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GEO-ENVIRONMENTAL & GEOTECHNICAL ASSESSMENT (GROUND INVESTIGATION) REPORT

**ISLAND SITE,
DURHAM WAY,
ROYSTON
SG8 5GX**



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Report Title: Geo-environmental & Geotechnical Assessment Ground Investigation Report for Island Site, Durham Way, Royston SG8 5GX

Report Status: Final v2.0

Job No: P5664J2968/JRO

Date: 17 April 2024

QUALITY CONTROL – REVISIONS

Version	Date	Issued By	Comment
1.0	09/04/24	JRO	Amended following Client Comments

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EXECUTIVE SUMMARY

Site Details	Site Address	Island Site, Durham Way, Royston SG8 5GX
	National Grid	534576 241504
	Site Area	0.46Ha
	Proposed Development	It is understood that the proposed development comprises the construction of new commercial warehouse, with an associated car park and service yard. Areas of soft landscaping are proposed around the site boundary.
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 from the desk study, and comprised Made Ground, to depths of up to 0.60m, underlain by white Chalk of the Holywell Nodular Chalk Formation to the base of the boreholes (maximum depth of 2.20m).
	Groundwater	Groundwater seepage was encountered within STP1 at 2.00m bgl during the intrusive investigation. In addition, combined groundwater and ground gas monitoring wells were installed within WS1, WS3 and WS5 to a depth of 2.06m bgl which was monitored on four occasions in March 2024. Water was recorded in WS1 at a depth of 1.82m bgl during the return visit. WS3 and WS5 were reported as dry.
Geo-environmental Assessment Summary and Recommendations		Following generic risk assessments, no contaminants have been found in excess of generic assessment criteria protective of human health within a "commercial" end use. No asbestos fibres were detected in the samples analysed in the laboratory. No significant concentrations of contamination have been recorded in any of the soil samples tested and there is not considered to be a significant risk of pollution to controlled waters. Gas monitoring has concluded a site classification of CS1 would be considered prudent and therefore no formal remedial measures are considered necessary. As with any ground investigation, the presence of further hotspots between sampling points cannot be ruled out, and caution must be exercised during construction works. Should any contamination be encountered, a suitably qualified environmental consultant should be informed immediately, so that adequate measures may be recommended.
Geotechnical Considerations	Foundations	Based on the ground and groundwater conditions encountered, traditional pad foundations of minimum dimensions 0.75m x 0.75m may be formed within the underlying Chalk at a minimum depth of 1.5m for an allowable bearing capacity of 225kPa.
	Sulphates	Buried concrete for foundations should be designed to Class DS-3 (AC2s) within the Made Ground. Buried concrete within chalk deposits only may be designed to DS-1 (AC-1s).
	Ground Floor Slabs	A ground bearing slab is considered to be suitable.
	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 2.5% and 5% are recommended for pavements constructed within the Made Ground and Chalk, respectively.
	Surface Water Drainage	In-situ testing has recorded infiltration rates ranging between 9.58×10^{-6} m/s and 3.12×10^{-5} m/s. Therefore, conventional soakaways may be suitable and should be designed in accordance with the recommendations provided in BRE DG 365 (2016): Soakaway design.
Recommendations		The following works are recommended: • Carry out soil waste classification to aid estimation of costs for off-site soil disposal or determine possibility for re-use on site; • Submit chemical testing results to appropriate waste facility to confirm waste classification; • Production of a Materials Management Plan (MMP) prior to commencement of works to ensure legal compliance of on-site soil movement (if Made Ground is to be excavated and re-used on site); • Seek approval of the Generic Quantitative Risk Assessment and Soil Gas Assessment from the Local Authority, NHBC and other relevant stakeholders; • 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. P5664J2968.</i>		

1 INTRODUCTION

1.1 Terms of Reference

- 1.1.1 Kiafield Properties Ltd & Kimberley Developments Ltd ("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 Island Site, Durham Way, Royston SG8 5GX (herein referred to as 'the site'). The site's location is presented in Figure 1, Appendix 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 January 2024.

1.2 Proposed Development

- 1.2.1 The proposed development is to comprise the construction of new commercial warehouse, with an associated car park and service yard. Areas of soft landscaping are located along the edges of the site.
- 1.2.2 For the purpose of geo-environmental assessment and selection of generic assessment criteria, the development is considered "commercial".
- 1.2.3 A plan of the proposed development is included in Figure 4, Appendix 1.
- 1.2.4 For the purpose of geotechnical assessment, it is considered that the project could be classified 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/rock 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 associated with recent previous developments close to the proposed development, 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 Preliminary Risk Assessment – Royston Industrial development, Royston Hertfordshire Revision 1	WSP	00043343/001	08 January 2014
Trade Park Royston – Phase II Ground Investigation and Interpretive Report	Ground Projects	80778-1	04 August 2022
Development Site Royston East – Phase II Ground Investigation and Interpretive Report	Ground Projects	80778-2	19 October 2022
Desk Study/Preliminary Risk Assessment Report for Island Site, Durham Way, Royston SG8 5GX	Jomas Associates Ltd	P5664J2968/JRO	29 February 2024

- 1.5.2 Jomas Associates have not been supplied with any previously produced reports pertaining to the site, at the time of writing this report.

1.6 Limitations

- 1.6.1 Jomas has prepared this report for the sole use of Kiafield Properties Ltd & Kimberley Developments Ltd, 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.

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- 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.
- 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	Island Site
Address of Site	Durham Way, Royston SG8 5GX
Approx. National Grid Ref.	534576 241504
Site Area (Approx)	0.46ha
Site Occupation	Vacant plot
Local Authority	North Hertfordshire District Council
Proposed Site Use	Construction of new commercial warehouse, with an associated car park and service yard. Areas of soft landscaping are located along the edges of the site.

2.2 Site Walkover

2.2.1 A site walkover survey was undertaken by Jomas Associates on 15th February 2024.

Table 2.2: Site Description

Area	Item	Details
On-site:	Current Uses:	The site comprises a vacant plot of land in an industrial setting. Waste appears to be handled at a specific storage area near the site access; however, some waste items were also present across the site.
	Evidence of historic uses:	Small concrete areas, possibly having been used to support site cabins, were observed in the south of the site.
	Surfaces:	The site predominantly comprises grass and gravel cover. A small area of hardstanding is present in the northeast of site around the access. A small area of hardstanding is also located in the southwest of the site. The hard cover is a mixture of concrete and asphalt.
	Vegetation:	With the exception of grass and brambles, no vegetation was noted on site.
	Topography/Slope Stability:	Overall, there are no significant changes to the ground level across the site; however, small mounds of soil were noted.
	Drainage:	No obvious evidence of drainage issues.

Area	Item	Details
	Services:	Manholes were observed in proximity to the site and therefore services may be present beneath the site.
	Controlled waters:	No controlled waters were noted on site.
	Tanks:	No petrol or diesel tanks were noted on site.
	Neighbouring land:	
	North:	Costa café, A505 highway, agricultural fields
	East:	Industrial estate
	South:	Industrial estate
	West:	Car park, Aldi supermarket, agricultural fields

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 Ltd, P5664J2968, February 2024). 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 earliest available (1885) historical maps indicates that the site comprised two agricultural plots at that time. By the map dated 1947, a narrow-gauge railway is shown to encroach upon the site before extending off to the west and south. The historic map from 1959 indicates that the narrow-gauge railway is no longer present, with the site once again devoid of any features. Few changes then occur on the historic maps until the present day.
- 2.3.3 The aerial imagery from 2018 shows the site to comprise a car park and various site cabins in the south and north of site. The imagery from 2021 indicates that most of the containers have been removed, with a car park still remaining in the middle of site.
- 2.3.4 At the end of the 19th century, the land in the vicinity of site predominantly comprised agricultural land, with some minor industrial uses including a railway line 450m south of the site. By the map dated 1970, various industrial and residential land uses have been developed in the surrounding area. The area to the south and east of site comprises an industrial trading estate, which is continually developed between the 1970's and present day.
- 2.3.5 The British Geological Survey indicates that the site is directly underlain by solid deposits of the Holywell Nodular Chalk Formation. No artificial deposits are reported within the site.
- 2.3.6 The solid deposits underlying the site are identified as a Principal aquifer.
- 2.3.7 A review of the Enviro+Geosight Report indicates that the site lies within a Source Protection Zone 3 (Total catchment).

- 2.3.8 There are 23No groundwater abstractions reported within 2km; nearest recorded as historical abstraction 710m south for direct spray irrigation. The nearest active groundwater abstraction is reported 942m east for direct potable water supply.
- 2.3.9 There is 1No surface water abstraction reported within 2km; recorded 1926m north as a historical abstraction for direct spray irrigation.
- 2.3.10 There are 3No potable abstractions reported within 2km; nearest recorded as active abstraction 942m east for direct potable water supply.
- 2.3.11 The nearest detailed river entry is reported 152m west as an 'inland river not influenced by normal tidal action'. There is 1No surface water feature reported within 250m of the site.
- 2.3.12 There are no Environment Agency Zone 2 or 3 floodplains reported within 50m of the site.
- 2.3.13 It was recommended that an intrusive investigation is undertaken to clarify potential risks to the identified receptors and assess the extent of Made Ground soils present at the site.
- 2.3.14 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 contaminated ground associated with previous site use – on site (S1) - Railway sidings (1947-1948) - Use as car park (recent aerial images) - Possible contamination associated with historic above ground fuel tank (associated with site cabin) (S2) - Potential for Made Ground associated with previous development operations – on site (S3) - Current and previous industrial use associated with Royston industrial park – off site (S4) - Vehicle repair, testing and servicing 40m southeast (recent) - Unspecified tanks: nearest 40m southeast (1992) - Unspecified factory 42m northeast (1977) - Unspecified works 84m east (1992) - Large chemical works approximately 150m east (1973)	- 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
	Accumulation and migration of soil gases (P5)		Severe	Unlikely	Moderate/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 (R6) - Principal aquifer 3No potable abstractions reported within 2km; nearest recorded as active abstraction 942m east for direct potable water supply 1No detailed river entry reported by Water Network 152m west as an ‘inland river not influenced by normal tidal action’	Medium	Low likelihood	Moderate	

3 PREVIOUS GROUND INVESTIGATIONS

3.1 Geo-environmental Preliminary Risk Assessment – Royston Industrial development, Royston Hertfordshire Revision 1 – WSP, January 2014

- 3.1.1 In 2014, WSP undertook a Geo-environmental Preliminary Risk Assessment (PRA) and preliminary geotechnical assessment for Royston Industrial Development, Royston, Hertfordshire. The study site of the WSP report encompassed a larger area than the Island Site, which comprises a small section within the Royston Industrial Development.
- 3.1.2 During the walkover survey of the WSP study site, limited evidence of contamination was observed, namely some localised fly-tipping/waste storage of a degraded oil drum and engine oil container on the southeast and northwest boundaries of the site respectively.
- 3.1.3 The historical review of potential sources and the environmental setting of the site are considered to be in agreement with this report.
- 3.1.4 WSP concluded that there was a low to medium risk with respect to potential risks to human health and controlled waters at the site from contaminants either present on the site itself, or migrating onto the site from the surrounding area. In addition, the Local Authority confirmed that although the site has not been designated as 'contaminated land' within their Contaminated Land Register as defined by Part 2A, the area has been initially risk assessed as 'Stage 1' and was considered medium priority under North Hertfordshire District Council's Contaminated Land Strategy, requiring more detailed consideration and future site investigation at a later date.
- 3.1.5 The geotechnical conclusions of the WSP report are also in broad agreement with this report.

3.2 Trade Park Royston – Phase II Ground Investigation and Interpretive Report – Ground Projects, August 2022

- 3.2.1 On 7th and 8th June 2022, a ground investigation at Trade Park Royston was undertaken by Applied Geology. The Trade Park Royston site is located approximately 90m north of the Island Site.
- 3.2.2 The scope of the ground investigation comprised 5No window sampling borehole to depths of between 1.67m and 1.79mbgl, 3No installations for gas and groundwater monitoring, 2No machine excavated soakaway trial pits to depths of 1.6m and 2.0mbgl, and 3No TRL Dynamic Cone Penetrometer tests.
- 3.2.3 The ground conditions on site comprised Made Ground to depths of between 0.2m to 0.6mbgl, overlying medium dense structureless chalk recovered as slightly sandy, silty gravel/slightly gravelly silt (considered to represent the Holywell Nodular Chalk Formation – Grade Dc/Dm) to the base of the boreholes between depths of 1.6m to 2.0mbgl.
- 3.2.4 Groundwater was not encountered in any of the exploratory boreholes during the ground investigation. The groundwater installations were recorded as dry on the return monitoring visit on 28th June 2022.
- 3.2.5 No evidence of dissolution features was encountered within the chalk.

- 3.2.6 Exceedances of polycyclic aromatic hydrocarbons (PAH) (benzo[b]fluoranthene, benzo[a]pyrene and dibenzo[a,h]anthracene) were encountered in one sample of Made Ground in DCS2 to the north of the site. The geo-environmental assessment indicates that there is negligible risk to human health and controlled water receptors.
- 3.2.7 Following a single gas monitoring visit, a gas screening value of 0.0022l/hr was calculated and therefore, the site was characterised as Characteristic Situation 1 for which no formal gas protection measures are considered necessary.
- 3.2.8 An allowable bearing pressure of 225kN/m² should be achievable for foundations placed in the medium dense Grade Dm/Dc Chalk. The minimum depth of foundations should be 1.2mbgl.
- 3.2.9 A preliminary design CBR value of 10% is recommended for the Made Ground. A preliminary design CBR value of 2% is recommended for the weathered structureless chalk.
- 3.2.10 The results of the soakaway testing indicate a design soil infiltration rate of 3.6x10⁻⁶ m/s is appropriate for SA1. The soakaway testing in SA2 did not produce a soil infiltration rate due to insufficient drainage.
- 3.2.11 The site has a Design Sulphate Class of DS-2 and an Aggressive Chemical Environment for Concrete class of AC-1s.
- 3.2.12 **Development Site Royston East – Phase II Ground Investigation and Interpretive Report – Ground Projects, October 2022**
- 3.2.13 On 8th June 2022 and between 23rd to 25th August 2022, a ground investigation at the Development Site Royston East was undertaken by Applied Geology. This site is located approximately 80m north of the Island Site.
- 3.2.14 The scope of the ground investigation comprised 5No window sampling borehole to depths of between 2.2m and 3.2mbgl, 9No machine excavated trial pits to depths of between 1.5m and 3.9mbgl, 4No soakage tests to depths of between 1.5m and 2.5mbgl, and 4No plate load tests at depths of between 0.3m and 0.4mbgl.
- 3.2.15 The ground conditions on site comprised Made Ground to depths of between 1.1m to 2.7mbgl, overlying brown sandy silt/slightly gravelly sand (possibly representing Head Deposits) encountered only in TP2 and TP4, overlying medium dense to very dense structureless chalk recovered as slightly sandy, silty gravel/slightly gravelly silt (considered to represent the Holywell Nodular Chalk Formation – Grade Dc/Dm) to the base of the boreholes at 5.45mbgl.
- 3.2.16 Groundwater was not encountered in any of the exploratory boreholes during the ground investigation. The groundwater installations were recorded as dry on the return monitoring visit on 28th June 2022.
- 3.2.17 No evidence of dissolution features was encountered within the chalk.
- 3.2.18 The results showed that no metals, Total Petroleum Hydrocarbon (TPH) or benzene, toluene, ethylbenzene, polycyclic aromatic hydrocarbons (PAHs) and xylenes (BTEX) have exceeded the screening criteria, and no asbestos was encountered.
- 3.2.19 It was reported that an allowable bearing pressure of 225kN/m² should be achievable for foundations placed in the medium dense Grade Dm/Dc chalk. The minimum depth of foundations should be 1.2mbgl.

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|--------|---|
| 3.2.20 | It was reported that the structureless chalk will likely be classified as Class 3 to Class 1A material. |
| 3.2.21 | A ground bearing slab was not considered feasible for the site. A suspended slab option should be adopted. |
| 3.2.22 | The results of the soakaway testing indicate a design soil infiltration rate of 4.8×10^{-6} m/s is appropriate for the weathered structureless chalk. It is not recommended to place soakaways within Made Ground. |
| 3.2.23 | The site has a Design Sulphate Class of DS-1 and an Aggressive Chemical Environment for Concrete class of AC-1s. |

4 GROUND INVESTIGATION

4.1 Scope of Works

4.1.1 A ground investigation was undertaken on 29th February and 5th March 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	5	WS1 – WS5	Up to 2.0mbgl	Obtain shallow samples for laboratory chemical and geotechnical testing. To allow in-situ geotechnical testing.
Soakage Trial Pits	2	STP1 & SPT2	Up to 2.2mbgl	To enable soil infiltration testing in general accordance with BRE 365. Obtain shallow samples for laboratory chemical and geotechnical testing.
Monitoring Wells	3	WS1, WS3 & WS5	Up to 2.0mbgl	Gas and groundwater monitoring wells.

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 well installations 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 infiltration rates for the underlying ground was undertaken by carrying out tests in general accordance with BRE 365. 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 (DETS) Ltd, 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	Natural
Basic Suite 3	8	0
Total Organic Carbon	2	0
Jomas Modified BRE SD-1 Suite	3	1
Asbestos Screen & ID	6	0

- 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

DETERMINAND	LIMIT OF DETECTION (mg/kg)	UKAS ACCREDITATION	TECHNIQUE
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, 2No. 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	6
BS1377:1990	Liquid and Plastic Limit Determination (Atterberg Limits)	6

4.3.10 In addition, 4No. 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 the Holywell Nodular Chalk 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)
Grey / greyish black slightly clayey sandy gravel, with medium cobble content locally at STP1 & STP2. Sand is fine to coarse. Gravel consists of fine to coarse angular to subrounded asphalt, brick, flint and rare plastic. Cobbles consist of brick. (MADE GROUND)	0.00	0.40 – 0.60	0.40 – 0.60
Structureless CHALK recovered as stiff to very stiff** white gravelly CLAY. Gravel consists of fine to medium angular to sub-angular chalk. (HOLYWELL NODULAR CHALK FORMATION – Dm Grade)	0.40 – 0.60	>1.70 - >2.20 (base not proven)	>1.30 - >1.60 (thickness not proven)

***Consistency estimated using semi-empirical correlations with SPT N-values, Plasticity Indices and published literature*

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
WS1		No groundwater strike reported.	
WS2		No groundwater strike reported.	
WS3		No groundwater strike reported.	
WS4		No groundwater strike reported.	
WS5		No groundwater strike reported.	
STP1	Seepage 2.0mbgl	-	Chalk
STP2		No groundwater strike reported.	

5.3.2 4No. Return groundwater monitoring visits were carried out between 7th and 26th March 2023, 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 (mbgl)	Depth to Base of Well – as gauged (mbgl)	Strata targeted by response zone
WS1	1.80 - Dry	1.00-2.00	1.83-1.90	Chalk
WS3	Dry	1.00-2.00	1.80-1.86	Chalk
WS5	Dry	1.00-2.00	2.00-2.06	Chalk

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 Asphalt gravel was reported within the Made Ground at all exploratory hole locations. No other visual or olfactory evidence of contamination was reported.

5.5 Limitations

5.5.1 All boreholes were terminated between 1.70-2.20mbgl due to natural chalk deposits preventing further progress of the drilling equipment.

5.5.2 The possible presence of further natural and/or manmade obstructions on site cannot be discounted.

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 proposed development is to comprise the construction of new commercial warehouse, with an associated car park and service yard. Areas of soft landscaping are located along the edges of the site.
- 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 2.15%, which gives an equivalent SOM of 3.7%. An SOM of 1% has been selected as this provides the most 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 **Error! Reference source not found.** Raw laboratory data is included in Appendix 3.

7.1.2 Results have been screened against generic assessment criteria for a “commercial” 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	8	S4UL 640	5	19	0
Cadmium	mg/kg	8	S4UL 190	<0.2	0.3	0
Chromium	mg/kg	8	S4UL 8600	6	24	0
Lead	mg/kg	8	C4SL 2330	29	84	0
Mercury	mg/kg	8	S4UL 320	<1	<1	0
Nickel	mg/kg	8	S4UL 980	5	12	0
Copper	mg/kg	8	S4UL 68000	18	20	0
Zinc	mg/kg	8	S4UL 730000	27	179	0
Total Cyanide ^A	mg/kg	8	CLEA v 1.06 33	<1	<1	0
Selenium	mg/kg	8	S4UL 12000	<2	<2	0
Boron Water Soluble	mg/kg	8	S4UL 240000	<1	2.8	0
Phenols	mg/kg	8	S4UL 440	<2	<2	0

Notes: ^A Generic 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
Naphthalene	mg/kg	8	S4UL 190	<0.1	<0.1	0
Acenaphthylene	mg/kg	8	S4UL 83000	<0.1	<0.1	0
Acenaphthene	mg/kg	8	S4UL 84000	<0.1	<0.1	0
Fluorene	mg/kg	8	S4UL 63000	<0.1	<0.1	0
Phenanthrene	mg/kg	8	S4UL 22000	<0.1	0.7	0
Anthracene	mg/kg	8	S4UL 520000	<0.1	0.17	0
Fluoranthene	mg/kg	8	S4UL 23000	<0.1	1.64	0
Pyrene	mg/kg	8	S4UL 54000	<0.1	1.46	0
Benzo(a)anthracene	mg/kg	8	S4UL 170	<0.1	0.86	0

Determinand	Unit	No. Samples Tested	Screening Criteria		Min	Max	No. Exceeding
Chrysene	mg/kg	8	S4UL	350	<0.1	0.76	0
Benzo(b)fluoranthene	mg/kg	8	S4UL	44	<0.1	1.08	0
Benzo(k)fluoranthene	mg/kg	8	S4UL	1200	<0.1	0.27	0
Benzo(a)pyrene	mg/kg	8	S4UL	35	<0.1	0.86	0
Indeno(123-cd)pyrene	mg/kg	8	S4UL	500	<0.1	0.65	0
Dibenzo(ah)anthracene	mg/kg	8	S4UL	3.5	<0.1	0.18	0
Benzo(ghi)perylene	mg/kg	8	S4UL	3900	<0.1	0.51	0
Total PAH	mg/kg	8	-	-	<1.6	9.1	-

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	6	S4UL	2000	<1	<1	0
>C ₁₀ -C ₁₂	mg/kg	6	S4UL	9700	<1	<1	0
>C ₁₂ -C ₁₆	mg/kg	6	S4UL	36000	<1	<1	0
>C ₁₆ -C ₂₁	mg/kg	6	S4UL	28000	<1	5	0
>C ₂₁ -C ₃₅	mg/kg	6	S4UL	28000	<6	66	0
Total TPH	mg/kg	6	-	-	<6	71	-

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

7.2 Asbestos in Soil

7.2.1 6No 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, no petroleum or polyaromatic hydrocarbons have been found in excess of their generic screening criteria for the protection of human health within a 'commercial' end-use scenario. The generic screening criteria considers all possible pathways between the source and the receptor, including vapour inhalation. On this basis, as no exceedances have been reported, a potential risk from vapour inhalation from a soil source is not considered to exist.

7.4 Summary of Human Health Generic Quantitative Risk Assessment

7.4.1 In summary, no exceedances of contaminants above the GAC were recorded in any of the soil samples tested.

7.5 Screening for Water Pipes Materials

7.5.1 The results of the analysis have been assessed for potential impact upon water supply pipes. Table 7.4 below summarises the findings of the assessment:

Table 7.4: 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	-	0.5	N/A	N/A	-
BTEX	-	0.1	N/A	N/A	-
MTBE	-	0.1	N/A	N/A	-
EC5-EC10	8	1	<1	<1	0
EC10-EC16	8	10	<2	<2	0
EC16-EC40	8	500	<7	71	0
Naphthalene	8	5	<0.1	<0.1	0
Phenols	8	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.

7.5.3 Determinands marked "N/A" were not analysed for as no evidence of their presence was obtained from the Desk Study.

7.5.4 The above suggests that upgraded pipe work is unlikely to be required.

7.5.5 The water supply pipe requirements for this site should be discussed at an early stage with the relevant utility provider.

7.6 Assessment of Soil Analytical Data with Respect to Controlled Waters

7.6.1 At the Preliminary Risk Assessment (Desk Study) stage, risks to controlled waters were "moderate".

7.6.2 The following controlled waters receptors were identified:

- Principal aquifer
- 3No potable abstractions reported within 2km; nearest recorded as active abstraction 942m east for direct potable water supply.
- 1No detailed river entry reported by Water Network 152m west as an 'inland river not influenced by normal tidal action'.

7.6.3 Pathways for migration of leachable/mobile contamination were considered to be potentially present within the underlying chalk deposits.

- 7.6.4 The ground conditions encountered are considered to confirm the expected geological succession and confirmed that potential pathways for migration of leachable/mobile contamination are present.
- 7.6.5 However, with reference to Section 5.4, no visual/olfactory evidence of potentially mobile contamination was encountered, and therefore a pollutant linkage to controlled waters is not considered to exist.
- 7.7 Waste Characterisation**
- 7.7.1 The classification of materials for waste disposal purposes was outside the scope of this report. Should quantities of material require off-site disposal, waste classification will be required to determine whether soils may be treated as hazardous or non-hazardous.
- 7.7.2 Note that Waste Acceptance Criteria (WAC) analysis may then be required by the landfill operator to determine whether materials can be disposed of at either an inert, stable non-reactive hazardous or hazardous landfill.
- 7.7.3 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 7th March 2024 and 26th March 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 983mb and 1015mb. During these visits pressure trends observed were rising and falling.
- 8.1.3 The results of the monitoring undertaken are summarised in Table 8.1 below, with the monitoring records presented in Appendix 6.

Table 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
WS1	4	0.0-0.3	0.1-0.3	19.7-20.8	0.0-0.2	0.0-+0.3	0.0-+0.3	1.80-Dry	1.00-2.00	Chalk
WS3	4	0.0-0.2	1.8-2.4	16.8-19.1	0.0-1.1	0.0-+0.1	0.0-+0.1	Dry	1.00-2.00	Chalk
WS5	4	0.0-0.2	0.5-1.3	19.0-20.1	0.0-1.5	-0.1-+0.3	-0.1-+0.3	Dry	1.00-2.00	Chalk

8.2 Screening of Results

- 8.2.1 As shown in Table 8.1, methane was reported to a maximum concentration of 0.3%. The concentrations of carbon dioxide ranged from 0.1 to 2.4% v/v. The maximum concentration of volatile organic compounds measured was 1.5ppm. 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 C buildings are defined as
- “commercial building with central building management control of any alterations to the building or its uses and central building management control of the maintenance of the building, including the gas protection measures. Single occupancy of ground floor and basement areas. Small to large size rooms with active ventilation or good passive ventilation of all rooms and other internal spaces throughout ground floor and basement areas. Probably civil engineering construction. Examples include offices, some retail premises, and parts of some public buildings (such as schools, hospitals, leisure centres and parts of hotels).”*
- 8.2.4 Type D buildings are defined as

“industrial style building having large volume internal space(s) that are well ventilated. Corporate ownership with building management controls on alterations to the ground floor and basement areas of the building and on maintenance of ground gas protective measures. Probably civil engineering construction. Examples are retail park sales buildings, factory shop floor areas, warehouses. (Small rooms within these style buildings should be separately categorized as Type B or Type C).”

8.2.5 Type D has been adopted as the relevant category for the majority of the proposed development. As indicated above some small areas will need to be categorised separately as Type C.

8.2.6 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).

8.2.7 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)

8.2.8 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 8.2.

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

Table 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	2.4	0.3	0.0072	1
CH ₄	0.2	0.3	0.0006	1

8.2.10 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.

8.2.11 BS 8576:2013 has been used to derived threshold levels for carbon monoxide and volatile organic compounds.

8.2.12 Given the recorded levels it is not considered that additional protection measures need to be incorporated to protect end users from the recorded carbon monoxide concentrations.

- 8.2.13 PID screening of the monitoring well headspace has revealed maximum concentrations of VOCs of 1.5ppm. No visual or olfactory evidence of potentially mobile contaminants has been reported and no exceedances generic assessment criteria reported for potentially volatile contaminants. Therefore, it is considered that the PID screening of monitoring well confirms the assessment that risks to human health receptors via vapour inhalation pathways are low/potentially significant/require further evaluation.

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 is to comprise the construction of new commercial warehouse, with an associated car park and service yard. Areas of soft landscaping are located along the edges of the site.
- Following generic risk assessments, no contaminants have been found in excess of generic assessment criteria protective of human health within a “commercial” end use.
- 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 end users associated with vapour risk inhalation from soils is considered negligible.
- The risk to controlled waters from soils is considered negligible.
- Gas monitoring has concluded the development may be considered “characteristic Situation 1” and therefore no formal remedial measures are considered necessary.
- Based on the information obtained to date, no formal remedial measures are considered necessary.
- As with any ground investigation, the presence of further hotspots between sampling points cannot be ruled out. Should any evidence of 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 9.1 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 9.1: Plausible Pollutants Linkages Summary (Pre-Remediation)

Potential Source (from desk study)	Pathway	Receptor	Relevant Pollutant Linkage?	Comment
- Potential for contaminated ground associated with previous site use – on site (S1) - Railway sidings (1947-1948) - Use as car park (recent aerial images) - Possible contamination associated with historic above ground fuel tank (associated with site cabin) (S2) - Potential for Made Ground associated with previous development operations – on site (S3) - Current and previous industrial use associated with Royston industrial park – off site (S4) - Vehicle repair, testing and servicing 40m southeast (recent) - Unspecified tanks: nearest 40m southeast (1992) - Unspecified factory 42m northeast (1977) - Unspecified works 84m east (1992) - Large chemical works approximately 150m east (1973)	- 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)	N	No formal remedial measures considered necessary. 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 deemed 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 (R6) - Principal aquifer 3No potable abstractions reported within 2km; nearest recorded as active abstraction 942m east for direct potable water supply 1No detailed river entry reported by Water Network 152m west as an ‘inland river not influenced by normal tidal action’	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.

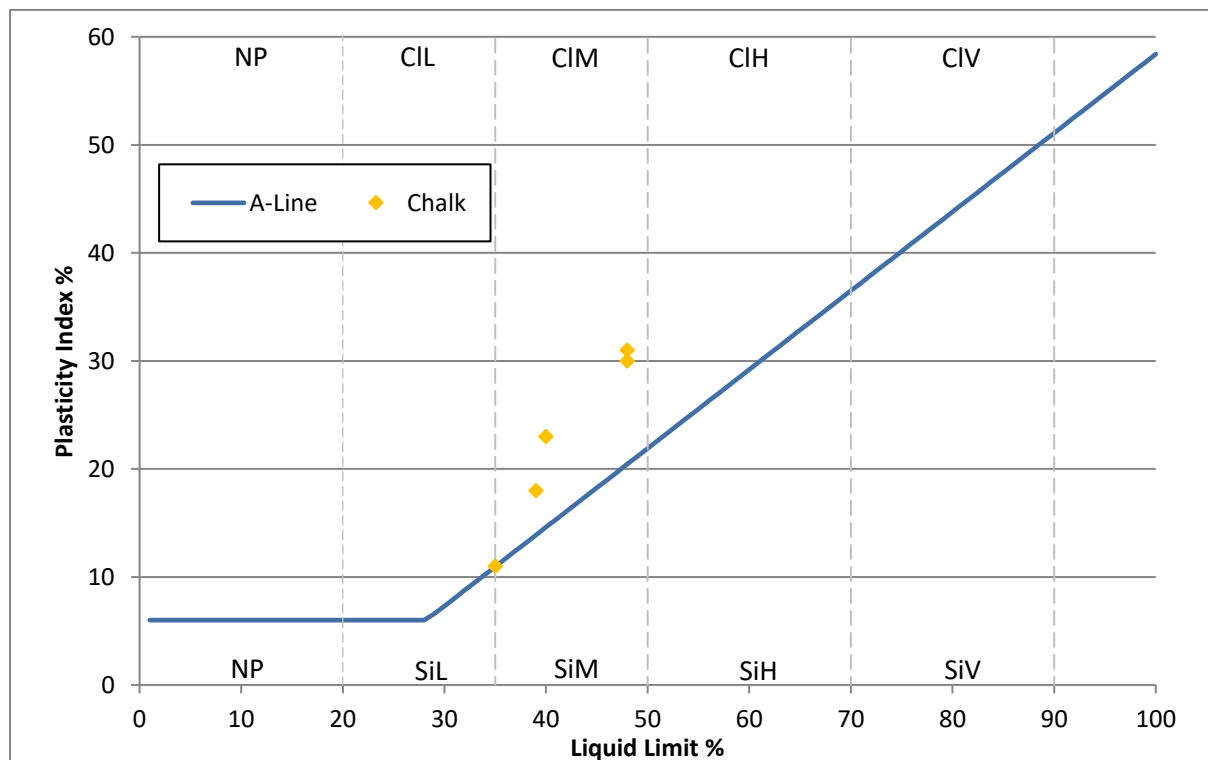
10.2 Plasticity of Cohesive Materials

10.2.1 Atterberg Limit determination was undertaken on 5No samples of chalk, at depths ranging from 0.50 to 1.90mbgl.

10.2.2 Plasticity Index values ranged from 11% to 31% and were indicative of “Low” to “intermediate” plasticity, as illustrated in Figure 10.1 below.

10.2.3 Modified Plasticity Index values ranged from 5.28% to 23.56%, indicating soils varying from “non - shrinkable” to “medium” volume change potential.

Figure 10.1: Plasticity Chart



10.3 Undrained Shear Strength

10.3.1 Standard Penetration Tests were undertaken at regular intervals throughout the windowless sample boreholes. Although the tests were undertaken in chalk, the shallow material was sufficiently weathered to be considered as “clay” for geotechnical purposes.

10.3.2 The results of the SPTs have been used to infer the undrained shear strength using the correlation suggested by Stroud (1974).

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

in which

c_u = mass shear strength (kN)

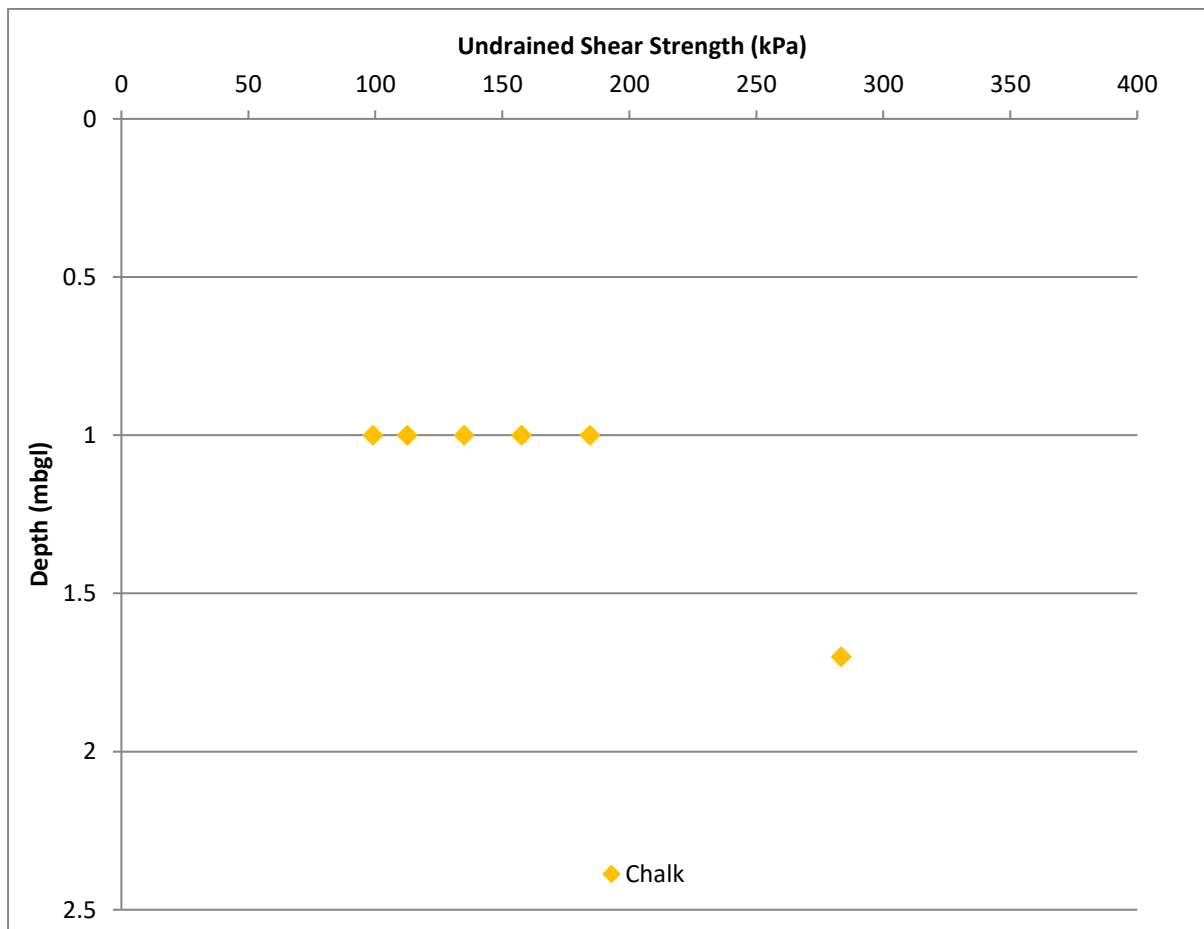
f_1 = constant

N = SPT Value achieved during boring operations

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

10.3.4 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 10.2: Undrained Shear Strength v Depth



10.4 Coefficient of Compressibility

10.4.1 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

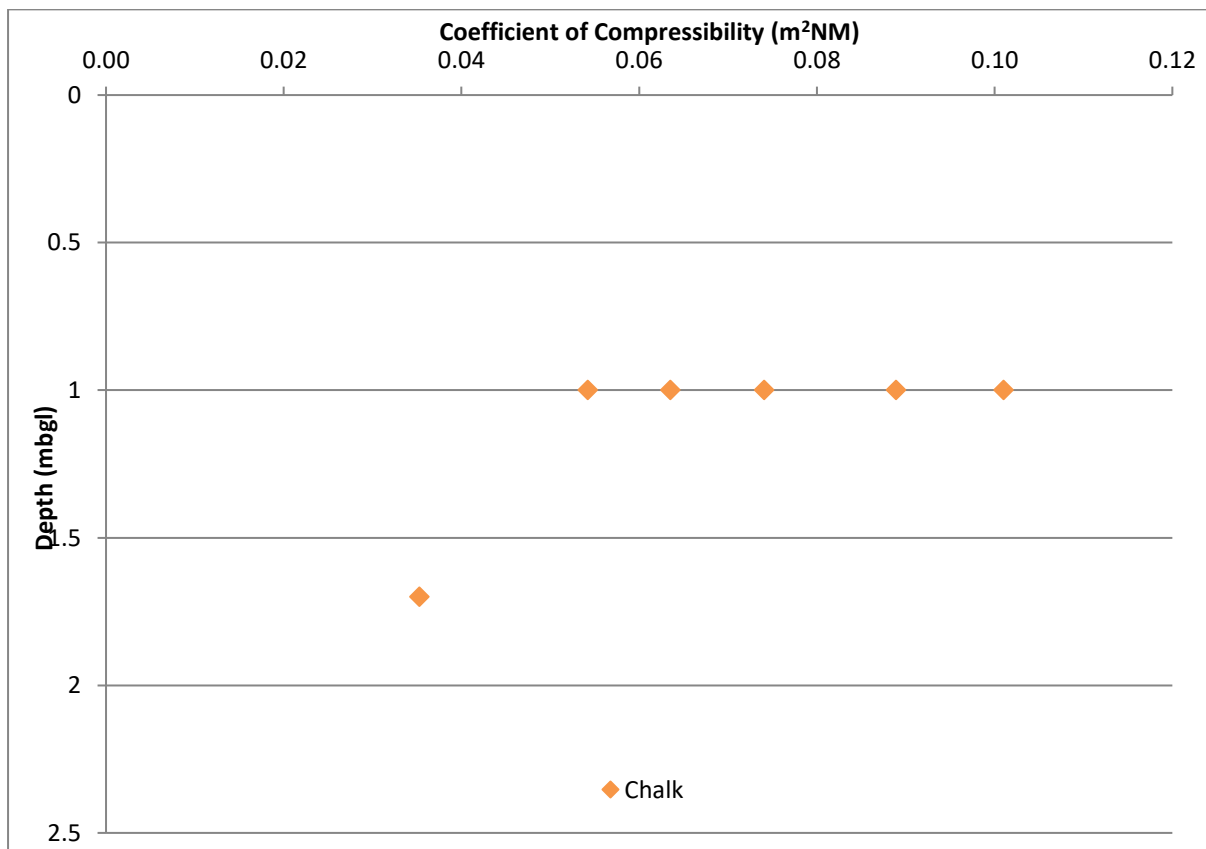
m_v = coefficient of compressibility (m^2/MN)

f_2 = constant dependent on the plasticity index

N = SPT Value achieved during boring operations

10.4.2 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).

Figure 10.3: Coefficient of Volume Compressibility (m_v) v Depth



10.4.3 As would be expected, the results broadly reduce with depth as the soil increases in strength as the over burden increases, reducing the potential for compressibility. This is considered to be due to the lack of overburden pressure at shallow depth allowing the clays to relax and so compress slightly when loaded.

10.4.4 The weathered chalk deposits are of “very low” to “medium” compressibility.

10.5 Density

10.5.1 In the absence of geotechnical laboratory test results, the correlations and suggested values given in BS8004:2015 have been used.

10.5.2 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
Holywell Nodular Chalk Formation	19

10.6 Effective Angle of Shearing Resistance / Angle of Friction

10.6.1 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.

10.6.2 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	Holywell Nodular Chalk Formation	25.0
WS2	Holywell Nodular Chalk Formation	23.5
WS3	Holywell Nodular Chalk Formation	29.0
WS4	Holywell Nodular Chalk Formation	25.0
WS5	Holywell Nodular Chalk Formation	23.4

10.7 Stiffness Moduli

10.7.1 In Chalk, the drained Young’s Modulus can be derived using the following equation.

$$E' = 5 * N$$

10.8 Summary of Derived General Properties

10.8.1 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	Made Ground	Holywell Chalk
Unit Weight (kN/m ³) ¹⁾	17	19
Drained Friction, ϕ' (°)	-	23.4 – 29.0 ³⁾
Drained Cohesion, c' (kPa)	-	0
SPT 'N' Value	-	22-63
Undrained Young's Modulus, E_u (MPa) ⁴⁾	-	
Drained Young's Modulus E' (MPa) ⁵⁾	-	110 – 315
Undrained Shear Strength, c_u (kPa) ⁶⁾	-	99 - 283
Plasticity Index (%)	-	11-31
Modified Plasticity Index (%)	-	5.24-23.56
Volume Change Potential [NHBC]	-	Non - shrinkable - Medium
Modulus of Volume Compressibility, m_v (m ² /MN) ⁸⁾	-	0.035 - 0.101

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⁾ Calculated from Table 1 of BS8004:2015 (Granular Soils with less than 15% fines) OR Correlation between N value and Φ (see chart in Guides and Standards – 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.

⁶⁾ 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 is not considered to provide a suitable bearing stratum due to the 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.

Conventional Foundations

11.2.4 It is considered that traditional pad foundations with dimensions of 1.2m x 1.2m may be formed within the underlying chalk at a minimum depth of 1.5mbgl for an allowable bearing capacity of 225kPa. . Total and differential settlements should be contained within tolerable limits.

11.2.5 This depth, however, does not take into account the depth of Made Ground or the distance to and species of any previous, existing and proposed trees, and foundations may need to be deepened further accordingly, in accordance with NHBC requirements.

11.2.6 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.

11.2.7 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).

11.2.8 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.

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 Table 11.1 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 Table 11.2 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	7	7.7-8.3	1615	N/A	DS-3	AC-2s
Holywell Nodular Chalk Formation	4	7.8-8.4	270	N/A	DS-1	AC-1s

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 A ground bearing slab may be suitable provided that:

- The depth of existing/proposed Made Ground does not exceed 600mm,
- Foundation depths do not exceed 1.5m due to NHBC building near tree deepening requirements,
- Ground floor construction is not undertaken when the surface soils are seasonally desiccated (i.e. during summer and autumn).

11.4.2 It is noted that one of the samples tested had a modified plasticity index that fell within the range of medium volume change potential. However, all other samples fell within the ranges of non-shrinkable soil / low volume change potential. This, along with previous experience in weathered chalk, leads to the consideration that overall, the soils are of low 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 Table 11.3 summarises the results of the in-situ CBR testing.

Table 11.3: Summary of CBR Test Results

Position	Depth Range (mm)	Stratum	CBR %	
			IAN 73/06	TRL 587
CBR1	50-250	Made Ground	22.3	22.1
	250-400	Made Ground	10.1	10.5
	400-500	Made Ground	18.2	18.2
CBR2	50-250	Made Ground	20.9	20.8
	250-500	Made Ground/Chalk	13.3	13.6
CBR3	50-500	Made Ground/Chalk	17.9	18.0
CBR4	50-250	Made Ground	19.5	19.5
	250-500	Made Ground/Chalk	12.2	12.6
CBR5	50-500	Chalk	11.8	12.3

- 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 2.5% for the preliminary design of pavements constructed upon Made Ground.
- 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 5% is considered suitable for the Chalk.
- 11.6.5 The near-surface soils are deemed to be of low permeability and should therefore be treated as being not frost-susceptible.
- 11.6.6 Additional CBR testing should be undertaken after detailed design is complete to confirm suitability.

11.7 Surface Water Drainage

BRE 365 Soakage Tests

11.7.1 Table 1.4 summarises the soakage rates, which were calculated based on the results of the soakage testing:

Table 1.4: Summary of BRE 365 Soakage Test Results

Position	Geology	Calculated Infiltration Rates (m/s)		
		1 st cycle	2 nd Cycle	3 rd Cycle
STP1	Holywell Nodular Chalk Formation	9.58x10 ⁻⁶	-	-
TP03	Holywell Nodular Chalk Formation	4.67x10 ⁻⁵	3.12x10 ⁻⁵	-

11.7.2 The result from STP1 is indicative of “low” permeability and “poor” drainage conditions. Results from STP2 are indicative of “medium” permeability and “good” drainage conditions.

11.7.3 Based on the above results and ground conditions encountered, conventional soakaways may be suitable and should be designed in accordance with the recommendations provided in BRE DG 365 (2016): Soakaway design.

11.8 Groundwater Control

11.8.1 During the investigation groundwater was reported within as “seeping” into STP1 at 2.0mbgl. No other groundwater strikes were reported.

11.8.2 During return monitoring groundwater was reported between 1.80mbgl and dry at 2.00mbgl within WS1. The wells within WS3 and WS5 were both reported to be dry on all occasions.

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 or may freely drain through the chalk.

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APPENDICES

APPENDIX 1 – FIGURES

APPENDIX 2 – EXPLORATORY HOLE RECORDS

APPENDIX 3 – CHEMICAL LABORATORY TEST RESULTS

APPENDIX 4 – GEOTECHNICAL LABORATORY TEST RESULTS

APPENDIX 5 – SOIL GAS MONITORING RESULTS

APPENDIX 6 – CBR TESTING RESULTS

APPENDIX 7 – BRE 365 SOIL INFILTRATION TESTING RESULTS

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