Report Title: **Phase 2 Ground Investigation**

Project Name: **Cloot Drove, Crowland**



Report Reference: **BRD4519-OR2-A**

Date: **December 2024**

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REPORT CONTROL SHEET

REPORT TITLE	**PHASE 2 GROUND INVESTIGATION**
PROJECT	**CLOOT DROVE, CROWLAND.**
CLIENT	**ALLISON HOMES EAST**

REPORT REFERENCE	ISSUE DETAIL	DATE	PREPARED BY	CHECKED BY
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BRD Environmental Limited

Geotechnical and Environmental Services

- Ground Investigation
- Japanese Knotweed Removal
- Soil, Water and Gas Testing
- Contamination Assessment
- Geotechnical Advice
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REPORT LAYOUT

This report is divided into the following four sections: Summary Report, Technical Report, Supporting Information and Appendices.

SUMMARY REPORT

This expanded executive summary provides the main findings of the work undertaken in brief non-technical language. This section provides an overview of the key outcomes for the benefit of non-specialists and concludes with the main recommendations. This section should only be relied upon in the context of the whole report and the Technical Report should be referred to with respect to any design decisions.

TECHNICAL REPORT

The main report section is intended to provide the technical detail of the investigation and is intended to provide the level of information required by current guidance documents and practice. The Technical Report is written in a language that, in part, assumes knowledge of subject matter so that it can be written in as concise a form as possible. Its intended audience is peers, regulators and other professionals in related disciplines.

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SUPPORTING INFORMATION

This section of the report provides background details of a generic nature together with specific technical approaches adopted by BRD and details of the guidance documents that are commonly referenced in the report. The section also includes explanations of technical terms to assist non-specialist readers in understanding the Technical Report. It should be noted that not all the information within this section is necessarily applicable to this specific report.

APPENDICES

The final section of the report presents the factual data collected and employed as part of the investigation.

APPENDIX 1 SITE PLANS

Site Location Plan	Ref. BRD4519-OP4-A
Proposed Development Layout	'Testing Layout' Pegasus Group, Dwg. P24-1403_DE_001-01 Rev. B, Dated 18/07/2024.
Exploratory Hole Location Plan	Ref. BRD4519-OD1-A
Zoned Ground Conditions	Ref. BRD4519-OD2-A

APPENDIX 2 EXPLORATORY HOLE & MONITORING RECORDS

Logs of trial pits.	Ref. TP01 to TP15
Photographic records of trial pits.	Ref. BRD4519-OP3-A
Logs of boreholes.	Ref. WS01 to WS15
Groundwater monitoring records.	1 x A4 page

APPENDIX 3 LABORATORY TEST RESULTS

DETS reports	24-14270.1	21 x A4 pages
	24-14271.1	7 x A4 pages
	24-14686.1	5 x A4 pages
SPT report	46294_1	18 x A4 pages

SUMMARY REPORT - GENERAL INFORMATION

SUBJECT	COMMENTS
CURRENT SITE CONDITION	The site is currently formed of two arable fields, with the internal field boundary aligned roughly east northeast to west southwest across the southern part of the site.
PROPOSED DEVELOPMENT	It is proposed that the site will be developed for residential use, including houses with private gardens, access roads, areas for parking and public open space.
HISTORICAL SUMMARY	The earliest map reviewed, 1887, shows the site to be part of three undeveloped fields. Little changed on the site between then and now, except for a short period it was part of an allotment and the infilling of a ditch that formed one of the internal field boundaries.
PUBLISHED GEOLOGY	The BGS map shows most of the site to be underlain by superficial Abbey Sand and Gravel onto bedrock of the Oxford Clay Formation. However, the northwestern corner is shown to be underlain by superficial Tidal Flat Deposits onto the Oxford Clay Formation.
ACTUAL GROUND CONDITIONS	The investigation has shown the ground conditions under the site comprise Superficial Deposits that range widely in nature and strength. They ranged from very soft to stiff fine-grained soils and loose to dense coarse-grained soils, and locally contained some organic materials. It is considered likely some of the soils are Tidal Flat Deposits and some are Abbey Sand and Gravel, however in places it has proven impossible to determine one from the other. Consequently, all the soils encountered have been referred to as Superficial Deposits. The base of the Superficial Deposits was not penetrated and, therefore, no bedrock was encountered.
HYDROGEOLOGY	Most of the site is underlain by a Superficial Secondary A Aquifer, the Abbey Sand and Gravel, with the underlying Oxford Clay Formation and the Tidal Flats Deposits classified as Unproductive Strata. The site is not within a Source Protection Zone (SPZ).
HYDROLOGY	There are drainage ditches on the site and along some of the site's boundaries, with the nearest surface watercourse being the River Welland, approximately 1.2km to the west. Most of the site is located in a Zone 3 area and is likely to be affected by flooding.
PREVIOUS GROUND REPORTS	BRD is not aware of any previous ground investigations having been conducted at the site. However, BRD has undertaken geo-environmental desk study research, and this has been reported separately.

SUMMARY REPORT - GEOTECHNICAL

SUBJECT	COMMENTS
EXCAVATIONS	It should be possible to forward excavations employing normal equipment. Excavations down to approximately 1.5m should remain stable in the short term, and should any minor seepages be encountered, for these excavations the use of a sump pump should be sufficient to keep them dry. However, for deeper excavations, groundwater ingress with associated excavation instability should be anticipated and pumping from a sump may not be sufficient to keep the excavations dry. For control of groundwater in deeper excavations the advice of a specialist should be sought and well-pointing will likely be required.
SUB-SURFACE CONCRETE	Design Sulphate Class of DS-2 and Aggressive Chemical Environment for Concrete class of AC-2 applies.
SOAKAWAYS	Due to the presence of shallow groundwater the site is not suitable for surface water disposal to soakaways.
PAVEMENT DESIGN	A preliminary design California Bearing Ratio (CBR) of less than 2% has been recommended.
FOUNDATIONS	
LIKELY FOUNDATION TYPE	Shallow conventional foundations, with light reinforcement, are possible across the northwestern area and parts of the southern area. However, across the rest of the site, and all plots within the zone of influence of trees, a piled foundation solution will be required.
VOLUME CHANGE POTENTIAL	Classification testing has shown the Superficial Deposits to have Medium Volume Change Potential.
ESTIMATED FOUNDATION DEPTHS	For the areas where shallow conventional foundations are possible then a minimum foundation depth of 0.9m will be required. Due to shallow groundwater, foundations below approximately 1.5m depth will not be practical and piled foundations will be required for plots that require deeper foundations.
HEAVE PROTECTION	Is likely to be required for some piled plots near boundary trees.

SUMMARY REPORT – CONTAMINATION ISSUES

SUBJECT	COMMENTS
SOIL RISKS TO HUMAN HEALTH	No unacceptable contamination in respect of human health have been identified by this investigation.
LANDFILL GAS	No plausible sources of landfill gas have been identified.
RADON GAS	Radon gas protection measures are not required.
RISKS TO THE WATER ENVIRONMENT	No unacceptable contamination risks to water resources have been identified by this investigation.
RISKS TO BUILDING MATERIALS AND SERVICES	No unacceptable contamination risks to building materials and services have been identified by this investigation.
REMEDIATION	No remedial works are considered necessary to facilitate the development at this stage.
ASBESTOS	No suspected asbestos containing materials has been observed in the soils inspected and no asbestos has been detected in the soil samples tested.
WASTE SOIL DISPOSAL	The Topsoil will be Non-hazardous waste, with most of the natural soils beneath the Topsoil classified as Non-hazardous and characterised as Inert waste for disposal to landfill. However, some organic materials were noted in the Superficial Deposits, and should significant volumes of this material need to be disposed of at a landfill it will potentially not be inert.

SUMMARY REPORT – KEY RECOMMENDATIONS

RECOMMENDATIONS
Contamination It is recommended that this report is submitted to the planning department of the Local Authority, the organisation undertaking the Building Control function and warranty providers to confirm that the investigation completed to date is satisfactory. Geotechnical To provide information for pile design, deep cable percussive boreholes will be required, with associated in-situ testing, sampling and geotechnical laboratory testing. Consideration could be given to undertaking some deep Cone Penetration Tests (CPT) to compliment the boreholes. A tree survey will be required for detailed foundation design. This survey with topographic survey data should be undertaken prior to any site clearance and removal of any trees. The survey should record the trunk location, height and species of the trees. To allow a more detailed assessment of the groundwater levels during the wetter months, longer term monitoring through the winter months could be considered. To allow a more detailed CBR assessment, targeted investigations with further testing could be considered.

1. INTRODUCTION TO TECHNICAL REPORT

1.1. CONTRACT DETAILS

CLIENT	Allison Homes Limited, trading as Allison Homes East.
SITE	Cloot Drove, Crowland.
CLIENT'S ADVISORS	BRD Environmental Limited (BRD) has been commissioned directly by the Client.
REPORT CONTEXT	It is understood that the Client intends to purchase the site and develop it for residential use.
REPORT TYPE	Combined Geotechnical Ground Investigation and Phase 2 Contamination Assessment.
REPORT OBJECTIVES	The site has been the subject of a desk study, referenced as follows: • 'Phase 1 Geo-Environmental Desk Study – Cloot Drove, Crowland', BRD Environmental Ltd, report ref. BRD4519-OR1-A, dated December 2024. The desk study identified a number of potential contamination sources that required further investigation and identified the need for some geotechnical investigation to inform the design of the new development. The purpose of this report is to present the findings of the Phase 2 Ground Investigation, and to present both geotechnical and contamination assessments of the ground conditions revealed.

1.2. SCOPE OF WORKS

The agreed scope of works was:

- Procure a general set of utility service records (electricity, gas, water, sewers, BT, fibre & independent providers) covering the site and immediate surroundings, if not already held by the Client.
- Mobilisation to site and production of health and safety documentation.
- Three days of windowless sampling using a percussive drilling rig to provide approximately 14-15No. boreholes to a nominal depth of 5m, ground conditions permitting. Undertake Standard Penetration Tests (SPT) at 1m intervals.
- Installation of a 5m depth combined gas and groundwater monitoring well (nominal 50mm diameter) into 8No. boreholes. Installations will be finished with a raised metal stopcock cover.
- Two days of trial pitting using a mechanical excavator to provide approximately 14-15No. trial pits to a nominal depth of 3m, ground conditions permitting.
- All exploratory points will be logged and sampled in general accordance with BS5930:2015+A1:2020 by supervising Geo-Environmental Consultant.
- In-situ geotechnical testing of fine soils using a Hand Shear Vane and/or Pocket Penetrometer.

- Determination of the accurate location and level of exploratory points by topographical grade GPS unit.

- Geo-Environmental Technician to undertake initial groundwater monitoring visit to determine resting groundwater levels and to collect water samples for geotechnical analysis.

- Chemical testing of soil samples to confirm the soils are uncontaminated, to determine waste classification for spoil disposal and to meet the requirements for new water supply pipe specification. Budget based on the following testing schedule:

    - 12No. Metals Suite - As, Cd, Cr, CrVI, Hg, Pb, Se, Cu, Ni and Zn.
    - 12No. Inorganics Suite – water soluble sulphate, pH, organic matter.
    - 12No. Speciated Polycyclic Aromatic Hydrocarbons (PAH).
    - 6No. Banded aliphatic/aromatic Total Petroleum Hydrocarbons (TPH).
    - 6No. Benzene, Toluene, Ethylbenzene, Xylene (BTEX) and Methyl Tertiary Butyl Ether (MTBE) compounds.
    - 6No. Organochlorine pesticides suite.
    - 3No. Semi-Volatile Organic Compounds (SVOC) suite.
    - 3No. Asbestos quantification.

- Chemical testing of 1No. soil sample for Waste Acceptance Criteria (WAC) to assist in establishing landfill type for soil disposal purposes.

- Geotechnical testing as appropriate to the nature of the ground conditions encountered, but the budget is based on the following testing schedule:

    - 8No. Moisture content.
    - 8No. Plasticity indices.
    - 6No. Particle size distribution by wet sieve with 3No. by follow on hydrometer.
    - 6No. pH and sulphate analysis - water.
    - 12No. pH and water soluble sulphate analysis - soil.
    - 12No. Total sulphate and sulphur analysis - soil.

- Provision of a combined factual and interpretative investigation report. Factual findings to include all exploratory point records, monitoring and test results. Interpretative reporting to include a summary of information from desk study research, a Generic Quantitative Contamination Risk Assessment (GQRA), waste soil classification and a Geotechnical Assessment providing comments on pavement design, concrete classification, soakaway feasibility, foundation design recommendations. Report to be supplied in an electronic Adobe pdf format.

1.3. REPORT LIMITATIONS

Any site boundary lines depicted on plans included within this report are approximate only and do not imply legal ownership of land. Any observations of tree species, asbestos containing materials within structures or invasive weeds, does not constitute a formal survey of such features. The identification of such features is therefore tentative only. In the case of Japanese Knotweed, BRD can undertake separate surveys for this plant undertaken by a Property Care Association qualified surveyor.

The report does not consider whether sensitive ecology or archaeology is present as these require consideration by professionals specialising in these matters. It should be recognised that the collection of desk study information may not be exhaustive and that other information pertinent to the site may be available.

The recommendations, interpretations and conclusions of this report are based solely on the ground conditions found at the exploratory holes. Due to the variability in the nature of ground,

conditions between exploratory holes can only be interpreted and not defined. The description of the site and the ground conditions is accurate only for the dates of the field works. In particular, groundwater levels can vary due to seasonal and other effects.

The assessment and interpretation of contamination risks is based on the scope of works agreed with the Client together with the budgetary and programme constraints imposed. Further investigation, analysis and assessment of contamination may be required by regulators or other third parties with an interest in the site. An ecological risk assessment of contaminated soils is beyond the scope of this report. This report is concerned with assessing those contamination risks which apply to the future use of the site through the proposed development as part of the planning regime. The assessment does not consider the risk to current site users or continued future use of the site in its current state. If development of the site should occur that differs from that proposed, then the findings of the contamination assessment would need to be re-evaluated.

At the time of writing, detailed information on the proposed structure, such as detailed layout, loadings and serviceability limits, was not available. Accordingly, where geotechnical design advice is provided it is on the prescriptive basis allowed for by Eurocode 7: employing conventional and conservative design rules. The scope of this investigation excludes a formal slope stability study, and any observations made regarding slopes are for information only.

2. SITE CHARACTERISTICS

2.1. SITE SETTING

SITE ADDRESS AND POST CODE	Land off Cloot Drove, Crowland, Peterborough, PE6 0JG.
NATIONAL GRID REFERENCE	Approximate centre of the site - 524558, 311117.

2.2. SITE DESCRIPTION

SUBJECT	COMMENTS
CURRENT SITE DESCRIPTION	The site is currently formed of two arable fields, with the internal field boundary aligned roughly east northeast to west southwest across the southern part of the site. It is formed by a flat lying, L-shaped parcel of land, with overall dimensions of approximately 465m by 300m and covers an area of approximately 8 hectares. Access to the site is gained through an open entrance in the northern part of the western boundary, via Cloot Drove. The northern boundary and northern part of the eastern boundary was formed by a drainage ditch, with a hedgerow forming the rest of the eastern boundary. The southern boundary was mainly formed by a hedgerow. The southern part of the western boundary was formed by a wooden fence, and the northern part by a ditch. The site's surface was formed by a ploughed arable field and there were no existing buildings on the site. There were hedgerows, which included mature trees, along the internal boundary in the southern half of the site and around the eastern and southern boundaries. No obvious signs or sources of on-site contamination were noted during the inspection. The water level in the ditch forming the northern boundary was approximately 1.50m below the general ground level across the site. There are overhead electricity cables, associated with the adjacent sub-station, aligned roughly east to west across the northern part of the site. In addition, there are underground electric cables and gas pipes close to the western boundary.
SURROUNDING LAND USE	The site is located on the northern outskirts of the town of Crowland, in a mixed residential, commercial and agricultural area. Beyond the northern and western boundaries is mainly further farmland, however there is an electricity sub-station just to the northwest. To the east is woodland and a commercial business and to the south a residential development.

SUBJECT	COMMENTS
PROPOSED DEVELOPMENT	It is proposed that the site will be developed for residential use, including houses with private gardens, access roads, areas for parking and public open space. A copy of the Proposed Development Plan is provided in Appendix 1.
HISTORICAL SUMMARY	The earliest maps reviewed show the site as part of three undeveloped fields, separated by roughly east northeast to west southwest aligned drainage ditches. In the early twentieth century most of the site was part of an allotment, however for most of its history the site has been agricultural. Between 2000 and 2006 one of the internal drainage ditches was removed, leaving the site as part of two fields.
PUBLISHED GEOLOGY	The site is shown to be mainly underlain by superficial Abbey Sand and Gravel, with Tidal Flat Deposits across the northwestern area. Beneath the Superficial Deposits the maps show bedrock of the Oxford Clay Formation. Abbey Sand and Gravel is described as sand and gravel that locally maybe clayey and the Tidal Flat Deposits as soft silty clay, with layers of peat and sand and a basal gravel. The Oxford Clay Formation is described as mudstone; however, it is likely to comprise a more weathered clay in its upper parts. There is no artificial ground or Made Ground, or faults shown on, or close to, the site.
RADON	Radon protection measures are not required.
HYDROGEOLOGY	Most of the site is shown to be underlain by a Secondary A Aquifer, Abbey Sand and Gravel, with Unproductive Strata, Tidal Flat Deposits, across the northwestern corner. The underlying bedrock, Oxford Clay Formation, is also classified as Unproductive Strata. There are no groundwater abstraction licenses within 250m, and the site is not located within a groundwater Source Protection Zone (SPZ).
HYDROLOGY	There are drainage ditches on the site and around the site's boundaries. These link into a complex array of drainage across the wider area. The closest surface water course is the River Welland, which is located approximately 1.2km west of the site, and in this area flows towards the north. There are no surface water abstraction licenses within 250m of the site. Most of the site is located in a Zone 3 area and is likely to be affected by flooding.

2.3. PREVIOUS INVESTIGATIONS

BRD is unaware of any previous ground investigations having been conducted at the site. However, the site has been the subject of geo-environmental desk study research by BRD and this has been reported separately as the Phase 1 Geo-Environmental Desk Study, reference BRD4519-OR1-A and dated December 2024. This current report should be read in conjunction with the previous desk study report.

2.4. PRELIMINARY CONCEPTUAL MODEL

2.4.1. Potential Contamination Sources

The previous desk study identified the following potential contamination sources:

- On-site use of polycyclic aromatic hydrocarbons (PAH), metals and pesticides.
- Migration of contaminants onto the site from local off-site garage workshop and electricity sub-station.

2.4.2. Invalid Contamination Linkages

No potential ground gas sources have been identified at the site and therefore no ground gas assessment is warranted within this report.

2.4.3. Preliminary Conceptual Model

The preliminary risks, based on the potential contaminant linkages, are detailed in the table below.

POTENTIAL SOURCES AND CONTAMINANTS	PATHWAYS (REFERENCE FROM MODEL)	RECEPTORS	HAZARD SEVERITY	PROBABILITY OF OCCURRENCE	POTENTIAL RISK
On-site use of PAHs, metals and pesticides.	Ingestion Inhalation Direct contact (1)	Future residents	Human health effects - Medium	The site does not have an industrial legacy; therefore, the probability of significant contamination is considered to be low – Low likelihood.	Moderate/Low
	Surface run-off and lateral migration (2)	Drainage ditches, on-site and along the boundaries.	Surface water – Mild		Low
	Lateral and vertical migration into the Aquifer/s (3)	Groundwater	Secondary A Aquifer – Mild		Low
	Direct Contact (4)	Building Materials and Services	Building materials - Medium		Moderate/Low
Off-site sources. Sub-station - Petroleum hydrocarbons and PCBs. Garage Workshop. Petroleum hydrocarbons, Solvents, Asbestos and Metals.	Ingestion Inhalation Direct contact (5)	Future residents	Human health – Medium	The nearby commercial businesses are considered unlikely to have caused significant contamination – Low likelihood	Moderate/Low
	Surface run-off and lateral migration into the Aquifer/s (6)	Drainage ditches on-site and along the boundaries.	Surface water – Mild		Low
	Lateral and vertical migration (7)	Groundwater	Secondary A Aquifer – Mild		Low

POTENTIAL SOURCES AND CONTAMINANTS	PATHWAYS (REFERENCE FROM MODEL)	RECEPTORS	HAZARD SEVERITY	PROBABILITY OF OCCURRENCE	POTENTIAL RISK
	Direct Contact (8)	Building Materials and Services.	Building materials - Medium		Moderate/Low

3. GROUND INVESTIGATION

3.1. INVESTIGATION DESIGN

METHODOLOGY	The investigation involved a mixture of machine excavated trial pits and windowless sampler boreholes. Trial pits were selected as they expose more soils than boreholes, which enables a more reliable record of the ground conditions encountered. Windowless sample boreholes were selected, as they allow in-situ testing of the soils and monitoring installations to be constructed.	
DATES OF SITE WORKS	The main field works were undertaken between 18th and 22nd November 2024. A monitoring visit was undertaken on the 28th November 2024.	
CONSTRAINTS TO EXPLORATORY HOLE LAYOUT	A 10m exclusion was formed either side of the overhead cables across the northern part of the site and, to avoid the underground utilities, from the western boundary.	
EXPLORATORY HOLE SPACING	The test locations were positioned on a rough herringbone arrangement at approximately 50m spacings.	
LAYOUT RATIONALE	**SOURCE / FEATURE**	**EXPLORATORY HOLE**
CONTAMINATION SOURCES TARGETED	PAHs, metals and pesticides across the site.	TP01 to TP15. WS01 to WS15.
	Electricity sub-station – Off-site to the northwest.	TP14 and WS15.
	Garage workshop – Off-site to the east.	TP01, TP06 and TP08. WS06 and WS07.
GROUND FEATURES TARGETED	General site coverage.	TP01 to TP15. WS01 to WS15.

CONTAMINATION SAMPLING PLAN	Based on the proposed end use, the sampling and analysis plan is more positively biased towards near surface samples as these represent the soils most likely to be available to future site users. Groundwater samples have been obtained from all boreholes on a single monitoring visit.
ANALYSIS PLAN	A general suite of contaminants, including metals, inorganics and polycyclic aromatic hydrocarbons (PAHs) was carried out on samples across the site. In addition, given the site's agricultural history, and the identification of nearby off-site garage workshop to the east and an electricity sub-station to the northwest, the following suites were also included; • 6No. pesticide suites on samples spread across the site, • 6No. fuel hydrocarbons suites including from samples taken from close to the eastern boundary (TP06) and northwestern corner of the site (WS15). • 3No. semi-volatile organic compound suites from samples taken from close to the eastern boundary (TP06) and the northwestern corner (WS15), • 1No. polychlorinated biphenyl (PCB) suite from a sample taken from close to the northwestern corner (WS15).

3.2. BRD FIELDWORK

TRIAL PITS	
REFERENCES	TP01 to TP15.
DEPTH RANGE	From 2.00m to 3.00m depth.
EXCAVATOR	Tracked 8 Tonne 360° excavator.
BACKFILL	All the trial pits were backfilled with arisings upon completion and compacted with rams of the excavator bucket.

WINDOWLESS SAMPLING BOREHOLES	
REFERENCES	WS01 to WS15.
DEPTH RANGE	From 3.00m to 4.45m.
RIG TYPE	Premier Drilling Rig.
INSTALLATION / BACKFILL	Eight boreholes (WS01, WS03, WS04, WS07, WS08, WS10, WS11and WS14) had monitoring wells installed. These comprised 50mm nominal diameter standpipes fitted with a gas tap and finished with a raised metal cover. The slotted response length of the well is shown on the individual logs. Bentonite seals are also indicated on the logs. The filter medium used was pea gravel. The rest of the boreholes were backfilled with arisings only.

MONITORING	
TYPE	Groundwater monitoring.
DATES	28th November 2024.
GROUNDWATER SAMPLING METHOD	Samples were retrieved using a sampling bailer dedicated to each well.

3.3. LABORATORY TESTING

GEOTECHNICAL TESTING	
The soil samples for geotechnical testing were forwarded to the laboratory of Soil Property Testing Ltd with pH and sulphate analysis undertaken at the laboratory of DETS Ltd. The geotechnical testing suite is detailed below. The UKAS accreditation of the individual test methods is shown on the laboratory test report included in the Appendices.	
TEST	**NUMBER OF SAMPLES TESTED**
Moisture content	8
Liquid and plastic limits	8
Particle size distribution by wet sieve	6
pH and Water-soluble Sulphate	12
Total Sulphur and Sulphate	12

SOIL CHEMICAL TESTING	
The soil samples for contamination and/or chemical geotechnical testing were forwarded to the laboratory of DETS Ltd and the testing suite is detailed below. The UKAS or MCERTS accreditation of the individual test methods is shown on the laboratory test report included in the Appendices.	
SOIL TESTS	**NUMBER OF SAMPLES TESTED**
Arsenic, Cadmium, Chromium, Chromium VI, Copper, Lead, Mercury, Nickel, Selenium, Zinc	12
Speciated Polycyclic Aromatic Hydrocarbons (PAH)	12
Total Petroleum Hydrocarbons (TPH) with full carbon banding and aliphatic/aromatic split	6
Benzene, Toluene, Ethylbenzene and Xylenes (BTEX) plus Methyl Tert Butyl Ether (MTBE)	6
Asbestos Identification	3
Semi-Volatile Organic Compounds (SVOCs)	3
Polychlorinated Biphenyls (PCBs)	1
Waste Acceptance Criteria (WAC) testing	1

GROUNDWATER CHEMICAL TESTING	
The water samples for geotechnical testing were forwarded to the laboratory of DETS Ltd and the testing suite is detailed below. The UKAS or MCERTS accreditation of the individual test methods is shown on the laboratory test report included in the Appendices.	
WATER TESTS	**NUMBER OF SAMPLES TESTED**
pH	6
Sulphate	6

4. GROUND CONDITIONS

4.1. OVERVIEW

The site and laboratory works have shown the ground conditions to generally comprise a thin layer of Topsoil over Superficial Deposits to the full depth of the trial pits and boreholes at depths down to 4.45m. The Superficial Deposits ranged from very soft to stiff fine-grained soils and loose to dense coarse-grained soils, and in places contained some organic materials. It is considered likely most are the Abbey Sand and Gravel, but some, particularly the soft clay, are likely Tidal Flat Deposits. The British Geological Survey (BGS) describes the Abbey Sand and Gravel as mainly sand and gravel that may be clayey and the Tidal Flat Deposits as mainly clay but with layers of sand and a basal gravel. In places it has proven impossible to determine one from the other. Consequently, to avoid misidentification, all the soils encountered beneath the Topsoil have been classified as Superficial Deposits.

The base of the Superficial Deposits was not penetrated during this investigation and, therefore, the depth and nature of the bedrock not revealed.

Details of the various stratigraphic units are given in the following sections.

4.2. TOPSOIL

Encountered at each test location from ground level down to depths ranging from 0.30m to 0.60m, and on average 0.36m. It generally comprised dark brown slightly gravelly very clayey organic fine sand, with the gravel generally consisting of fine sub-rounded flint.

4.3. SUPERFICIAL DEPOSITS

Superficial Deposits were encountered beneath the Topsoil down to the base of each test location at depths down to 4.45m, and, as noted above, were variable in nature and strength.

In the northwestern part of the site it generally comprised medium dense orange brown clayey very sandy fine to coarse sub-rounded to sub-angular gravel of flint and sandstone, with some patches of fine sand and firm slightly sandy clay.

However, across the central area of the site it was more variable with much more fine-grained strata encountered, some of which was weak and deep. In addition, observations of the coarse-grained soils in this area revealed more loose material compared to the northwestern area. The fine-grained Superficial Deposits across the central area ranged from very soft grey slightly sandy slightly organic clay to firm grey brown slightly sandy slightly gravelly clay, with the gravel generally consisting of fine to coarse sub-rounded to sub-angular flint. The coarse-grained Superficial Deposits across the central area ranged from loose red brown clayey very sandy gravel to dense sand and gravel, with the gravel generally consisting of fine to coarse sub-rounded to sub-angular flint and sandstone.

Across the southeastern part of the site the ground conditions remained variably fine and coarse-grained, however, the fine-grained soils were generally at least firm and the coarse-grained soils medium dense. The exception to this was at the two boreholes formed in the corners of the southern area, WS01 and WS03, both of which contained soft slightly gravelly sandy clay. Generally, the fine-grained soils in this southeastern area ranged from firm brown slightly gravelly sandy clay to stiff grey brown slightly gravelly slightly sandy clay, with the gravel content generally consisting of fine to medium sub-rounded to sub-angular flint. Except in the corners at WS01 and WS03 where some of the strata was loose, the coarse-grained soils across the southeastern part of the site generally ranged from medium dense clayey gravelly medium sand to medium dense orange brown clayey sandy gravel. With the gravel generally comprising fine to coarse sub-rounded to sub-angular flint and sandstone.

4.4. GEOTECHNICAL COMMENTS

The ground conditions across the site were variable and in places weak. The weak soils comprised very soft or soft clay and locally were deep, such as at WS10 where very soft clay was encountered down to 3.00m depth. Consequently, parts of the site will not be suitable for shallow conventional foundations.

This area is known to have shallow groundwater levels and observations of the water level in the surrounding ditches and made during the investigation and subsequent monitoring indicate the local groundwater level is approximately 1.5m depth. In the trial pits, side wall instability occurred once groundwater seepages were encountered, which will limit the depth foundations can be taken down to.

4.5. CONTAMINATION OBSERVATIONS

No visual or olfactory evidence of contamination was noted during the forwarding of the exploratory holes.

4.6. GROUNDWATER BEHAVIOUR

During the progressing of the machine excavated trial pits groundwater seepages, which were generally fast, were noted at depths between 0.80m and 2.30m. On completion of the boreholes standing water levels between 1.50m and 2.80m depth were recorded. At the subsequent monitoring visit the standing water levels in the borehole wells was recorded between 0.40m and 1.80m depth.

The range of readings and observations was wide. However, based on observations of the water level in the drainage ditches forming the site's boundaries and measurements carried out during this investigation, it is considered, at the time of this investigation, the local groundwater level was in the region of 1.5m depth.

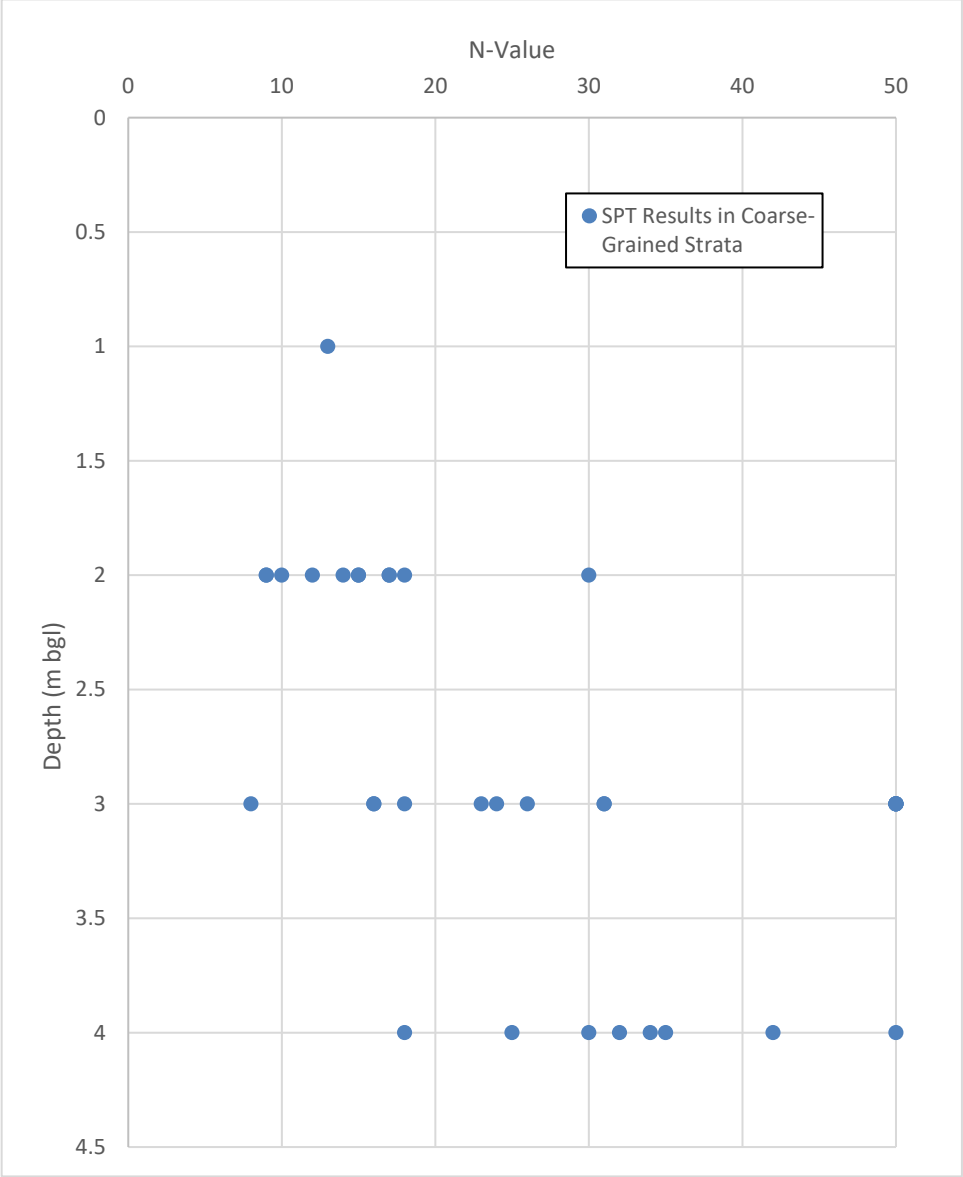
5. GEOTECHNICAL PROPERTIES

5.1. COARSE SOIL PARAMETERS

5.1.1. Standard Penetration Tests

5.1.1.1. Coarse-Grained Superficial Deposits

The N-values derived from the standard penetration testing in the coarse-grained Superficial Deposits ranged from 8 to 50 for 125mm of progress and are shown on the graph below. Typically, they were above 10 and increased with depth.



5.1.2. Particle Size Distribution

Particle size distribution (PSD) testing was carried out on six samples of the Superficial Deposits. The recorded results ranged from 8% to 43% fines content, 35% to 53% sand content and 2% to 54% gravel content. The results from the PSD tests indicate the samples tested varied from slightly gravelly sandy clay to clayey very sandy gravel, and the variation of results reflects the wide variation of soils forming the Superficial Deposits.

5.2. FINE SOIL PARAMETERS

5.2.1. Index Property Testing

SOIL TYPE	Fine-grained Superficial Deposits
PLASTICITY INDEX (PI)	Up to 21% oversize particles present.
MODIFIED PI	10% to 26%.
NHBC CLASS	Low and medium volume change potential.

5.2.2. Undrained Shear Strength

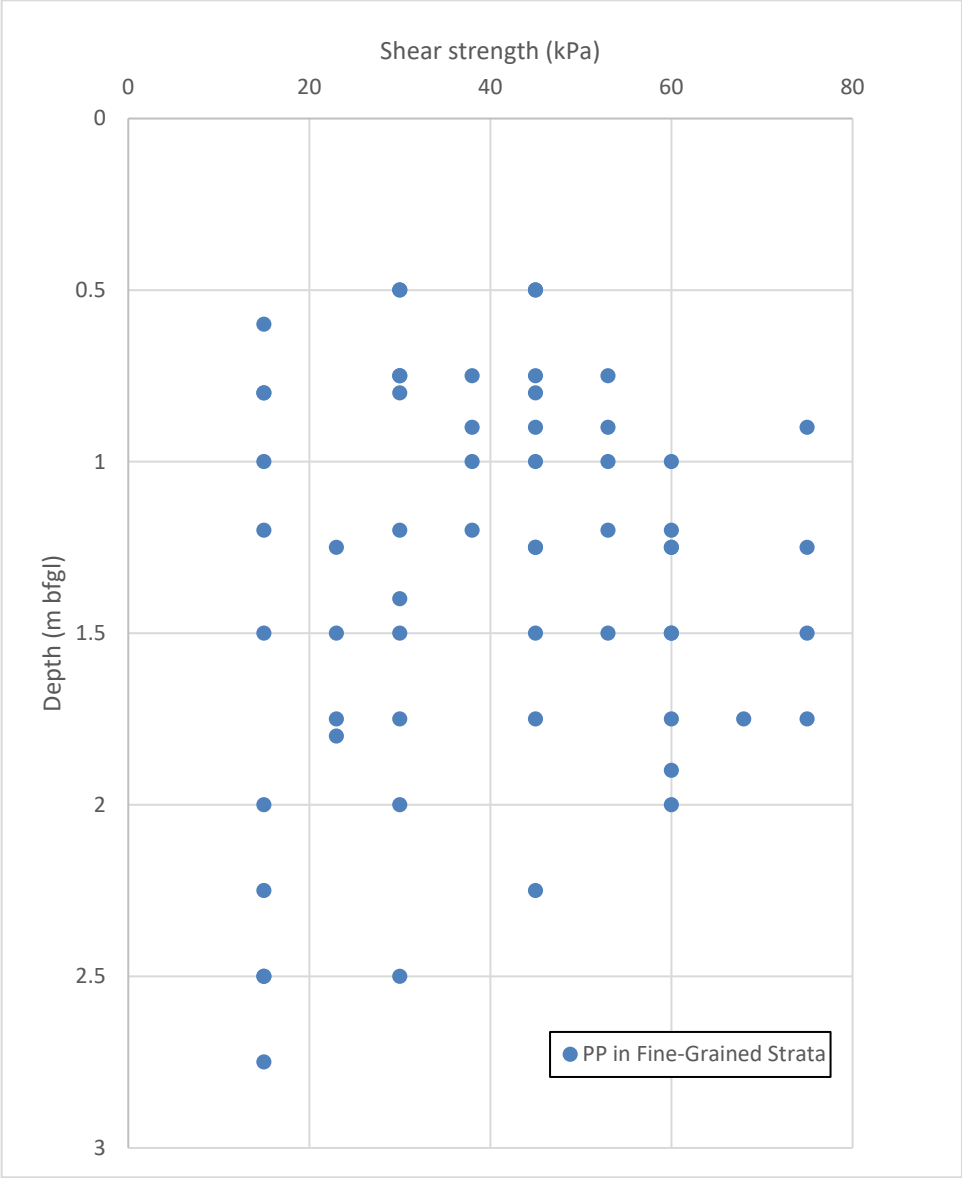
This section discusses the laboratory and in-situ tests that produce either direct or indirect measures of undrained shear strength.

5.2.2.1. Hand Shear Vane

SOIL TYPE	Fine-grained Superficial Deposits
UNCORRECTED RESULTS	35kPa to 100kPa.
CORRECTED RESULTS AND JUSTIFICATION	Using a correction factor μ=0.94, based on Bjerrum 1972, the corrected results ranged from 33kPa to 94kPa, indicating soils ranging from low strength to high strength.
DISCUSSION OF CORRECTED RESULTS	Eight tests were undertaken either in-situ or on samples from depths ranging from 0.8m to 2.0m. Most of the results indicate soils with medium strength and generally increased with depth. However, one, taken from TP09 in the central area at 0.8m depth indicated soils of low strength, and one taken from TP05 in the southeastern area at 1.3m depth indicated soils of high strength.

5.2.2.2. Hand Penetrometer

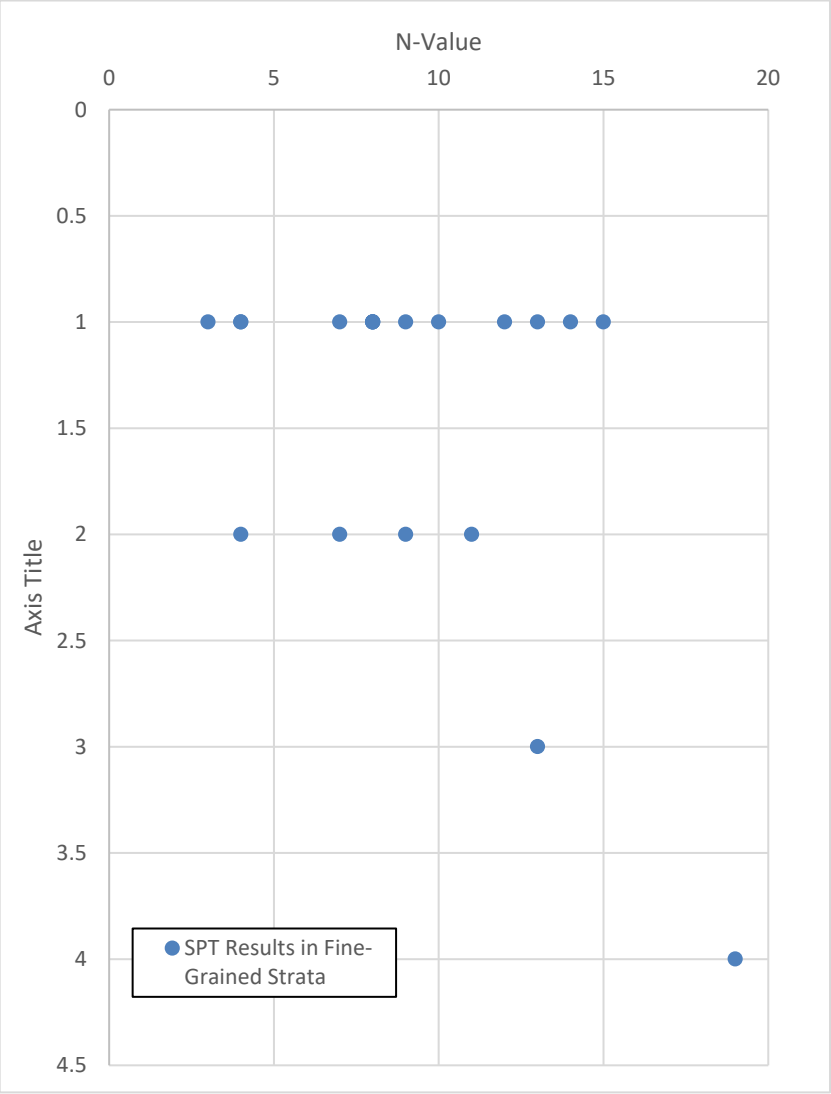
The results of the pocket penetrometer tests undertaken in the field on samples taken from the boreholes are shown on the graph below, and then discussed in the table below.



SOIL TYPE	Fine-grained Superficial Deposits
DISCUSSION OF RESULTS	The results of the tests ranged from 15kPa to 75kPa, which indicates soils of very low to high strength. The graph highlights the wide range of strength recorded and that there is no obvious increase in strength with depth.

5.2.2.3. Standard Penetration Test Correlations

The SPT N-values from the fine-grained Superficial Deposits ranged from 3 to 19 are shown on the graph below. Using a correlation factor of 5, the N-values have been converted to shear strengths ranging from 15kPa to 95kPa, which is similar to the range of results recorded in the pocket penetrometer testing. As with the hand penetrometer results there is no obvious increase in N-values with depth, and the range of results reflects the variable strength of the soils.



5.3. SULPHATE AND pH

	SUPERFICIAL DEPOSITS			
	Sulphate		pH	
Characteristic Value	500mg/l		5.6units	
Justification	Highest groundwater result.		Mean of lowest 20% of soil results.	
	No. of tests	Results Range	No. of tests	Results Range
Soil	15	<10 to 77mg/l	15	4.3 to 7.9units
Groundwater	6	98 to 530mg/l	6	7.0 to 7.3units
Total Potential Sulphate	12	Not applicable as pyrite unlikely in the samples tested.		

6. GEOTECHNICAL ASSESSMENT

6.1. INTRODUCTION

The following advice and recommendations are based on the construction of two storey houses. The Proposed Development Layout Plan is included in Appendix 1. From assessment of the nature of the ground conditions and the type of proposed structures, it is considered that the situation falls within EC7 Geotechnical Category 2.

Should the nature of the development be changed then the results of this investigation would need to be reviewed and reassessed.

6.2. EXCAVATIONS

STABILITY	Any excavation requiring man entry should be battered back to a safe angle, supported by an appropriate proprietary trench support system or adequately shored to provide safe working conditions. Shoring to any excavation requiring man entry must be designed by a suitably qualified and experienced engineer. Any support system will require regular inspection as detailed in published guidelines to ensure the excavation support is adequate and appropriate for the ground conditions present. It is anticipated that narrow trench excavations above groundwater should remain relatively stable and open for short periods. However, once groundwater is encountered then side wall instability should be anticipated. From the observations and monitoring carried out during this investigation, it is considered the local groundwater level is at approximately 1.50m depth. On encountering groundwater seepages most of the trial pits suffered excavation instability that resulted in them being terminated. On this basis, it is considered excavations should remain stable down to approximately 1.5m depth, however for deeper excavations provision for side wall support will be required. Please note, groundwater levels vary seasonally and will likely be shallower during the wetter winter months. This should be taken into consideration when planning the works. If more detail of the groundwater levels over the wetter winter months is required, then further monitoring will be required. Excavations below the water table at this site will result in excavation difficulties due to 'running sands,' therefore, should deeper excavations be required then appropriate groundwater control in the form of 'well-pointing' will be required.
EQUIPMENT	It should be possible to progress excavations with conventional equipment.

GROUNDWATER CONTROL	On the basis of the groundwater encountered during the investigation, for excavations down to approximately 1.5m depth, should minor seepages be encountered, it is considered the use of pumping from a sump should be sufficient to keep excavations dry. For deeper excavations ingress of groundwater should be anticipated and it may be fast. Therefore, provision for an appropriate groundwater control mechanism will be required. For deeper excavations, we recommend the advice of a groundwater control specialist be sought regarding a suitable means of groundwater control. It is likely that 'well-pointing' will be required. Any groundwater control system should be designed and operated to minimise the loss of fines from the soil matrix as this could adversely affect settlement. As stated above, it should be noted that groundwater levels vary seasonally and will be shallower during the wetter winter months. This should be taken into consideration when planning the works.

6.3. SUB-SURFACE CONCRETE

Classification of the Design Sulphate Class (DS) and Aggressive Chemical Environment for Concrete (ACEC) has been undertaken in accordance with the BRE SD1:2005 Concrete in Aggressive Ground. In view of the known site history, the site is considered as a natural ground location, and based on the strata encountered and presence of shallow groundwater, groundwater is considered as mobile.

ALL SITE SOILS	
SITE / SOIL CATEGORY	Natural ground.
DESIGN SULPHATE CLASS	DS-2
GROUNDWATER REGIME	Mobile.
ACEC CLASS	AC-2

6.4. SOAKAWAYS

At the time of the investigation the local groundwater level was at approximately 1.5m depth and during the wettest periods of the year it is likely to be shallower. The Environment Agency will object to the use of infiltration devices that lead to the direct input to groundwater and seek that in excess of a 1m thick unsaturated zone is present between the base of the infiltration device and the seasonal high maximum groundwater level. Due to the shallow local groundwater level this will not be possible, and it is, therefore, considered that the disposal of collected surface water to soakaways will not be feasible at this site.

6.5. PAVEMENT CONSTRUCTION

The ground conditions at the likely formation level, approximately 0.5m depth, were variably coarse and fine-grained and included some weak soils. California Bearing Ratio (CBR) testing was not carried out as part of this investigation, however based on site observations, it is recommended that, at this stage, a preliminary design CBR of less than 2% is assumed.

Consideration could be given to utilising soil reinforcement techniques, such as the use of geo grid. In addition, further targeted investigations could be carried out to allow a more detailed assessment and potentially zone the site for areas of differing CBR values.

6.6. PRELIMINARY FOUNDATION RECOMMENDATIONS

6.6.1. Introduction

The proposals are for a residential development comprising of houses and associated infrastructure.

The investigation has shown the ground conditions to generally comprise a thin layer of Topsoil onto Superficial Deposits down to the base of all the test locations, at depths down to 4.45m. The Superficial Deposits were variable in nature and strength and ranged from very low strength to high strength fine-grained soils and loose to dense coarse-grained soils.

The fine-grained soils were typically grey brown slightly gravelly slightly sandy clay and classification testing indicates these soils have low and medium volume change potential. To allow a conservative approach, a medium volume change potential classification should be adopted for design.

The coarse-grained soils were typically orange or red brown clayey sand and gravel of flint and sandstone.

The northwestern area and most of the southeastern area was underlain by either medium dense coarse-grained soils or medium strength fine-grained soils. The central area and parts of the southeastern area being underlain by more variable and weaker soils. A drawing dividing the site into zones underlain by medium dense or medium strength soils and variable weak soils at 1.0m depth, 'Zoned Ground Conditions at 1.0m Depth,' is provided in Appendix 1.

The local groundwater level is anticipated to be approximately 1.5m depth, and once groundwater is encountered side wall instability should be anticipated.

6.6.2. Floor Slabs

Much of the near surface soils are fine-grained with a volume change potential. In consideration of these soils, fully suspended floor slabs designed and constructed in accordance with NHBC Standards are recommended at this development.

6.6.3. Traditional Footings

6.6.3.1. Northwestern Area and Most of the Southeastern Area

For the parts of the site underlain by medium dense coarse-grained soils or medium strength fine-grained soils, the adoption of shallow strip footings bearing upon the Superficial Deposits at a depth of at least 0.9m should be suitable. Based on the Pegasus Group drawing, 'Testing Layout,' reference P24-1403_DE_001-01 Revision B and dated 18th July 2024, which is provided in Appendix 1, this applies to the following Plots;

Northwestern Area

- 1 to 12
- 16 to 18
- 28 to 41

Southeastern Area

- 90 to 113
- 123 to 129
- 135 to 150
- 162 to 165.

For the areas and plots referred to above a presumed bearing value of 85kN/m^2 is considered appropriate for foundations up to 1m wide. Total settlement should be within tolerable limits, of which, due to the variable nature of the ground, some will take place during the construction period with the rest following over time.

Due to the variable nature of the soils and to limit differential settlement, for any shallow traditional foundations it is recommended light reinforcement be placed in the base of the footings.

During construction, any soft spots found at foundation formation level should be excavated and replaced with lean mix concrete. Foundation excavations should be kept dry and left open for the minimum amount of time possible. Where foundations cannot be completed immediately, a blinding layer of concrete should be placed.

Please note, the fine-grained Superficial Deposits have been shown to have a medium volume change potential and for the plots within the influence of existing or planned trees this will need to be accounted for by deepening the foundations. Trees were noted around the southern and eastern boundaries and along the internal ditch, therefore, it is the plots neighbouring these areas that are most likely to be affected. A tree survey will be required to allow determination of the specific plots affected.

Due to the shallow local groundwater and likelihood of side wall instability once the groundwater has been encountered, it will not be practical to deepen foundations, consequently, the tree influence affected plots will require piling.

6.6.3.2. Central Area and Some of the Southeastern Area

For the parts of the site underlain by variable and weak soils, due to the depth of the variable and weak ground extending below the local groundwater level, it will not be practical to form shallow strip footings, and piled foundations will be required.

6.6.4. Piling

For the areas of the site underlain by variable and weak soils and the plots within the zone of influence of trees a piled foundation solution is recommended. Piles should be taken down through the Superficial Deposits and into the underlying bedrock, which although unproven in this investigation is expected to comprise Oxford Clay Formation. Consideration for shallow groundwater should be made.

In addition, the existing trees around the site's boundaries and along the internal ditch may cause soil heave. In the influence zone of trees, pile caps and ground beams will have to be separated from the soil by a suitable void former on the sides and in the case of ground beams, underneath. Piles will have to be designed to withstand the seasonal movements exerted by the remaining and proposed vegetation either by the use of suitable reinforcement or by the provision of sleeving through the swelling zone. Such precautions against heave should be designed and constructed in accordance with NHBC Standards.

To allow pile design, further investigations involving deeper boreholes in-situ testing, sampling and geotechnical laboratory testing will be required and it is recommended the advice of a piling specialist is sought early on in this process.

6.7. RECOMMENDATIONS FOR FURTHER GEOTECHNICAL WORK

To provide information for pile design, deep cable percussive boreholes will be required, with associated in-situ testing, sampling and geotechnical laboratory testing. Consideration could be given to undertaking some deep Cone Penetration Tests (CPT) to compliment the boreholes.

A tree survey will be required for detailed foundation design. This survey with topographic survey data should be undertaken prior to any site clearance and removal of any trees. The survey should record the trunk location, height and species of the trees.

To allow a more detailed assessment of the groundwater levels during the wetter months, longer term monitoring through the winter months could be considered.

To allow a more detailed CBR assessment, targeted investigations with further testing could be considered.

7. RISK ESTIMATION – SOILS

7.1. HUMAN HEALTH

The Generic Assessment Criteria (GAC) employed below are for residential with plant uptake land use as this is the proposed form of development.

CONTAMINANT	UNITS	NUMBER OF TESTS	MAXIMUM CONCENTRATION	GAC	NUMBER EXCEEDING GAC
Arsenic	mg/kg	12	24	37	0
Cadmium	mg/kg	12	0.4	22	0
Chromium (total)	mg/kg	12	29	910	0
Chromium (hexavalent)	mg/kg	12	<2	21	0
Copper	mg/kg	12	26	2,400	0
Lead	mg/kg	12	46	200	0
Mercury	mg/kg	12	<1	11	0
Nickel	mg/kg	12	30	180	0
Selenium	mg/kg	12	<2	250	0
Zinc	mg/kg	12	78	3,700	0
pH	Units	21	4.3 to 7.9	<5-10>	0
Naphthalene	mg/kg	12	<0.1	2.3	0
Acenaphthylene	mg/kg	12	<0.1	170	0
Acenaphthene	mg/kg	12	<0.1	210	0
Fluorene	mg/kg	12	<0.1	170	0
Phenanthrene	mg/kg	12	0.13	95	0
Anthracene	mg/kg	12	<0.1	2,400	0
Fluoranthene	mg/kg	12	0.29	280	0
Pyrene	mg/kg	12	0.25	620	0
Benzo(a)anthracene	mg/kg	12	<0.1	7.2	0
Chrysene	mg/kg	12	0.15	15	0
Benzo(b)fluoranthene	mg/kg	12	0.15	2.6	0
Benzo(k)fluoranthene	mg/kg	12	<0.1	77	0
Benzo(a)pyrene	mg/kg	12	<0.1	2.2	0
Indeno(1,2,3-cd)pyrene	mg/kg	12	<0.1	27	0
Dibenzo(a,h)anthracene	mg/kg	12	<0.1	0.24	0
Benzo(ghi)perylene	mg/kg	12	<0.1	320	0
TPH Aliphatic C5-C6	mg/kg	6	<0.01	42	0
TPH Aliphatic C6-C8	mg/kg	6	<0.05	100	0
TPH Aliphatic C8-C10	mg/kg	6	<2	27	0
TPH Aliphatic C10-C12	mg/kg	6	<2	130	0
TPH Aliphatic C12-C16	mg/kg	6	<3	1,100	0
TPH Aliphatic C16-C35	mg/kg	6	<10	65,000	0
TPH Aliphatic C35-C44	mg/kg	6	<10	65,000	0

CONTAMINANT	UNITS	NUMBER OF TESTS	MAXIMUM CONCENTRATION	GAC	NUMBER EXCEEDING GAC
TPH Aromatic C5-C7	mg/kg	6	<0.01	70	0
TPH Aromatic C7-C8	mg/kg	6	<0.05	130	0
TPH Aromatic C8-C10	mg/kg	6	<2	34	0
TPH Aromatic C10-C12	mg/kg	6	<2	74	0
TPH Aromatic C12-C16	mg/kg	6	<2	140	0
TPH Aromatic C16-C21	mg/kg	6	<3	260	0
TPH Aromatic C21-C35	mg/kg	6	<10	1,100	0
TPH Aromatic C35-C44	mg/kg	6	<10	1,100	0
Benzene	mg/kg	6	<0.002	0.87	0
Toluene	mg/kg	6	<0.005	130	0
Ethylbenzene	mg/kg	6	<0.002	47	0
Xylene (total of all types)	mg/kg	6	<0.002	56	0
Methyl Tert Butyl Ether (MTBE)	mg/kg	6	<0.005	49	0
Semi-Volatile Organic Compounds (SVOCs)	mg/kg	3	<LOD	LOD*	0
Organochlorine Pesticides	mg/kg	6	<LOD	LOD*	0
Polychlorinated Biphenyls (PCBs)	mg/kg	1	<LOD	LOD*	0
Asbestos Quantification	%	2	<0.001	0.001	0

Notes: *Limit of detection (LOD): Given the large amount of compounds in this group, coupled with the lack of GAC for certain compounds, any concentrations above the limit of detection will be highlighted in the first instance. Please refer to the LQM / CIEH or the EIC / AGS / CLAIRE documents for additional assessment criteria if required.

DISCUSSION OF RESULTS	
None of the samples record any contaminants at concentrations exceeding their respective assessment criteria.	
METALS	None of the metal compounds are elevated above the human health assessment criteria.
PAH	None of the PAH compounds are elevated above the human health assessment criteria.
TPH	None of the TPH compounds are elevated above the human health assessment criteria.
BTEX & MTBE	None of the BTEX or MTBE compounds are elevated above the human health assessment criteria.
SVOC	None of the SVOC compounds were above the LOD.
ASBESTOS	Asbestos has not been detected in any of the samples analysed or visually identified in any of the soils at the site.
PESTICIDES	None of the pesticide compounds were above the LOD.

DISCUSSION OF RESULTS	
PCB	None of the PCB compounds were above the LOD.

No obvious evidence of contamination was noted during the investigation and none of the samples tested recorded any elevated concentrations of potential contaminants.

7.2. WATER ENVIRONMENT

It is not appropriate to consider assessment criteria for human health in relation to the risk to the water environment, however currently there are no generic soil assessment criteria in respect of the water environment. In the absence of any groundwater testing, the soil results are assessed on the basis of professional judgement.

The site is not above a Principal Aquifer and the nearest surface watercourse is approximately 1.2km west. In addition, the site is not within a Source Protection Zone and there are no surface water or groundwater abstraction licenses within 250m. Therefore, the controlled waters receptors for the site is not considered to be highly sensitive.

The contaminant concentrations recorded in the soils at the site are not considered to be at such levels that they would present a cause for concern to the underlying water environment.

7.3. BUILDING MATERIALS

CONTAMINANT	UNITS	NUMBER OF TESTS	MAXIMUM CONCENTRATION	GAC	NUMBER EXCEEDING GAC
pH	units	21	4.3 to 7.9	<5.5	1
Sulphate (w/s)	mg/l	21	530	500	1
Sum of SVOC + Aliphatic TPH >C5-C10 + Aromatic TPH >C5-C10 above detection limits	mg/kg	6	<LOD	2	0
Sum of Aliphatic TPH >C10-C21 + Aromatic TPH >C10-C21 above detection limits	mg/kg	6	<LOD	10	0
Sum of Aliphatic TPH >C21-C34 + Aromatic TPH >C10-C35 above detection limits	mg/kg	6	<LOD	500	0
Sum of BTEX + MTBE above detection limits	mg/kg	6	<LOD	0.1	0
Phenols	mg/kg	3	<LOD	2	0
Cresols and chlorinated phenols	mg/kg	3	<LOD	2	0
Naphthalene	mg/kg	12	<0.1	0.5	0
Benzo(a)pyrene	mg/kg	12	<0.1	0.5	0

RESULTS EXCEEDING BUILDING MATERIALS ASSESSMENT CRITERIA	
WATER SOLUBLE SULPHATE	Concentrations of water-soluble sulphate are such that they could detrimentally impact sub-surface concrete. The impact on concrete mix design is a geotechnical issue that is considered separately, and so no further comment is made on these results within this contamination assessment.
pH	The acidic pH values recorded are such that they could detrimentally impact sub-surface concrete. The impact on concrete mix design is a geotechnical issue that is considered separately, and so no further comment is made on these results within this contamination assessment.

8. RISK EVALUATION

8.1. REVISED CONCEPTUAL MODEL

Following completion of the Phase 2 Investigation, the Conceptual Site Model has been revised as follows.

ADDITIONAL POLLUTANT LINKAGES	During the ground investigation, no additional sources of contamination were identified.
INVALID CONTAMINANT LINKAGES	The Initial Conceptual Model presented in the Desk Study identified the historical use of PAHs, metals and pesticides as a potential on-site source of contamination and migration of contaminants from the nearby electricity sub-station and garage workshop to the east as potential off-site sources of contamination. No elevated concentrations of contaminants were recorded in the testing. This includes pesticides across the site, PCBs and hydrocarbons from close to the electricity sub-station and hydrocarbons, BTEX, MTBE and semi-volatile hydrocarbons from test locations relatively close to the garage workshop. No potential sources of carbon dioxide or methane ground gases were identified as part of the desk study and therefore no pollutant linkage for ground gases were included as part of the Initial Conceptual Model. No evidence to contradict this finding was revealed as part of the intrusive investigation, and therefore it is concluded that carbon dioxide and methane ground gases are not a cause for concern at the site. On the basis of the above, it is considered each of the potential pollutant linkages has been shown to be invalid.
LIMITATIONS AND UNCERTAINTIES	It is considered that there are no significant limitations or uncertainties in the contamination assessment for the site.

8.2. UPDATED CONTAMINATION RISK ASSESSMENT

The contamination linkages identified in the revised conceptual site model will now be evaluated as to their severity.

SOURCES AND CONTAMINANTS	PATHWAYS (REFERENCE FROM MODEL)	RECEPTORS	POTENTIAL RISK
On site use of PAHs, metals and pesticides	Inhalation Ingestion Direct Contact	Future residents	Negligible
	Surface run-off and lateral migration	Drainage ditches, on-site and along the boundaries.	Negligible
	Lateral and vertical migration into Aquifer	Groundwater	Negligible

SOURCES AND CONTAMINANTS	PATHWAYS (REFERENCE FROM MODEL)	RECEPTORS	POTENTIAL RISK
	Direct contact	Building Materials and Services	Negligible
Off-site sources. Sub-station - Petroleum hydrocarbons and PCBs. Car and Garage Workshops. Petroleum hydrocarbons, Solvents, and Metals.	Inhalation Ingestion Direct Contact	Future residents	Negligible
	Surface run-off and lateral migration	Drainage ditches, on-site and along the boundaries.	Negligible
	Lateral and vertical migration into Aquifer	Groundwater	Negligible
	Direct contact	Building Materials and Services	Negligible

The contamination risks that are presented to the various receptor groups are discussed further in the following sections:

SOIL RISKS TO HUMAN HEALTH
No soil risks to human health have been identified at the site.

GROUND GAS RISKS
No risks from ground gases have been identified at the site.

RISK TO WATER ENVIRONMENT
No risks to the water environment have been identified at the site.

RISK TO BUILDING MATERIALS AND SERVICES
No risks to building materials and services have been identified at the site.

8.3. RISK MANAGEMENT

8.3.1. Introduction

Following the contamination risk assessment, no significant risks for human health, controlled waters or water supply pipes have been identified.

It is recommended that this report is submitted to the planning department of the Local Authority, the organisation undertaking the Building Control function and warranty providers to confirm that the investigation completed to date is satisfactory.

8.3.2. Further Contamination Assessment

It is considered that no further ground investigation is required for contamination assessment purposes.

8.3.3. Outline Remediation Strategy

Due to the absence of contamination risks, no remediation is considered necessary.

8.4. SOIL RE-USE AND WASTE SOIL DISPOSAL

Topsoil should be viewed as a resource rather than a waste. As the topsoil is suitable for residential garden use in terms contamination, the topsoil at the site should be stripped and any surplus reused on other developments. It should be noted that topsoil, even if uncontaminated, is unlikely to constitute 'inert waste' due to its high organic matter content.

It is considered that most of the Superficial Deposits disposed of from the site will be classified as 'non-hazardous waste' and characterised for disposal to landfill as 'inert waste.' However, some organic materials were noted in the Superficial Deposits from the central area of the site, although generally at depths of approximately 2.0m or deeper. Should significant volumes of these be encountered and require disposal off-site, then it is possible they will be classified as 'non-hazardous.'

The chemical results should be forwarded to the proposed landfill site and the waste classification confirmed prior to disposing of any surplus soils. Waste Acceptance Criteria (WAC) testing of the soils will also be required where the soil is to be disposed of at a landfill. Such WAC testing has been completed on one sample of the Superficial Deposits and the results are in the Appendices, which confirm the soil tested complies with the inert waste limits. The waste code from the European Waste Catalogue (EWC) 2002 for the soils would be 17 05 04 'Soil and Stones, not containing dangerous substances.'

9. HEALTH AND SAFETY FILE INFORMATION

9.1. INTRODUCTION

The aim of the following sections is to present pertinent Health and Safety information that has arisen from the current investigation/survey works discussed in this report. The aim is to identify health and safety controls that may be necessary during any subsequent maintenance, refurbishment, demolition or construction works. The information is not exhaustive and stems only from the aspects identified within the scope of the works undertaken by BRD.

Where BRD has been appointed as a Principal Contractor, then this information shall form the Health and Safety Files as required by the Construction Design and Management (CDM) Regulations 2015.

Reports are always forwarded to the Client and they shall be responsible for ensuring this safety information is disseminated to those who need it.

The works undertaken by BRD are detailed in the previous sections of this report.

9.2. HAZARDS

During the course of the BRD works the following noteworthy safety hazards have been identified:

9.2.1. Contamination

Although no contamination has been identified, as with any construction site, if any anomalous material is encountered during the redevelopment, then expert environmental advice should be sought.

9.2.2. Asbestos

No asbestos containing materials were observed in the soil or on the surface and no asbestos fibres were detected in the soils tested.

9.2.3. Other Issues

During the BRD works the following safety hazard was identified:

- Some of the drainage ditches along the site's boundaries have standing water in them, which presents a danger of drowning.

9.3. EXISTING STRUCTURES

There were no existing buildings on the site.

9.4. HAZARDOUS MATERIALS

BRD did not construct anything with hazardous materials.

Should any soils be imported to the site, in particular Topsoil, they should be tested to confirm their suitability in the development.

9.5. UTILITY SERVICES

There are existing overhead electric cables across the site and some underground services close to the western boundary. No previously unidentified utility services were encountered during the BRD works.

The utility services plans held by the Client should be referred to.

REPORT SPECIFIC REFERENCES

- 'Phase 1 Geo-Environmental Desk Study – Cloot Drove, Crowland', BRD Environmental Ltd, report ref. BRD4519-OR1-A, dated December 2024.

SUPPORTING INFORMATION

GROUND INVESTIGATION

Exploratory holes are logged by an experienced Geo-Environmental Consultant in general accordance with 'Code of practice for site investigations' BS5930:2015+A1:2020, British Standards Institution, 2020. Soil samples for chemical and geotechnical analysis are taken from the exploratory holes at intervals dictated by the nature of the soils and the objectives of the investigation.

Where stated on the logs of inspection pits, trial pits or boreholes (where insitu testing has not been undertaken), the relative density of coarse (sand and gravel) soils is tentative only. Such assessments of density are on the basis of visual inspection only taking into consideration such factors as drilling rates, stability of pit side walls, appearance and behaviour under excavation.

Where Chalk strata is encountered it is logged and graded in general accordance with CIRIA guidance 'C574 - Engineering in Chalk'. It should be recognised that where percussive drilling methods are employed, the structure of the Chalk is destroyed and therefore the grading stated on such logs is either tentative or absent where it is not possible to assess the grade.

Hand Dug Inspection Pits

Hand tools are used to forward shallow inspection pits as a cost effective method of describing and sampling near surface soils. The technique is also used where exposure of existing footings is required. The depth reached by such techniques is a function of the nature of the ground and generally does not exceed 1.5m

Trial Pits

Mechanically excavated trial pits allow detailed inspection of near surface ground due to the large volume of soil exposed. A wheeled backhoe loader is the usual machine for digging trial pits that are typically 3 to 4.5m deep, 0.5m wide and 3m long.

Windowless Sampling Boreholes

This type of borehole is formed by a small tracked dynamic percussion drilling rig with samples retrieved in thin plastic liners within the narrow diameter steel sampling tubes. Borehole depths of up to 5m are typical, but in exceptional circumstances up to 15m depth can be achieved. This is the smallest type of rig that is capable of undertaking Standard Penetration Tests (SPTs).

Hand Held Window Sampling

Hand held window sampling is a useful method of drilling narrow diameter boreholes particularly where access is difficult. Hand held mechanical percussive hammers are used to drive the sampling tube into the ground. The soil samples are collected within the hollow metal sampling tubes and inspected via the open window along one side. Window sampling boreholes can be forwarded to depths of 3m to 6m depending upon ground conditions.

Cable Percussive Boreholes

This form of drilling involves repetitive dropping of a tube into the soil under its own weight from a tripod support. The sample is obtained from the clay cutter head in fine soils or a bailer for wet granular soils. As the borehole progresses SPTs can be undertaken and relatively undisturbed samples can be obtained. Typically these boreholes are 15 to 25m deep, but depths of double that can be achieved in soils, but only thin weak rock layers can be penetrated.

Rotary Boreholes

Where competent rock is required to be drilled then rotary drilling techniques are required. The drilling rigs can vary in size from small tracked units to larger units mounted on four wheel drive trucks. Rotary open hole drilling techniques break the rock into small fragments and so recovery of any samples is limited. In contrast, rotary coring retrieves excellent samples. Some rigs also allow windowless sampling to be undertaken through soil layers. There are no practical limits to the depths that this drilling method can achieve.

Dynamic Probing

Dynamic probing comprises a sectional rod with a sacrificial cone at the base of slightly larger diameter than the rod. The rod is driven into the ground by a constant mass falling through a set distance. The number of blows required to forward the rod per 100mm is then recorded and presented in a graph of N_{10} values. The standard applicable to dynamic probing is "BS EN ISO 22476-2:2005 Incorporating corrigendum no. 1, Geotechnical investigation and testing — Field testing — Part 2: Dynamic probing" BSi, February 2007.

Static Cone Penetration Tests

Cone Penetration Tests (CPT) consist of pushing a conical 60° cone into the ground at a constant rate and recording the force required to do this. Sensors in the cone record other information and this data can be correlated to a number of different geotechnical parameters.

Dynamic Penetrometer

The Transport Research Laboratory Dynamic Cone Penetrometer (TRL DCP) uses an 8 kg hammer dropping through a height of 575mm to drive a 60° cone of 20mm maximum diameter into the ground. The depth driven either per blow or per several blows is recorded. The strength of each of the soil layer encountered is then calculated by converting the penetration rate (mm per blow) into an approximate California Bearing Ratio (CBR) value employing the correlation proposed by TRL.

Gas Monitoring

Gas monitoring is undertaken with a portable gas monitor for oxygen, Methane, Carbon Dioxide, Hydrogen Sulphide and Carbon Monoxide together with recording of atmospheric pressure and any flow rate.

Vapour Monitoring

Headspace tests and monitoring for Volatile Organic Compounds (VOC) or Semi Volatile Organic Compounds (SVOC) is undertaken using a Photo Ionisation Detector (PID). The MiniRAE models used have a 10.6 eV lamp calibrated for isobutylene. The PID is useful tool to indicate the presence of a wide range of volatile compounds, but only provides semi-quantitative data as different compounds provide a different response and thus the reading is not a true reflection of the actual concentration present.

Low PID readings can be recorded in natural uncontaminated organic soils or even as a result of atmospheric pollution. It is generally accepted by consultants and regulators that recorded values in excess 50 parts per million (ppm) represents the presence of organic compound pollutants and in excess of 100 ppm such contamination may be significant.

The headspace test procedure involves the collection of a sample of suspected contaminated soils and placing within a sample bag. A tight seal to the bag is formed with a similar volume of air trapped to that of the soil and the sample is left for fifteen minutes to allow volatilisation of any contaminants. The bag is then pierced by, and sealed around, the sample probe of the PID and a reading taken.

Borehole well monitoring is undertaken by connecting the PID directly to the gas tap on the monitoring well installation.

Groundwater Level Monitoring

Groundwater levels are recorded with an electronic dip meter that has a detector end that is lowered into the borehole well. An audible signal is made when water is reached and the depth recorded from the graduated tape used to lower the detector. Where there is potential for a separate Light Non Aqueous Phase Liquid (LNAPL) to be present floating on the groundwater an oil/water interface meter is used in preference to a conventional dip meter so that any such floating product can be detected.

Geotechnical Sampling

BRD schedule a range of geotechnical testing as appropriate to the identified ground conditions, available budget and the proposed development. Different types of soil samples are obtained as appropriate to the ground conditions and planned testing.

SAMPLE TYPE	***SYMBOL USED ON LOGS***	***DESCRIPTION***
Disturbed	*D*	*Small disturbed soil samples of about 1 to 2 kg are collected in plastic bags.*
Bulk	*B*	*Large disturbed bulk samples up to about 20 to 30 kg are collected in plastic bags*
Undisturbed	*U*	*'Undisturbed' samples generally collected in plastic or metal tubes within cable percussive boreholes of 100mm diameter for samples of fine soils of firm to stiff consistency. Can also be representative of samples taken by cutting plastic sample liners from windowless sampling drilling methods. It is recognised that such samples do not generally meet Eurocode sample quality requirements for the tests commonly employed. However, given the wealth of experience with these sampling methods this continues to be common in United Kingdom practice particularly for less sensitive developments where more expensive sampling techniques are not economically justifiable.*
Undisturbed	*UT*	*A thin walled steel sampler developed by Archway Engineering called a UT100 in an attempt to gain better quality samples of soft to firm fine soils when using cable percussive drilling methods.*

Contamination Sampling

BRD schedule contamination testing as appropriate to the ground conditions, available budget, potential contaminants and the proposed development. Samples are collected in single use laboratory supplied containers.

Soil samples are retrieved in plastic containers and/or amber glass jars with a lined plastic cap. Contamination samples are indicated by a 'J' on exploratory hole logs.

Water samples are collected in plastic bottles and/or amber glass jars with a lined plastic cap then placed in cool boxes together with freezer packs. Water samples are indicated by a 'W' on exploratory hole records, but generally such samples are not tested as testing from dedicated monitoring wells is preferred for sample quality reasons.

Samples retrieved from the exploratory holes are dispatched to the laboratory by overnight courier. Where samples cannot be transported directly from site they are temporarily stored in the BRD dedicated sample storage facility which includes refrigeration where necessary. The individual accreditation of the test methods is detailed in the laboratory test report.

GEOTECHNICAL ASSESSMENT

Under Eurocode 7 (EC7) the following risk ranking is applied to geotechnical projects:

GEOTECHNICAL CATEGORY	***DESCRIPTION***
1	*Small and relatively simple structures for which it is possible to ensure that the fundamental requirements will be satisfied on the basis of experience and qualitative geotechnical investigations with negligible risk. For example, straightforward ground conditions, local experience, no excavation below the water table unless this will be straight forward.*
2	*Conventional types of structures and foundations. No difficult soil or loading conditions. Quantitative geotechnical data and laboratory testing. Routine procedures for field and laboratory testing. Conventional structures and no exceptional geotechnical risk. For example, spread, raft and piled foundations, retaining walls, bridge piers and abutments, embankments, ground anchors, tunnels and excavations.*
3	*Those structures not in Categories 1 and 2 such as very large or unusual structures, structures involving abnormal risks, or unusual or exceptionally difficult ground or loading conditions. Structures in highly seismic areas. Structures in areas of probable site instability or persistent ground movements that require separate investigation or special measures.*

GEOTECHNICAL PARAMETERS

Soakage Tests

Soakage tests comprise the filling of a test pit with water and recording the time taken for the water to drain away. The tests are undertaken in general accordance with 'Digest DG 365: Soakaway design' BRE, Revised 2016. The test pits are usually gravel filled for safety with a slotted vertical pipe through which water observations are made. Water is generally supplied by a tanker to allow fast filling of the pits with water. Compliant tests are filled and allowed to drain near empty three times.

Standard Penetration Tests

The standard penetration test (SPT) determines the resistance of soils at the base of a borehole to the dynamic penetration of a split barrel sampler and the recovering of disturbed samples for identification purposes. In gravelly soils and some soft rocks a solid cone is used in preference to the sampler.

The basis of the test consists in driving a sampler by dropping a hammer of 63.5 kg mass on from a height of 760 mm. The number of blows (N value) necessary to achieve a penetration of the sampler of 300 mm is recorded. The test is described in 'Geotechnical investigation and testing — Field testing — Part 3: Standard penetration test - BS EN ISO 22476-3:2005 Incorporating corrigendum no. 1', BSi, 2007.

The uncorrected N values of the SPT tests are recorded upon the borehole logs together with a record of blows for each 75mm test portion including the seating blows. Where the full test depth cannot be achieved due to refusal on hard stratum, the number of blows and the distance achieved is recorded and the N value given as >50. The abbreviation SPT(c) is used upon the logs indicates that the test was performed with a solid cone rather than a split spoon sampler.

It is necessary to apply a correction to the N values to account for the effects of energy delivery using the equation: $N_{60} = \frac{E_r}{60} N$ *where* E_r *is the energy ratio of the specific test equipment.*

In the case of tests in sand, for the effects of overburden and rod length the equation is modified to $N_{60} = \frac{E_r}{60} \; x \; \lambda \; x \; C_N \; x \; N$ *where* λ *is the correction factor for energy losses due to the rod length and* C_N *is the correction factor for vertical stress due to overburden of the soil.*

Sulphate

In order to compare the laboratory soil test results with 'Concrete in aggressive ground. BRE Special Digest 1: 2005' (BRE, 2005) laboratory results are converted to SO_4 *mg/l. Laboratory results expressed as* SO_3 *g/l and are multiplied by a factor of 1200 to express the results as* SO_4 *mg/l.*

Index Property Tests

In accordance with National House Building Council (NHBC) Standards Chapter 4.2 – Building near trees, the laboratory plasticity indexes are assessed against their volume change potential. The Modified Plasticity Index is defined as the Plasticity Index of the soil multiplied by the percentage of particles with a nominal diameter of less than 425µm. Whilst the NHBC Standards were developed for residential buildings, the advice is equally applicable to a large number of other types of low rise structures.

Hand Shear Vane

The undrained shear strength of the fine (i.e. clay) soils at the site can be established using hand shear vane apparatus. Usually three readings are taken at every depth tested and the uncorrected results recorded on the exploratory point log. Shear vane readings from depths below 1.2m depth in trial pits are from tests performed on excavated soil. In accordance with Eurocode 7 — Geotechnical design — Part 2: Ground investigation and testing EN 1997-2:2007 the results should be corrected. BRD employ only simple correction methods as the more complex correction methodologies imply undue accuracy to a test that has distinct disadvantages and limitations.

Pocket Penetrometers

The Pocket Penetrometer is a lightweight instrument for use by field personnel to check visual classification of soils. It is a simple test and there is inherent uncertainty related to the small volume of soil being tested and so the results should be used with appropriate caution. Pocket penetrometers are calibrated in terms of unconfined compressive strength and once converted to undrained shear strength (divide by two) the results are further reduced by a factor of 1.5 - 2.0 as the device tends to overestimate strengths.

Instrument Reading (uncompressive strength in kg/cm²)	*Indicative Undrained Shear Strength (kN/m²)*	*Indicative Consistency*	*Indicative strength*
1.0	*25 – 33*	*Soft*	*Low*
1.5	*38 – 50*	*Soft to firm*	*Low to medium*
2.0	*50 - 67*	*Firm*	*Medium*
2.5	*63 – 83*	*Firm to stiff*	*Medium to high*
3.5	*88 – 116*	*Stiff*	*High*
4.5	*113 – 150*	*Stiff to very stiff*	*High to very high*

CONTAMINATION ASSESSMENT METHODOLOGY

UK Policy

The UK Government's policy in relation to land affected by historic contamination is based on a 'suitable for use' approach. The approach recognises that the risks presented by any given level of contamination will vary greatly according to the use of the land and a wide range of other factors, such as the underlying geology of the site. Contamination risks therefore need to be assessed on a site-by-site basis. The 'suitable for use' approach limits requirements for remediation to the work necessary to prevent unacceptable risks to human health or the environment in relation to either the current use or future use of the land.

The three main drivers for contamination assessment and remediation are:

- *Voluntary action.*
- *Development as part of the planning regime.*
- *Regulatory action to mitigate unacceptable risks e.g. Part 2A of the Environmental Protection Act 1990.*

Contaminant linkages

For a contamination risk to exist there must be a 'contaminant linkage' from the contaminant (source) via a pathway (the route from contaminant to receptor) to a receptor (the entity that could be harmed). The absence of a contaminant, pathway or receptor breaks the contaminant linkage and therefore no contamination risk exists.

Contamination is typically present at a site (in the ground and/or in the underlying groundwater) as a result of a historic or current industrial use, usually as a result of leaks, spills or disposal of residues, wastes and excess raw materials from the industrial processes. Contamination may also be present due to:

- *The deliberate application of chemicals e.g. the spraying of herbicide/pesticide.*
- *Migration of pollutants from adjacent land.*
- *Naturally occurring processes e.g. elevated concentrations of particular heavy metals associated with specific geological strata.*

Conceptual Site Model

The conceptual site model can be defined as a textual or graphical representation of the identified contaminant linkages for a given site. The model forms the basis for designing the investigation as the aim will be to target all of the potential contaminant linkages to determine, through the subsequent phases of risk assessment, whether or not they pose an actual risk.

It is important that the conceptual site model is updated with new information as the various investigation, risk assessment and remediation works are completed.

Technical Guidance

The technical and legal framework for contamination assessment is complex. The process adopted through this report for assessing contamination risks is in general accordance with the following guidance, as listed below:

- *'Investigation of Potentially Contaminated Sites - Code of Practice - BS 10175:2011+A2:2017', The British Standards Institution 2017.*
- *Land Contamination Risk Management, Environment Agency, 2021.*
- *'Guidance for the safe development of housing on land affected by contamination - R&D66: 2008', NHBC/Environment Agency, 2008.*

Risk Assessment Methodology

In line with the technical guidance, the contamination risk assessment follows a series of phased stages for each particular site:

PHASE	***DESCRIPTION***	***RISK ASSESSMENT STAGE***
PHASE1	*Generally limited to desk based research and a site walkover survey to develop an initial conceptual site model and identify what risks, if any, are likely to be presented by the site.*	***Hazard Identification and Assessment*** *A preliminary stage of risk assessment concerned with identifying and characterising the hazards that may be associated with a particular site and identifying potential contaminant linkages.*
PHASE 2	*This phase is concerned with establishing whether contamination is present, usually through intrusive ground investigation, and then evaluating the degree and magnitude of the associated risks.*	***Risk Estimation*** *A stage concerned with estimating the likelihood that receptors will suffer adverse effects if they come into contact with, or are otherwise affected by, a hazardous substance or agent under defined conditions.* ***Risk Evaluation*** *A stage of risk assessment concerned with evaluating the acceptability of estimated risks, taking into account the nature and scale of the risk estimates, any uncertainties associated with the assessment and the broad costs and benefits of taking action to mitigate risks.*
PHASE 3	*The appraisal and selection of remediation techniques, their implementation and verification.*	***Risk Management*** *The process whereby decisions are made to accept a known or assessed risk and/or the implementation of action to reduce the consequences or probabilities of occurrence.*

Risk Classification

The objective of risk assessment is to identify the nature and magnitude of the potential risks and should be based on a consideration of both:

- *The likelihood/probability of an event [taking into account both the presence of the hazard and receptor and the integrity of the pathway].*
- *The severity of the potential consequence [taking into account both the potential severity of the hazard and the sensitivity of the receptor].*

There is a need for a logical, transparent and repeatable system in defining the categories of severity of consequence and likelihood as well as for the risk itself and therefore the following risk rating matrix is employed:

		SEVERITY OF CONSEQUENCE			
		SEVERE	***MEDIUM***	***MILD***	***MINOR***
PROBABILITY	***HIGH LIKELIHOOD***	*Very High Risk*	*High Risk*	*Moderate Risk*	*Moderate/Low Risk*
	LIKELY	*High Risk*	*Moderate Risk*	*Moderate/Low Risk*	*Low Risk*
	LOW LIKELIHOOD	*Moderate Risk*	*Moderate/Low Risk*	*Low Risk*	*Negligible Risk*
	UNLIKELY	*Moderate/Low Risk*	*Low Risk*	*Negligible Risk*	*Negligible Risk*

These risk classifications are defined as follows:

- *Very High Risk - There is a high probability that severe harm could arise to a designated receptor from an identified hazard at the site without appropriate remediation action.*
- *High Risk - Harm is likely to arise to a designated receptor from an identified hazard at the site without appropriate remediation action.*
- *Moderate Risk - It is possible that without appropriate remediation action harm could arise to a designated receptor. It is relatively unlikely that any such harm would be severe, and if any harm were to occur it is more likely that such harm would be relatively mild.*
- *Low Risk - It is possible that harm could arise to a designated receptor from an identified hazard. It is likely that, at worst if any harm was realised any effects would be mild.*
- *Negligible Risk - The presence of an identified hazard does not give rise to the potential to cause harm to a designated receptor.*

This risk assessment matrix and classification system is based on guidance produced by Department for Environment, Food and Rural Affairs (Defra) and the Environment Agency in connection with contaminated land assessment.

RISK ESTIMATION - SOILS

Introduction to Soil Human Health Generic Assessment Criteria (GAC)

The Environment Agency (EA) and Department of Environment Food and Rural Affairs (DEFRA) had previously issued revised guidance following the consultation about the DEFRA publication "Assessing risks from land contamination – a proportionate approach. Soil Guideline Values: the Way Forward". This resulted in a revised version of the Contaminated Land Exposure Model (CLEA) model (version 1.06) and a few of the previously published Soil Guideline Values (SGVs) were revised.

The main legislative driver for dealing with historical land affected by contamination is Part 2A of the Environmental Protection Act 1990. Revised Statutory Guidance to support Part 2A was published in April 2012. This Guidance introduced a new four-category system for classifying land under Part 2A for cases of a Significant Possibility of Significant Harm to human health,1 where Category 1 includes land where the level of risk is clearly unacceptable and Category 4 includes land where the level of risk posed is acceptably low. The impact assessment for the new Statutory Guidance stated "The new statutory guidance will bring about a situation where the current SGVs/GACs are replaced with more pragmatic (but still strongly precautionary) Category 4 screening levels (C4SLs) which will provide a higher simple test for deciding that land is suitable for use and definitely not contaminated land". The C4SLs are still derived using the CLEA model, but adopt a slightly different approach to toxicological assessment and exposure modelling.

In March 2014, the outcome of "SP1010 – Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination - Final Project Report" (CL:AIRE) was published. Due to slightly ambiguous wording within this report, Lord de Mauley, Parliamentary Under Secretary, DEFRA wrote to all local authorities on 3 September 2014 to confirm that the published C4SLs were final and that they can be used in risk assessment undertaken under the planning regime.

Whilst there are proposals for the industry to develop C4SLs for other contaminants, these have only produce limited results to date. BRD do not believe that C4SLs could be developed by a single organisation with sufficient confidence. BRD has therefore employed other, more conservative guidance based on the CLEA model (detailed below) within this assessment for compounds where C4SLs are not available. However, it should be noted that the results of this investigation may need to be reinterpreted as new C4SLs become available.

Due to the limited number of published C4SL values at this time, the Chartered Institute of Environmental health (CIEH) and Land Quality Management Ltd (LQM) have produced Generic Assessment Criteria (GAC) known as Suitable for Use Levels (S4ULs), for use in contaminated land human health risk assessment. These S4ULs (2014) have been derived for a large number of substances using the current CLEA model and are therefore consistent with current guidance. They also incorporate the revised exposure parameters as adopted by the C4SL programme, but have not adopted the revised toxicological approach adopted by the C4SLs and so remain a more conservative assessment criteria. The substances for which SGVs were previously published have also been revised as new S4ULs in light of the new exposure parameters proposed by the C4SL programme, and therefore effectively replace the existing SGVs.

In addition, in December 2009, other GAC for less common substances were produced by the Environmental Industries Commission (EIC), The Association of Geotechnical and Geoenvironmental Specialists (AGS) and Contaminated Land: Applications in Real Environments (CL:AIRE) using the CLEA model. These are referred to as the EIC/AGS/CLAIRE GAC.

In summary, C4SLs have been used where these are available. For those substances where C4SLs have yet to be issued, then the S4ULs have been adopted or in some cases, the EIC/AGS/CLAIRE GAC. All of the previously produced SGVs have now either been withdrawn, or superseded by the respective C4SLs or S4ULs.

The only exception to this approach is the PAH compound benzo(a)pyrene (BaP) where a C4SL guideline value has been produced, whereas BRD has adopted the S4UL value. The C4SL for BaP relates to its use as a surrogate marker compound representing all of the genotoxic PAH compounds as a mixture, rather than this individual compound. BRD has therefore adopted the compound specific S4UL value as the initial screening value, for consistency with the other PAH compounds before then employing the C4SL is necessary.

It should be noted that unless otherwise stated, all the assessment criteria adopted within this report have been derived based on a sandy loam soil at pH 7 and the values quoted are for a conservative soil organic matter content of 1% where applicable (i.e. organic contaminants).

Human Health - Soil Generic Assessment Criteria

The results of the soils analysis have been compared to generic assessment criteria for the default exposure scenarios comprising either residential land with plant uptake, residential land without plant uptake, or commercial/industrial land use. The criteria values selected are listed in the table below and full details on the source are referred to above. Where ~~applicable~~ deemed appropriate, the results have also been assessed with reference to the required statistical tests presented within CL:AIRE Professional Guidance: "Comparing Soil Contamination Data with a Critical Concentration".

ANALYSIS	***GENERIC ASSESSMENT CRITERIA (mg/kg unless stated)***			***SOURCE***
	RESIDENTIAL WITH PLANT UPTAKE	***RESIDENTIAL WITHOUT PLANT UPTAKE***	***COMMERCIAL / INDUSTRIAL***	
Arsenic	*37*	*40*	*640*	*C4SL*
Cadmium	*22*	*150*	*410*	
Chromium (total)$	*910*	*910*	*8,600*	*S4UL*
Chromium VI	*21*	*21*	*49*	*C4SL*
Lead	*200*	*310*	*2,330*	
*Mercury**	*11*	*15*	*320*	*S4UL*
Selenium	*250*	*430*	*12,000*	
Nickel	*180*	*180*	*980*	
Copper	*2400*	*7,100*	*68,000*	
Zinc	*3,700*	*40,000*	*730,000*	
pH	*<5 – 10> units*			*Professional judgement*
Naphthalene	*2.3*	*2.3*	*190*	*S4UL*
Acenaphthylene	*170*	*2,900*	*83,000*	
Acenaphthene	*210*	*3,000*	*84,000*	
Fluorene	*170*	*2,800*	*63,000*	
Phenanthrene	*95*	*1,300*	*22,000*	
Anthracene	*2,400*	*31,000*	*520,000*	
Fluoranthene	*280*	*1,500*	*23,000*	
Pyrene	*620*	*3,700*	*54,000*	
Benzo(a)anthracene	*7.2*	*11*	*170*	
Chrysene	*15*	*30*	*350*	
Benzo(b)fluoranthene	*2.6*	*3.9*	*44*	
Benzo(k)fluoranthene	*77*	*110*	*1,200*	
Benzo(a)pyrene	*2.2*	*3.2*	*35*	
Indeno(1,2,3-cd)pyrene	*27*	*45*	*500*	
Dibenzo(a,h)anthracene	*0.24*	*0.31*	*3.5*	*S4UL*
Benzo(ghi)perylene	*320*	*360*	*3,900*	
TPH Aliphatic C5-C6	*42*	*42*	*3,200*	
TPH Aliphatic C6-C8	*100*	*100*	*7,800*	
TPH Aliphatic C8-C10	*27*	*27*	*2,000*	
TPH Aliphatic C10-C12	*130*	*130*	*9,700*	
TPH Aliphatic C12-C16	*1,100*	*1,100*	*59,000*	
TPH Aliphatic C16-C35	*65,000*	*65,000*	*1,600,000*	

ANALYSIS	GENERIC ASSESSMENT CRITERIA (mg/kg unless stated)			SOURCE
	RESIDENTIAL WITH PLANT UPTAKE	RESIDENTIAL WITHOUT PLANT UPTAKE	COMMERCIAL / INDUSTRIAL	
TPH Aliphatic C35-C44	65,000	65,000	1,600,000	
TPH Aromatic C5-C7	70	370	26,000	
TPH Aromatic C7-C8	130	860	56,000	
TPH Aromatic C8-C10	34	47	3,500	
TPH Aromatic C10-C12	74	250	16,000	
TPH Aromatic C12-C16	140	1,800	36,000	
TPH Aromatic C16-C21	260	1,900	28,000	
TPH Aromatic C21-C35	1,100	1,900	28,000	
TPH Aromatic C35-C44	1,100	1,900	28,000	
Benzene	0.87	3.3	98	C4SL
Toluene	130	880	56,000	S4UL
Ethylbenzene	47	83	5,700	
Xylene^	56	79	5,900	
MTBE	49	73	7,900	EIC/AGS/CL:AIRE GAC

Notes:
** The S4UL for methyl mercury has been adopted as the worst case mercury compound as generally there is no desk study evidence to suggest the potential for elemental mercury on the majority of sites.*
^ The lowest S4UL of either p-xylene, o-xylene or m-xylene has been adopted for each land use as a conservative measure.
$ S4UL for Chromium III adopted, as in the absence of Chromium VI it is likely that all of the chromium will be in this form as these are the two most common and stable forms of chromium in the soil environment.

Where no GAC is available, any concentrations exceeding the laboratory limit of detection are identified and discussed in more detail.

Water Environment - Soil Generic Assessment Criteria

There are no UK published Generic Assessment Criteria for soil test results in respect of the risk to the water environment and therefore risk estimation is on the basis of the professional judgement and experience of BRD to employ values that are a reasonable concentration above which concern for water resources is valid.

The Total PAH GAC employed is the sum of the 16No. priority PAH compounds regularly tested for in contaminated land analysis (i.e. US EPA 16PAHs). BRD employ a soil screening based upon the total PAH limit for 'inert waste' of 100mg/kg. The rationale is based on PAHs are recognised to be generally of low solubility and the risk to the water environment is correspondingly low.

In respect of Total Petroleum Hydrocarbons, BRD employ a value of 500 mg/kg as a screening value in comparison to the sum of the component aliphatic and aromatic TPH carbon bands. The employed soil screening value is based upon:

- *In common with some other consultants, the professional judgement and experience of BRD suggests that this value is a reasonable concentration above which concern for water resources is valid. The rationale is based on the fact that lower concentrations of fuel based contaminants are more likely to naturally degrade than migrate any great distance.*
- *BRD is aware of regional Environment Agency groundwater and contaminated land teams historically employing 500 mg/kg as a screening value for considering whether or not TPH could represent a risk to water resources.*
- *The value mirrors the mineral oil Waste Acceptance Criteria limits for what is considered 'inert waste'.*

Should elevated contaminants that pose a potential risk to the water environment be identified then site specific assessment criteria should be developed.

Building Materials and Services – Soil Generic Assessment Criteria

Some hydrocarbon compounds are known to both attack and permeate through certain plastic pipe materials, with the primary concern being the degradation and tainting of water supplies. The UK Water Industry Research (UKWIR) has therefore produced a document 'Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites' (ref. 10/WM/03/21) that specifies threshold criteria for the adoption of 'standard' polythene (PE) or PVC pipes, protective barrier pipe and ductile iron/steel/copper pipes.

The UKWIR threshold assessment criteria from Table 3.1 of this document for standard PE pipes have been employed. It should be noted that the approach taken by UKWIR is very conservative, and both the document and research are flawed. However, it is these values that are being using to specify water pipe materials and therefore it is appropriate to consider them.

The UKWIR guidance is particularly flawed in respect of the chemical analysis it expects as it seeks a limit of detection that is generally below limits that are reasonable or commonly employed in contaminated land assessment. The UKWIR seeks that where a substance is below the limit of detection it should be taken as being present at half this concentration. For the larger suite of chemicals where the limit is against a sum of compounds, this approach would mean that a sample of virgin sub-soil from a greenfield site with absolutely no contamination would actually fail the criteria for using standard PE pipes. To avoid this situation, BRD have adopted the approach of summing only those compounds detected above their respective limits of detection.

In terms of building materials, the primary concern is in respect of concrete as certain commonly occurring natural ground conditions can adversely impact on buried concrete as discussed in 'Special digest 1:2005 Concrete in aggressive ground', BRE, 2005.

ANALYSIS	***GENERIC ASSESSMENT CRITERIA***	***SOURCE***
pH	*<5.5*	*BRE Special Digest 1:2005*
Sulphate (w/s)	*500 mg/l*	*BRE Special Digest 1:2005*
Sum of any VOC above detection limits	*0.5 mg/kg*	*Relevant compounds adapted from UKWIR Table 3.1*
Sum of SVOC + Aliphatic TPH >C5-C10 + Aromatic TPH >C5-C10 above detection limits	*2 mg/kg*	
Sum of Aliphatic TPH >C10-C21 + Aromatic TPH >C10-C21 above detection limits	*10 mg/kg*	
Sum of Aliphatic TPH >C21-C34 + Aromatic TPH >C10-C35 above detection limits	*500 mg/kg*	
Sum of BTEX + MTBE above detection limits	*0.1 mg/kg*	
Phenols	*2 mg/kg*	
Cresols and chlorinated phenols	*2 mg/kg*	
Naphthalene	*0.5 mg/kg*	
Benzo(a)pyrene	*0.5 mg/kg*	

RISK ESTIMATION – GROUNDWATER

The initial assessment of the contamination risk to groundwater is by comparing dissolved groundwater concentrations with screening values (GAC) that are protective of groundwater resources.

The reference source for the target concentrations is generally the EA's Environmental Quality Standards (EQS) (accessed July 2018: http://evidence.environment-agency.gov.uk/ChemicalStandards/report.aspx?cid=17), the Water Supply (Water Quality) Regulations 2016 and the DW1/DW2 criteria from the Surface Water (Abstraction for drinking water)(classification) Regulations 1996. The target concentrations are outlined in the table below. The 'Petroleum Hydrocarbons in Groundwater: Guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies'. CL:AIRE, 2017 has also been used as reference source for the values.

ANALYSIS	***GENERIC ASSESSMENT CRITERIA (GAC)***	***SOURCE***
Arsenic	*50 µg/l*	*DW1 & EQS*
Cadmium	*5 µg/l*	*EQS*
Chromium (total)	*50 µg/l*	*DW2 & EQS*
Copper	*50 µg/l*	*DW1*
Nickel	*20 µg/l*	*EQS*
Lead	*50 µg/l*	*DW1*
Mercury	*1 µg/l*	*WSR*
Selenium	*10 µg/l*	*WSR*
Zinc	*5 mg/l*	*DW2*
Cyanide	*50 µg/l*	*WSR*
pH	*6 to 9 units*	*EQS*
Benzene	*10 µg/l*	*EQS*
Toluene	*74 µg/l*	*EQS*
Ethylbenzene	*300 µg/l*	*WHO guideline*
Xylene	*30 µg/l*	*EQS*
Methyl tert-butyl ether (MTBE)	*15 µg/l*	*Taste and odour threshold.*
Naphthalene	*2 µg/l*	*EQS*
Benzo(a)pyrene	*0.0017 µg/l*	*EQS – Less than Limit of Detection (LOD)*
Total PAH	*0.2 µg/l*	*DW1*
TPH Aliphatic C5-C6	*15,000 µg/l*	*World Health Organization (WHO) guide values for TPHCWG fractions in drinking water*
TPH Aliphatic C6-C8	*15,000 µg/l*	
TPH Aliphatic C8-C10	*300 µg/l*	
TPH Aliphatic C10-C12	*300 µg/l*	
TPH Aliphatic C12-C16	*300 µg/l*	
TPH Aromatic C5-C7	*10 µg/l*	
TPH Aromatic C7-C8	*700 µg/l*	
TPH Aromatic C8-C10	*300 µg/l*	
TPH Aromatic C10-C12	*90 µg/l*	
TPH Aromatic C12-C16	*90 µg/l*	
TPH Aromatic C16-C21	*90 µg/l*	
TPH Aromatic C21-C35	*90 µg/l*	

There are no available generic assessment criteria for some of the analytical parameters which have been scheduled, for example hexavalent chromium, and some VOC compounds. These parameters will be assessed based on professional judgement should they exceed the limit of detection.

RISK ESTIMATION - GROUND GAS

Introduction

A variety of potentially hazardous gases occur in naturally in the ground environment. Microbial decay of organic matter under anaerobic conditions and geological processes can lead to the generation of Methane and Carbon Dioxide, but can also include traces gases such as Hydrogen sulphide and Carbon monoxide.

Methane is a colourless and odourless gas that has the hazardous properties of being flammable and, at certain air/Methane mixtures, explosive. Methane has a low toxicity, but can be a simple asphyxiant due to the displacement of oxygen.

Carbon Dioxide is a colourless, odourless and non-combustible gas that has the hazardous property of being a highly toxic chemical. At concentrations of 3% by volume, shortness of breath and headaches will occur becoming acute by 6%. At levels of above 10% by volume headache, visual distortion, tremors and rapid loss of consciousness occur. Concentrations of Carbon Dioxide above 22% by volume are likely to be fatal. The effects of Carbon Dioxide poisoning are made more severe if there is accompanying reduction in oxygen concentrations.

Hydrogen sulphide is a colourless and flammable gas that has an odour of rotten eggs. It is important to that the sense of smell is over powered at higher concentrations. The gas is toxic and can be an asphyxiant.

Carbon monoxide is a colourless, odourless and explosive gas in air mixtures that has the hazardous property of being a highly toxic chemical.

Radon is a naturally occurring colourless and odourless gas that is radioactive. It is formed by the radioactive decay of radium which in turn is derived from the radioactive decay of uranium, both of which are minerals that can be found in many soil types. Whilst it is recognised that the air inside every building contains radon, some buildings built in certain defined areas of the country might have unacceptably high concentrations and require special precautions to be taken. The maps contained within BRE211:2015 'Radon: guidance on protective measures for new buildings' identify areas where no radon protection measures are necessary or where higher concentrations are present that either basic or full radon protection measures are required to be fitted to all new buildings, extensions or refurbishments.

Basis of Gas Assessment

In order to classify the level of risk and need, if any, for gas protection measures at a site with the potential for a gas problem, consideration of each of the following is necessary:

- *The source of the gas.*
- *The generation potential of the gas.*
- *The location of the source and the geological setting.*
- *Boreholes flow rate and estimated surface emission rate.*
- *The nature of the proposed development.*
- *Confidence in the knowledge of the gas regime.*

The gas assessment is made with reference to 'C665 - Assessing risks posed by hazardous ground gases to buildings', Construction Industry Research and Information Association (CIRIA), 2007 and 'BS8485:2015+A1:2019 – Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings' BSi 2019.

Gas Screening Value

The methods within CIRIA C665 and BS8485 both use the gas concentrations together with the borehole flow rates to define a characteristic situation for a site based on the limiting borehole gas volume flow for Methane and Carbon Dioxide. This limiting borehole gas volume flow is called the Gas Screening Value (GSV) and is expressed below:

Gas Screening Value (l /hr) = borehole flow rate (l/hr) x gas concentration (fraction)

The calculation of GSV is completed for both Methane and Carbon Dioxide and then the 'worse case' maximum values are used in the assessment. The assessment is to determine the gas regime at the site is dependent upon the nature of the development.

Characteristic Gas Situation

The characteristic situation for many sites is determined from evaluation of the Gas Screening Value derived against the criteria in the following table.

Characteristic situation	**Hazard potential**	**Gas Screening Value (CH4 or CO2 l/hr)**	**Additional factors**
CS1	*Very low risk*	*<0.07*	*Typically Methane ≤1% and/or Carbon Dioxide ≤5%. Otherwise consider an increase to characteristic situation 2.*
CS2	*Low risk*	*0.07 to <0.7*	*Borehole air flow rate not to exceed 70 l/hr. Otherwise consider an increase to characteristic situation 3.*
CS3	*Moderate risk*	*0.7 to <3.5*	*-*
CS4	*Moderate to high risk*	*3.5 to <15*	*Quantitative risk assessment required to evaluate the scope of protection measures.*
CS5	*High risk*	*15 to <70*	*-*
CS6	*Very high risk*	*>70*	*-*