: Development Industry Code of Practice (DoWCoP) and approved by a Qualified Person ahead of the commencement of any material movement

8 SOIL GAS RISK ASSESSMENT

8.1 Soil Gas Results

- 8.1.1 Four return monitoring visits have been undertaken between 9th February 2024 and 28th February 2024, to monitor wells installed within boreholes at the site for soil gas concentrations and groundwater levels.
- 8.1.2 During these visits atmospheric pressure ranged between 975mb and 1010mb.
- 8.1.3 The results of the monitoring undertaken are summarised in Table 8.8.1 below, with the monitoring records presented in Appendix 5.

Table 8.8.1: Summary of Gas Monitoring Data

Hole No.	Number of monitoring events	CH ₄ (%)	CO ₂ (%)	O ₂ (%)	VOCs (ppm)	Steady Flow Rate (l/hr)	Peak Flow Rate (l/hr)	Depth to water (mbgl)	Well Response Zone as installed (top/bottom) (mbgl)	Strata targeted by response zone
WS2	4	0.0 – 0.3	0.1 – 0.2	18.1 – 21.3	0.0 – 0.1	-0.4 – +0.3	-0.5 – +0.3	0.00 – 0.18	1.00 – 3.10	Weald Clay Formation
WS12	4	0.0 – 0.2	0.3 – 1.9	18.3 – 21.2	0.1 – 7.1	0.0 – +0.2	0.0 – +0.2	2.38 – 3.43	1.00 – 3.40	Weald Clay Formation
WS17	4	0.0 – 0.2	0.1 – 2.7	19.0 – 21.2	0.1 – 0.2	-0.3 – 0.0	-0.3 – 0.0	0.29 – 0.63	1.00 – 2.60	Weald Clay Formation

8.2 Screening of Results

- 8.2.1 As shown in Table 8.8.1, methane was reported to a maximum concentration of 0.3%. The concentrations of carbon dioxide ranged from 0.1 to 2.7% v/v. The maximum concentration of volatile organic compounds measured was 7.1ppm. The maximum gas flow rate recorded was 0.3l/hr.
- 8.2.2 In the assessment of risks posed by hazardous ground gases and selection of appropriate mitigation measures, BS8485 (2015) + A1 (2019) identifies four types of development, termed Type A to Type D.
- 8.2.3 Type A buildings are defined as
- “private ownership with no building management controls on alternations to the internal structure, the use of rooms, the ventilation of rooms or the structural fabric of the building. Some small rooms present. Probably conventional building construction (rather than civil engineering). Examples include private housing and some retail premises.”*
- 8.2.4 The soil gas assessment method is based on that proposed by Wilson & Card (1999), which was a development of a method proposed in CIRIA publication R149 (CIRIA, 1995). The method uses both gas concentrations and borehole flow rates to define a characteristic situation based on the limiting borehole gas volume flow for methane and carbon dioxide. In both these methods, the limiting borehole gas volume flow is renamed as the Gas Screening Value (GSV).

8.2.5 The Gas Screening Value (litres of gas per hour) is calculated by using the following equation

$$\text{GSV} = (\text{Concentration}/100) \times \text{Flow rate}$$

Where concentration is measured in percent (%)

and flow rate is measured in litres per hour (l/hr)

8.2.6 In accordance with CIRIA C665, worst case conditions are used in the calculation of GSVs for the site. These have been summarised below in Table 8.8.2.

8.2.7 The Characteristic Situation is then determined from Table 8.5 of CIRIA C665.

Table 8.8.2: Summary of Gas Monitoring Data and Gas Screening Value

Gas	Concentration (v/v %)	Peak Flow Rate (l/hr)	GSV (l/hr)	Characteristic Situation (after CIRIA C665)
CO ₂	2.7	0.3	0.0081	1
CH ₄	0.3	0.3	0.0009	1

8.2.8 Based on the calculated GSVs, and in consideration of the conceptual site model, the site is classified as Characteristic Situation 1 (CS1), and therefore no formal gas protection measures are considered to be necessary.

9 GEO-ENVIRONMENTAL ASSESSMENT SUMMARY AND RECOMMENDATIONS

9.1 Land Quality Impact Summary

9.1.1 Following the ground investigation, the following is noted:

- It is understood that the proposed development will comprise the construction of residential dwellings with some communal/amenity soft landscaping, private gardens and associated roadways.
- Following generic risk assessments, elevated concentrations of lead were detected in soils in excess of generic assessment criteria for the protection of human health within a residential with plant uptake end-use scenario. These elevated concentrations were localised within an area proposed to contain communal landscaping only, and therefore is considered appropriate to utilise less stringent assessment criteria and therefore these soils are considered suitable to remain provided no private gardens are proposed within this area of site.
- No asbestos containing materials or fibres were detected in the Made Ground samples analysed in the laboratory.
- A significant risk to plant growth has not been identified.
- The risk to controlled waters from soils is considered negligible.
- Based on the calculated GSVs, and in consideration of the conceptual site model, the site is classified as Characteristic Situation 1 (CS1) and no formal gas protection measures are considered to be necessary.
- Upgraded potable water supply pipe materials are unlikely to be required. The water supply pipe requirements for this site should be discussed at an early stage with the relevant utility provider.
- Based on the existing proposed development plan, no formal remedial measures are considered necessary. This is on the basis that only communal soft landscaping is proposed within the north of the site, in the area as shown on Figure 5. If the proposed development changes, this assessment should be revised accordingly.
- As with any ground investigation, the presence of further hotspots between sampling points cannot be ruled out. Should any contamination be encountered, a suitably qualified environmental consultant should be informed immediately, so that adequate measures may be recommended.

9.1.2 The above conclusions are made subject to approval by the statutory regulatory bodies.

9.2 Review of Pollutant Linkages Following Ground Investigation

9.2.1 The site CSM has been revised and updated from that suggested in the desk study in view of the ground investigation data, including soil laboratory analysis results. Table 9.9.1 highlights whether pollutant linkages identified in the original CSM are still relevant following the risk assessment, or whether pollutant linkages, not previously identified, exist.

SECTION 9
GEO-ENVIRONMENTAL ASSESSMENT SUMMARY AND
RECOMMENDATIONS

Table 9.9.1: Plausible Pollutants Linkages Summary (Pre-Remediation)

Potential Source (from desk study)	Pathway	Receptor	Relevant Pollutant Linkage?	Comment
- Potential for Made Ground associated with previous development operations – on site (S1) - Current and previous industrial use – off site (S2)	- Ingestion and dermal contact with contaminated soil (P1) - Inhalation or contact with potentially contaminated dust and vapours (P2) - Permeation of water pipes and attack on concrete foundations by aggressive soil conditions (P6)	- Construction workers (R1) - Maintenance workers (R2) - Neighbouring site users (R3) - Future site users (R4) - Building foundations and on site buried services (water mains, electricity and sewer) (R5)	X	No formal remedial measures required. See Section 9.1 above for details. The findings of this report should be included in the construction health and safety file, with adequate measures put in place for the protection of construction and maintenance workers. Contact should be made with relevant utility providers to confirm if upgraded materials are required. The concrete classification to protect buried concrete is discussed in Section 11.3
	Accumulation and migration of soil gases (P5)		N	Site has been characterised as CS1 and no gas protection measures are considered necessary.
	- Leaching through permeable soils, migration within the vadose zone (i.e., unsaturated soil above the water table) and/or lateral migration within surface water, as a result of cracked hardstanding or via service pipe/corridors and surface water runoff (P3) - Horizontal and vertical migration of contaminants within groundwater (P4)	- Neighbouring site users (R3) - Building foundations and on site buried services (water mains, electricity and sewer) (R5) - Controlled Waters (Aquifer) (R6)	N	A significant risk of impact to controlled waters has not been identified. The concrete classification to protect buried concrete is discussed in Section 11.3

10 DERIVATION OF GEOTECHNICAL PARAMETERS

10.1 Introduction

10.1.1 A summary of ground conditions obtained from the ground investigation and the derived geotechnical parameters is provided below.

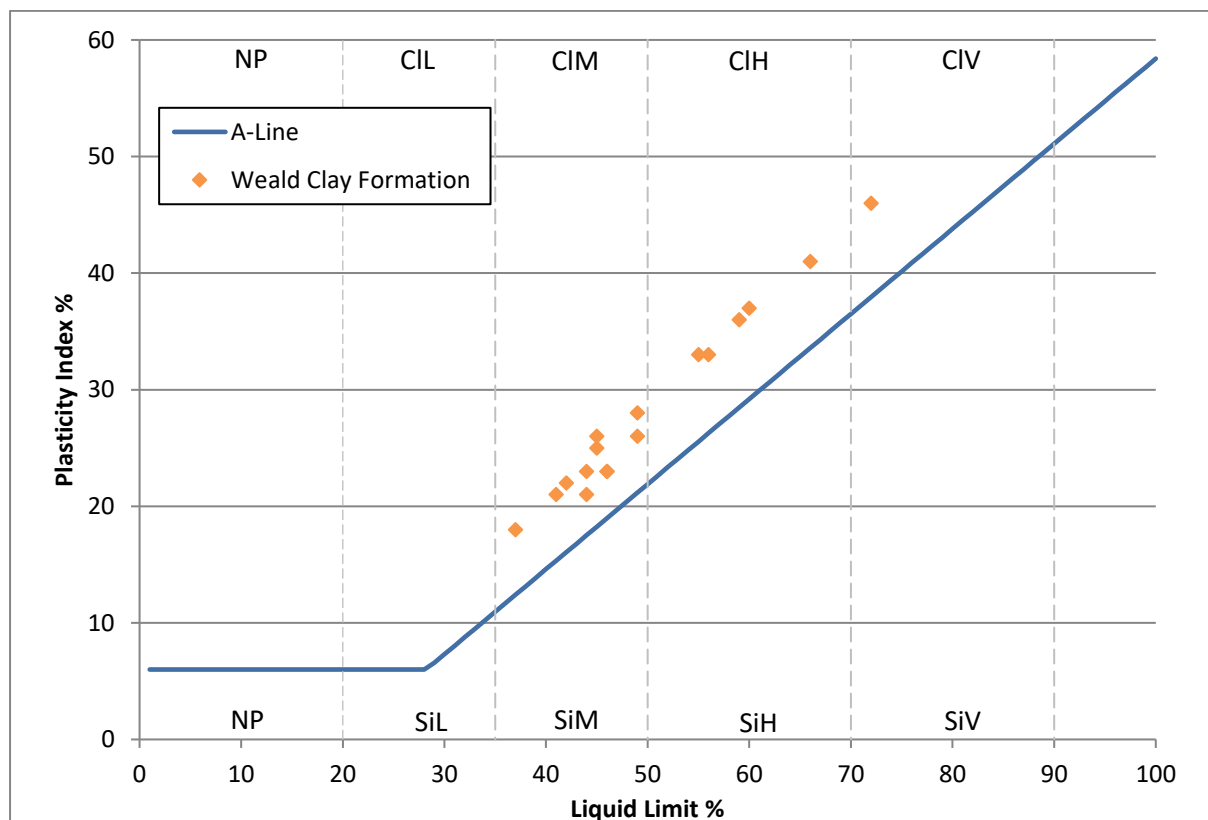
10.2 Plasticity of Cohesive Materials

10.2.1 Atterberg Limit determination was undertaken on 18No samples of Weald Clay Formation, at depths ranging from 0.40m to 3.60mbgl.

10.2.2 Plasticity Index values ranged from 18% to 46% and were indicative of “medium” to “high” plasticity, as illustrated in Figure 10.1 below. One sample was reported as being ‘non-plastic’ and the test was therefore aborted.

10.2.3 Modified Plasticity Index values ranged from 18% to 46%, indicating soils with “low” to “high” volume change potential.

Figure 10.1: Plasticity Chart

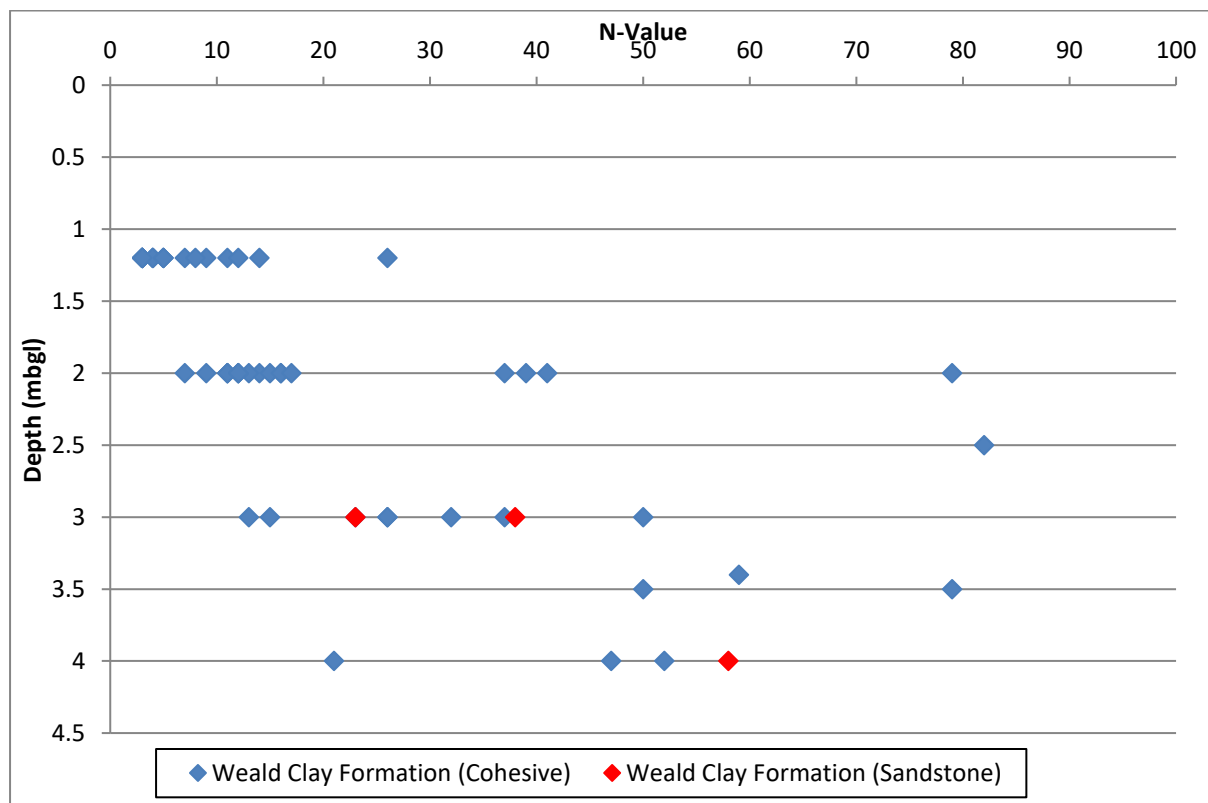


10.3 Standard Penetration Tests

10.3.1 Standard Penetration Tests were undertaken at regular intervals throughout the windowless sample boreholes. The results of the SPTs are plotted against depth in Figure 10.2 below.

- 10.3.2 The strata have been grouped into “Weald Clay Formation – Cohesive” and “Weald Clay Formation – Sandstone”.
- 10.3.3 N_{equi} results have been calculated for both strata where the SPT crossed strata boundaries or where the full 300mm of penetration could not be achieved for 50 or more blows.
- 10.3.4 Where only minimal penetration was achieved, the test was considered as a ‘refusal’, and no N_{equi} result was calculated.

Figure 10.2: SPT 'N' Value v Depth



- 10.3.5 Overall, there is a weak correlation of increasing SPT N-value with depth.
- 10.3.6 WS13 shows lower N-values at depth, attributed to a groundwater strike reported at 3.1mbgl.

10.4 Undrained Shear Strength

- 10.4.1 As discussed above, the N values recorded in the clay vary with depth, this infers that the undrained shear strength of the clay similarly varies. Figure 10.3 below shows the undrained shear strength inferred by the correlation suggested by Stroud (1974);

$c_u = f_1 \times N$ can be applied,

in which

c_u = mass shear strength (kN)

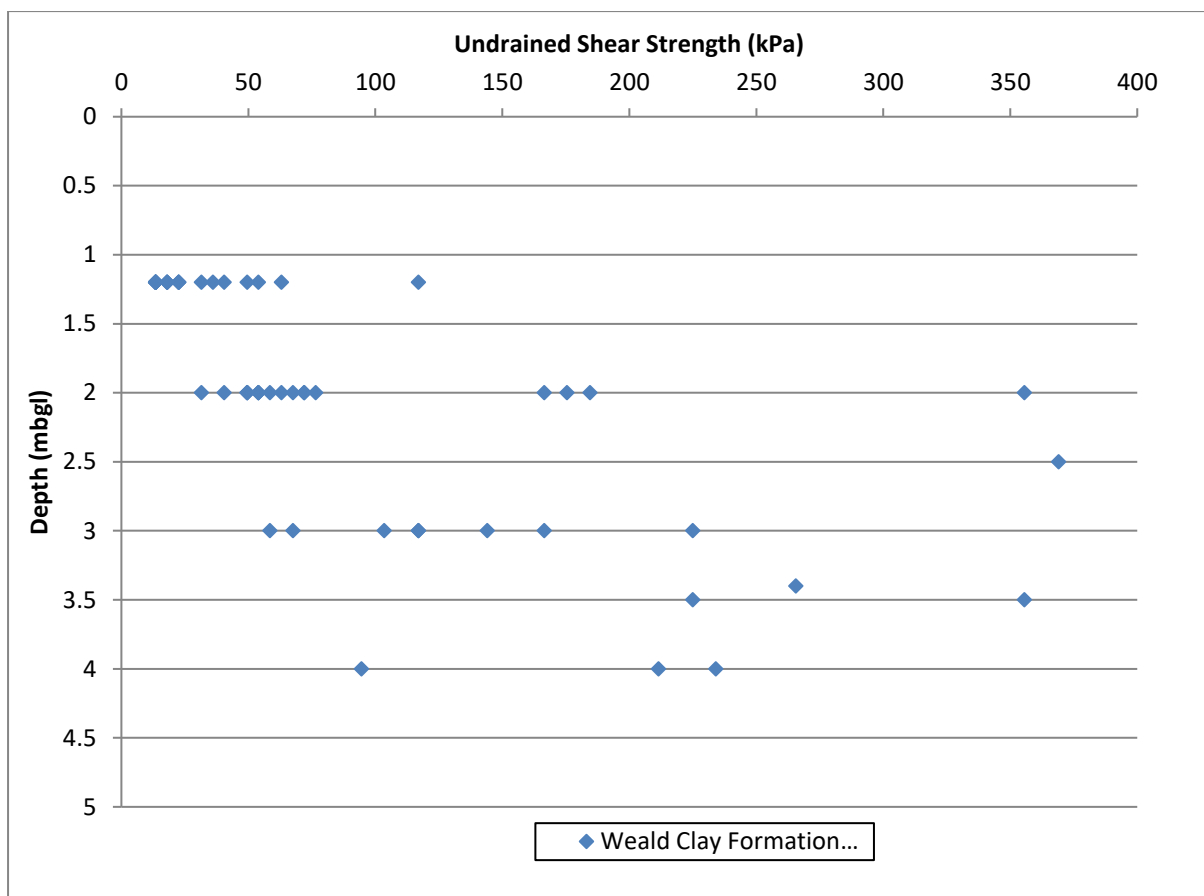
f_1 = constant

N = SPT Value achieved during boring operations

10.4.2 In the above equation f_1 is dependent on the plasticity of the material that the SPT is being carried out in. As the plasticity indices were shown to be greater than 25% a value for f_1 of 4.5 has been adopted after Tomlinson (2001).

10.4.3 The graph below shows the shear strength profile of the encountered cohesive materials at the site, based on the SPT to shear strength correlation described above.

Figure 10.3: Undrained Shear Strength v Depth



10.5 Coefficient of Compressibility

10.5.1 Stroud and Butler (1974) developed a relationship between the coefficient of compressibility (m_v) and SPT 'N' value.

$m_v = 1 / f_2 \times N$ can be applied,

in which

m_v = coefficient of compressibility (m^2/MN)

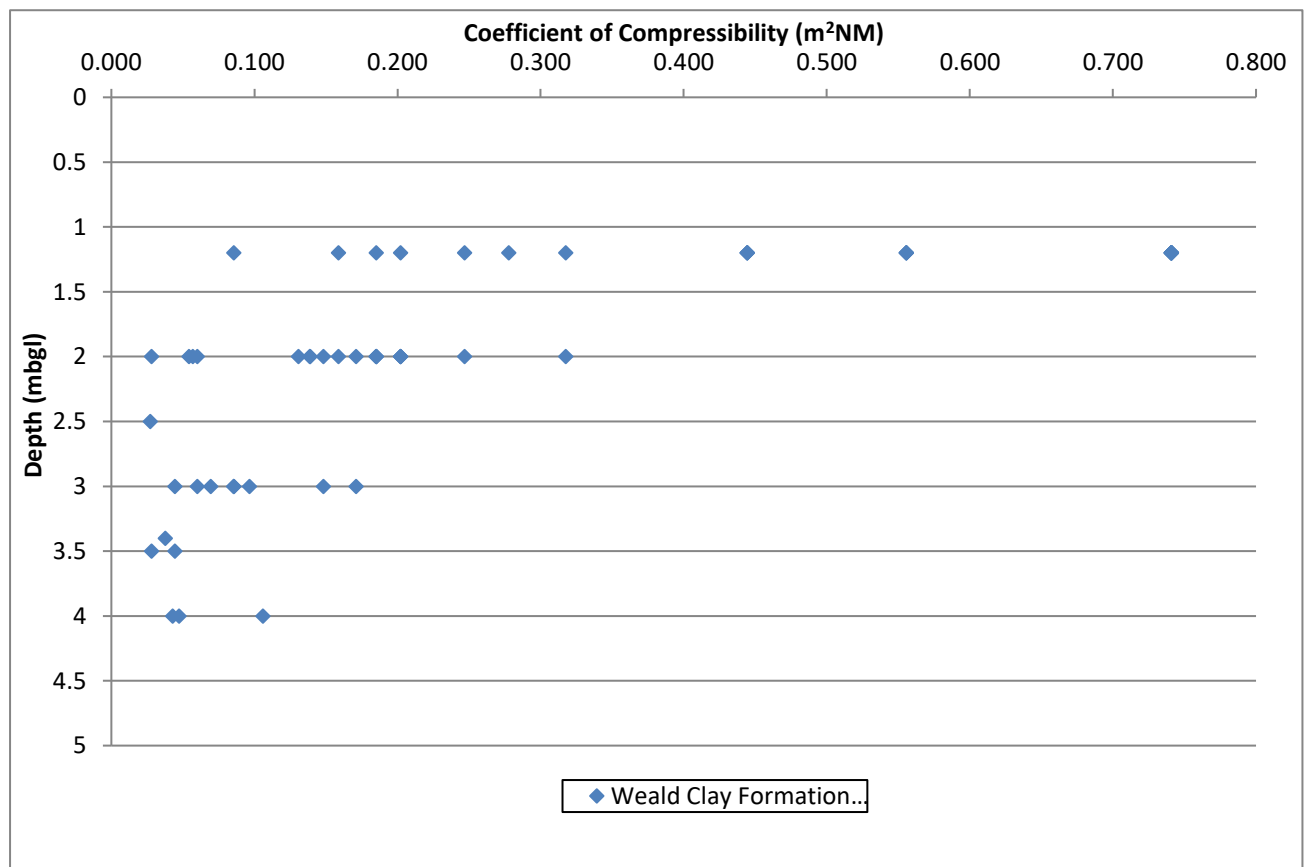
f_2 = constant dependent on the plasticity index

N = SPT Value achieved during boring operations

10.5.2 Using the plasticity indices obtained and the graphs provided in Tomlinson (2001) a value of f_2 of 0.45 has been taken and used with the SPT 'N' values to infer coefficient of compressibility (m_v).

10.5.3 Where the undrained shear strength of the clays was measured using the quick undrained triaxial methodology, the m_v value was calculated by rearranging the equations for f_1 and f_2 and substituting in the measured undrained shear strength.

Figure 10.4: Coefficient of Volume Compressibility (m_v) v Depth



10.5.4 As would be expected, the results reduce with depth as the clay increases in strength and the over burden increases, reducing the potential for compressibility.

10.5.5 The results from of the Weald Clay Formation are generally of "very low" to "medium" compressibility with near surface clays of "medium" to "high" compressibility.

- 10.5.6 This is considered to be due to the weathering and softening of near-surface deposits, combined with a lack of overburden pressure at shallow depth allowing the clays to relax and so compress when loaded.

10.6 Density

- 10.6.1 In the absence of geotechnical laboratory test results, the correlations and suggested values for both cohesive and granular materials given in BS8004:2015 have been used.

- 10.6.2 The derived Unit Weights are summarised below in Table 10.1.

Table 10.1: Derived Unit Weights

Strata	Unit Weight (kN/m ³)
Made Ground	17
Weald Clay Formation (Cohesive)	18
Weald Clay Formation (Sandstone)	19

10.7 Effective Angle of Shearing Resistance / Angle of Friction

- 10.7.1 In cohesive soils, the effective angle of shearing resistance can be derived from the plasticity index of the soil, using the following equation presented in BS8004:2015.

$$\phi' = 42 - (12.5 \times \text{LOG}_{10}(\text{PI}))$$

Where PI = Plasticity Index.

- 10.7.2 Values have been calculated for all available Plasticity Index results and are presented in Table 10.2.

Table 10.2 Derived Angles of Shearing Resistance

Sample	Stratum	Derived Angle of Shearing Resistance (°)
WS1 @ 0.4m	Weald Clay Formation (Cohesive)	23.0
WS2 @ 2.9m	Weald Clay Formation (Cohesive)	25.5
WS3 @ 1.5m	Weald Clay Formation (Cohesive)	24.3
WS4 @ 0.7m	Weald Clay Formation (Cohesive)	22.5
WS5 @ 1.5m	Weald Clay Formation (Cohesive)	22.4
WS6 @ 2.0m	Weald Clay Formation (Cohesive)	24.5
WS7 @ 2.5m	Weald Clay Formation (Cohesive)	25.0
WS8 @ 3.6m	Weald Clay Formation (Cohesive)	25.0
WS9 @ 0.6m	Weald Clay Formation (Cohesive)	21.2

Sample	Stratum	Derived Angle of Shearing Resistance (°)
WS10 @ 1.2m	Weald Clay Formation (Cohesive)	21.8
WS12 @ 1.4m	Weald Clay Formation (Cohesive)	24.3
WS13 @ 3.5m	Weald Clay Formation (Cohesive)	25.0
WS14 @ 0.7m	Weald Clay Formation (Cohesive)	26.3
WS15 @ 0.65m	Weald Clay Formation (Cohesive)	25.5
WS18 @ 1.6m	Weald Clay Formation (Cohesive)	23.9
WS18 @ 2.3m	Weald Clay Formation (Cohesive)	25.2
WS20 @ 3.0m	Weald Clay Formation (Cohesive)	23.0

- 10.7.3 In granular materials, the effective angle of friction can be derived directly from shear box testing, or indirectly using the methodology outlined in Table 1 of BS8004:2015, using a combination of the SPT N-Values, particle size distribution of the soil, and the field descriptions of angularity of the gravel fraction. This method assumes that the fines content of the material is less than 15%. An alternative method is to refer to the correlation between angle of friction and SPT N-values postulated by Peck *et al* (1967) and reproduced in Tomlinson (2001).

10.8 Stiffness Moduli

- 10.8.1 In cohesive materials, the undrained stiffness modulus (Young's Modulus) can be derived using the correlation with SPT N-Values, presented in CIRIA Report R143.

$$Eu = 1.2 * N$$

- 10.8.2 The drained Young's Modulus for cohesive material can also be derived from the SPT-N values, as follows:

$$E' = 0.9 * N$$

- 10.8.3 In granular materials, the drained Young's Modulus can be derived using the following correlation:

$$E' = N$$

10.9 Summary of Derived General Properties

- 10.9.1 Based on the analysis of the ground investigation data and past experience with similar deposits, the following derived general parameters are given in Table 10.3.

Table 10.3 Derived Geotechnical Parameters

Property	Weald Clay Formation (Cohesive)	Weald Clay Formation (Granular)
Unit Weight (kN/m ³) ¹⁾	18	19

Property	Weald Clay Formation (Cohesive)	Weald Clay Formation (Granular)
Drained Friction, ϕ' (°)	21.2 – 26.3 ²⁾	34 – 41 ³⁾
Drained Cohesion, c' (kPa)	0	-
SPT 'N' Value	3 – 82	23 – 58
Undrained Young's Modulus, E_u (MPa) ⁴⁾	3.6 – 90.2	-
Drained Young's Modulus E' (MPa)	2.7 – 73.8 ⁵⁾	23 – 58 ⁶⁾
Undrained Shear Strength, c_u (kPa) ⁷⁾	13.5 – 369	
Plasticity Index (%)	18 – 46	-
Modified Plasticity Index (%)	18 – 46	-
Volume Change Potential [NHBC]	Low to High	-
Modulus of Volume Compressibility, m_v (m ² /MN) ⁸⁾	0.027 – 0.741	-

¹⁾ Derived from Figures 1 and 2 of BS8004:2015.

²⁾ Calculated from: $\phi' = (42^\circ - 12.5 \log 10/I_p)$ for $5\% \leq I_p \leq 100\%$ Where, I_p is the soil's plasticity index (BS8004:2015).

³⁾ Correlation between N value and Φ (Relation of N-values and Friction Angle by Peck et al).

⁴⁾ Calculated from: $E_u = 1.2 N$ MPa, based on the guidance given in CIRIA Report 143.

⁵⁾ Calculated from: $E' = 0.9 N$ Mpa, based on the guidance given in CIRIA Report 143.

⁶⁾ Calculated from: $E' = 1.0 N$ Mpa, based on the guidance given in CIRIA Report 143.

⁷⁾ The undrained shear strength (c_u) of the cohesive soils was correlated to the SPT "N" values using Stroud (1974), where $c_u = f_1 N$ and f_1 is factor related to the Plasticity Index (PI) of the clay (a value of f_1 equal to 5.0 for $PI \leq 25\%$ and a value of f_1 value equal to 4.5 for $PI > 25\%$).

⁸⁾ Calculated from: $m_v = 1/f_2 N$ m²/MN, f_2 is a coefficient proposed by Stroud and Butler (1975) and varies with Plasticity Index (PI) as presented in Figure 27 of CIRIA Report 27 or $10/c_u$.

11 GEOTECHNICAL ENGINEERING RECOMMENDATIONS

11.1 General

11.1.1 Subsequent to intrusive investigation of the site and receipt of the laboratory test results, the following geotechnical assessments have been made.

11.2 Proposed Foundations

General

11.2.1 All topsoil is to be stripped from beneath proposed structures ahead of development.

11.2.2 The Made Ground and very soft near-surface Weald Clay is not considered to provide suitable bearing strata due to their low and variable bearing properties, and the unacceptable risk of total and differential settlement.

11.2.3 All foundations should be deepened beneath these deposits and any soft/loose soils encountered in order to found within underlying competent strata.

11.2.4 As soils of “high” volume change potential are present, heave precautions will be required against the side of foundations and ground beams in accordance with the requirements set out in NHBC Standards Chapter 4.2.

Conventional Foundations

11.2.5 It is considered that traditional strip/trench-fill foundations up to 1m wide may be formed within the underlying Weald Clay Formation at a minimum depth of 2.0m for an allowable bearing capacity of 100kPa. Alternatively, pad foundations with dimensions of 1.2m x 1.2m could be formed for an allowable bearing capacity of 130kPa. Total and differential settlements should be contained within tolerable limits.

11.2.6 This depth, however, does not take into account the depth of Made Ground or the distance to, and species of, any previous, existing, or proposed trees and foundations may need to be deepened further in accordance with NHBC requirements, for soils of “high” volume change potential.

11.2.7 Where foundations need to change levels as a result, the foundations should be stepped and reinforced. These steps should be no deeper than half of the width of the foundation and each step should not exceed 0.5m.

11.2.8 If foundations span different strata, e.g. sand and clay, they should either be deepened to terminate in a single soil stratum, or suitable reinforcement included (to be detailed by the structural engineer).

11.2.9 Foundations greater than 2.50m deep would require structure-specific design by a structural engineer. In this instance, consideration could be given to the use of piled foundations instead, which might be preferable in terms of economy and practicality.

11.2.10 Where any unexpected or soft ground conditions are encountered during the groundworks, works in that area should cease and the advice of a suitably qualified geotechnical engineer sought.

Raft Foundations

- 11.2.11 Alternatively, a raft foundation may be a suitable option.
- 11.2.12 Such a foundation should be formed on a suitable thickness of well-engineered granular sub-base, should provide an allowable bearing capacity of 50kN/m².
- 11.2.13 Prior to laying the suitable thickness of well-engineered granular sub-base, the formation level should be inspected by a suitably qualified and experienced specialist. Any loose or soft material should be removed to a suitable depth and replaced with well-graded, properly compacted granular fill or lean mix concrete. The formation should be blinded if left exposed for more than a few hours or if inclement weather is experienced.
- 11.2.14 In order to keep settlements within tolerable limits, the raft foundation should comprise a continuously well reinforced slab beneath the building.
- 11.2.15 In addition, reinforced concrete beams / thickening of the raft may be required beneath the structural walls or beneath lines of columns.
- 11.2.16 Any existing granular sub-base or granular Made Ground could potentially be lifted and re-engineered.

11.3 Aggressive Ground Conditions

- 11.3.1 Sulphate attack on building foundations occurs where sulphate solutions react with the various products of hydration in Ordinary Portland Cement (OPC) or converted High-Alumina Cement (HAC). The reaction is expansive, and therefore disruptive, not only due to the formation of minute cracks, but also due to loss of cohesion in the matrix.
- 11.3.2 In accordance with BRE Special Digest 1, the characteristic values of sulphate used to determine the concrete classification are determined using the methodology summarised in below.

Table 11.1: Concrete in the Ground Characteristic Value Determination

No Samples in the dataset	Method for determining the sulphate characteristic value
1 - 4	Highest value
5 - 9	Mean of the top 2No highest results
10 or greater	Mean of the top 20% highest results

- 11.3.3 summarises the analysis of the aggressive nature of the ground for each of the strata encountered within the ground investigation.

Table 11.2: Concrete in the Ground Class

Stratum	No Samples	pH range	Characteristic WS Sulphate (mg/l)	Characteristic Total Potential Sulphate (%) ¹⁾	Design Sulphate Class	ACEC Class
Made Ground	19	5.5 – 6.5	25	N/A	DS-1	AC-1

Weald Clay Formation	8	5.2 – 8.9	207	N/A	DS-1	AC-1
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1) Applies to soils containing more than 0.3% of Oxidisable Sulphides, calculated in accordance with BRE SD-1

11.3.4 Analysis of the results indicates that the underlying soils do not contain appreciable concentrations of oxidisable sulphates and therefore the Design Class is dependent on the soluble sulphate content and pH only.

11.3.5 The concrete structures, including foundations, will need to be designed in accordance with BS EN 1992-1-1:2004+A1:2014. It is recommended that the advice of this publication be taken for the design and specification of all sub-surface concrete.

11.4 Ground Floor Slabs

11.4.1 Given the presence of shrinkable soils, it is recommended that suspended floor slabs are used with an adequate void designed according to NHBC Standards. As a guide, initial modelling indicates a requirement for a sub-floor void of at least 300mm due to the presence of shrinkable soils of “high” volume change potential.

11.5 Excavations

11.5.1 Temporary excavations within the Made Ground and granular soils are unlikely to remain stable and some form of temporary support or battering back to a safe angle is likely to be required.

11.5.2 Temporary excavations within the cohesive soils are likely to remain relatively stable in the short term though some spalling may be anticipated.

11.5.3 Ground works should always be designed in such a manner to avoid entry into excavations by construction or maintenance personnel. However, in the event that such works cannot be avoided or designed out, they should only be undertaken in accordance with a safe system of work, following an appropriate risk assessment and in accordance with any legislative requirements, e.g. Confined Spaces Regulations.

11.6 Road Pavements

11.6.1 summarises the results of the in-situ CBR testing.

Table 11.3: Summary of CBR Test Results

Position	Depth Range (mm)	Stratum	IAN 73/06 CBR (%)	TRL 587 CBR (%)
WS1	100-600	Topsoil/Weald Clay Formation	0	0
	600-800	Weald Clay Formation	6.1	6.6
	800-1000	Weald Clay Formation	4.8	5.3
WS2	100-1000	Topsoil/Weald Clay Formation	0	0
WS4	100-400	Topsoil/Weald Clay Formation	0	0
	400-900	Weald Clay Formation	5.3	5.9

Position	Depth Range (mm)	Stratum	IAN 73/06 CBR (%)	TRL 587 CBR (%)
	900-1000	Weald Clay Formation	12.7	13.1
WS8	100-500	Topsoil/Weald Clay Formation	0	0
	500-1000	Weald Clay Formation	16.5	16.7
WS10	100-600	Topsoil/Weald Clay Formation	0	0
	600-700	Weald Clay Formation	7.4	7.9
	700-1000	Weald Clay Formation	13.6	14.0
WS11	100-900	Topsoil/Weald Clay Formation	0	0
	900-1000	Weald Clay Formation	10.1	10.5
WS13	100-600	Topsoil/Weald Clay Formation	0	0
	600-900	Weald Clay Formation	10.1	11.3
	900-1000	Weald Clay Formation	18.2	19.9
WS14	100-900	Topsoil/ Weald Clay Formation	0	0
	900-1000	Weald Clay Formation	12.7	13.1
WS17	100-400	Topsoil/ Weald Clay Formation	0	0
	400-500	Weald Clay Formation	12.7	13.1
	500-1000	Weald Clay Formation	2.9	3.4
WS18	100-1000	Topsoil/ Weald Clay Formation	0	0
WS20	100-900	Topsoil/ Weald Clay Formation	0	0
	900-1000	Weald Clay Formation	2.3	2.7

- 11.6.2 The engineering characteristics of Made Ground are variable and the results of in-situ testing do not predict the overall settlements that may occur. It would therefore be prudent to assume a CBR value of 1% for the preliminary design of pavements constructed upon Made Ground and near-surface deposits of the Weald Clay Formation.
- 11.6.3 In-situ CBR testing using a TRL DCP gives only a short-term estimated value, which may be influenced by seasonal variations in the moisture content of the soil or due to resistance against local granular inclusions.
- 11.6.4 Based on the test results, and with reference to the equilibrium suction-index CBR values provided in the Transport Road Research Laboratory (TRRL) Laboratory Report 1132 (1984), a preliminary CBR value of 2.5% is considered suitable for the Weald Clay Formation.
- 11.6.5 Given the low CBR value it is likely that either ground improvement, e.g. lime/cement stabilisation, increased capping, or geogrid reinforced sub-base construction will be required.
- 11.6.6 The near-surface soils are deemed to be of low permeability and should therefore be treated as being not frost susceptible.
- 11.6.7 Full calculations are provided in Appendix 6.

11.6.8 Additional CBR testing should be undertaken after detailed design is complete to confirm suitability.

11.7 Surface Water Drainage

Falling Head Permeability Tests

11.7.1 Falling head permeability tests were undertaken within the windowless sampler boreholes.. Each test was undertaken over a 1-hour period. summaries the falling head permeability test results:

Table 11.4: Summary of Soakage Test Results

Position	Depth Range of Test (m)	Results (m/s)
WS2	0.30 – 1.20	Insufficient drainage
WS4	0.30 – 1.20	Insufficient drainage
WS8	0.30 – 1.20	Insufficient drainage
WS10	0.30 – 1.20	Insufficient drainage
WS11	0.30 – 1.20	Insufficient drainage
WS14	0.30 – 1.20	Insufficient drainage
WS18	0.30 – 1.20	Insufficient drainage
WS20	0.30 – 1.20	Insufficient drainage

11.7.2 Based on the above results and ground conditions encountered, conventional soakaways are unlikely to be feasible. More favourable results may be obtained by undertaking additional tests in accordance with the requirements of BRE DG 365 (2016): Soakaway Design.

11.7.3 Full calculations are provided in Appendix 7.

11.8 Groundwater Control

11.8.1 During the investigation groundwater was reported within windowless sampler boreholes WS4, WS13 at 3.0m-4.0mbgl and 3.1mbgl depth, respectively. Groundwater was not reported within the remaining boreholes.

11.8.2 During return monitoring groundwater was reported at depths of between 0.00m (ground level) and 3.43mbgl. Such variance suggests the presence of perched water bodies and infilled surface water that is unable to drain through the impermeable soils, as opposed to the natural groundwater table.

11.8.3 Subject to seasonal variations, any groundwater encountered during site works could be readily dealt with by conventional pumping from a sump used to collate waters.

11.8.4 Surface water or rainfall ingress could be similarly dealt with.

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APPENDICES

APPENDIX 1 – FIGURES

APPENDIX 2 – EXPLORATORY HOLE RECORDS

APPENDIX 3 – CHEMICAL LABORATORY TEST RESULTS

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