EARTH ENVIRONMENTAL
& GEOTECHNICAL

GeoEnvironmental
Site Investigation Report

Ings Road

Liversedge

June 2021

On behalf of

Kirklees Neighbourhood Housing

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GEOENVIRONMENTAL SITE INVESTIGATION

INGS ROAD

LIVERSEDGE

Report Ref: A3914/21/SI

JUNE 2021

Prepared on Behalf of:

KIRKLEES NEIGHBOURHOOD HOUSING

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Version B.0

Date: 4th June 2021

Prepared for: Kirklees Neighbourhood Housing

Prepared by: Earth Environmental & Geotechnical Ltd
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Definition of Version Code:
D. Applied during initial drafting of the report before it has been reviewed.
C. Applied after the report has been reviewed but before it has been approved by the Project Manager.
B. Applied after the Project Manager has approved the report ready for issue to the client.
A. Applied to reports after external/internal review.

The version number starts at "0" and is raised by "1" at each re-type.

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TABLE OF CONTENTS

LIST OF FIGURES

TABLES

APPENDICES

1.0 EXECUTIVE SUMMARY

Appointment	A Site Investigation has been commissioned by Kirklees Neighbourhood Housing to examine ground conditions for eight proposed new residential bungalows with associated off-street parking and soft landscaping at a site in Liversedge, West Yorkshire.
The Investigation	The investigation comprised window sample boreholes with associated sampling and in situ testing, laboratory geotechnical and contamination testing.
The Site	The site is located in Liversedge approximately 300m to the east of Littletown. The approximate National Grid Reference for the centre of the site is SE 20664 24144 (X 420664, Y:424144:) with the closest postcode being WF15 6DB. The site is underlain by the solid geology of the Pennine Lower Coal Measures.
Site History	Historical archives show the site to have just contained of a road named Bottom Lane running north east to south west through the site. In the 1970s mapping, a building named Ings Grange is shown to be present in the western portion of the site. The building was demolished in the 2000s with the area where it was present becoming a flat grassed area surrounded by bunds. At the time of reporting, the site was a grassed plot of land that sloped towards the south west with the western portion of the site being a flat area surrounded by bunds.
Ground Conditions Encountered	The exploratory holes generally encountered Made Ground to a maximum depth of 1.50m bgl (WS03). Underlying the Made Ground at all locations were deposits of clay followed by completely weathered to very weathered mudstone and sandstone. Groundwater was encountered only in WS04 at 2.40m.
Geotechnical Assessment	Foundation options are conventional shallow strip/pad foundations at a minimum depth of 1.0m bgl. It should be noted that there are trees on and adjacent to the site which may influence the depth at which foundations should be placed. It should also be noted that weathered mudstone and sandstone was encountered at the base of every borehole. Pavement Design – preliminary design value = 1% in Made Ground. Design Sulphate Class = DS-1 ACEC Site Classification = AC-1s
Contamination Assessment	Risk from contamination to groundworkers during development – Moderate to Low Risk from contamination to future site users – Moderate to Low. Soil Waste Assessment: 5 samples tested all classified as Non-Hazardous.
This sheet is intended to provide a summary only of the report. It does not provide a definitive engineering analysis for the purposes of costing or construction and is subject to the limitation of the agreed brief.	

2.0 INTRODUCTION

2.1 Background

A site investigation has been commissioned by the Bernard Taylor Partnership on behalf of Kirklees Neighbourhood Housing to examine ground conditions for eight proposed new residential bungalows with associated off-street parking and soft landscaping at a site in Liversedge, West Yorkshire.

2.2 Previous Investigations

2.2.1 Earth Environmental & Geotechnical Ltd, Phase I GeoEnvironmental Desk Study (A3914/21), dated February 2021

Historical archives show the site to have just contained a road named Bottom Lane running north east to south west through the site. In the 1970s mapping, a building named Ings Grange is shown to be present in the western portion of the site. The building was demolished in the 2000s with the area where it was present becoming a flat grassed area surrounded by bunds. At the time of reporting, the site was a grassed plot of land that sloped towards the south west with the western portion of the site being a flat area surrounded by bunds.

Potential off-site sources of contamination were assessed to include current and historical industrial land uses surrounding the site including railway lines and industrial works.

The risk from soil contamination to residential end users was considered to be **LOW**. The risk from ground gas to end users was considered to be **LOW**. The risk of groundwater flooding was **NEGLIGABLE** with the site is not being located within an Environment Agency Zone 2 or Zone 3 floodplain.

An intrusive investigation was recommended to establish geotechnical parameters for the design of foundations, floor slabs and pavement construction. As part of the geotechnical investigation, it was recommended that samples are recovered for contamination testing and to confirm whether there are any potential risks.

2.3 Terms of Reference

Earth Environmental and Geotechnical Ltd (EEG) have been commissioned by the Client, to undertake a Site Investigation of the site in accordance with proposal A3914/20 dated 18th January 2021. The objectives of this investigation are as follows:

- *Provide factual information on the work undertaken including sampling location plan, borehole logs, geotechnical and chemical testing.*
- *Tier 1 (semi-quantitative) risk assessment will be undertaken. This will compare the concentrations of soil contaminants identified against current and appropriate published guidelines, in relation to identified receptors, e.g. existing/ future end users and site neighbours.*
- *Classification of soil for offsite disposal.*
- *Assessment of ground conditions for foundation design.*

2.4 Report Scope

This report presents full factual records of the site work carried out, the ground conditions encountered in the exploratory holes, the in situ and laboratory test results. All information collected has been used to provide an interpretation of the ground conditions, with recommendations on geotechnical design and potential ground contamination risks for the proposed development.

2.5 Limitations of the Study

The report is written in the context of an agreed scope of work and budget and should not be used in a different context. New information, improved practices or changes in legislation may require a reinterpretation of the report in whole or in part. EEG reserve the right to amend either conclusions or recommendations in light of any further information that may become available. The report is provided for the sole use by the client and is confidential to them.

Recommendations within this report are also based on exploratory records and examination of samples and, where applicable, laboratory tests. No liability can be accepted for conditions not revealed by the boreholes particularly at intervening locations. Whilst every effort is made to ensure accuracy of data supplied, all opinions expressed as to the spatial distribution of strata between sampling locations is for guidance only and no responsibility is accepted as to its accuracy.

3.0 SITE LOCATION & DESCRIPTION

The site is located in Liversedge approximately 300m to the east of Littletown. The approximate National Grid Reference for the centre of the site is SE 20664 24144 (X 420664, Y:424144:) with the closest postcode being WF15 6DB.

The site is an irregular parcel of land with access from Ings Road to the south west of the site. The maximum dimensions are 57m north east to south west and 73m north west to south east. The site occupies an area of approximately 0.32 hectares. The eastern portion of the site slopes to the south west with the western portion being flat but surround by soil bunds.

The site is set within a generally residential area. Residential dwellings are present in all directions from the site with a Job Centre also present to the south. Ings Road is present adjacent to the southern site boundary and Listing Court is present adjacent to the north.

The site location is shown in the aerial photograph presented as Figure 1, below.

Figure 1: Aerial Photograph Showing Site Location

Access to the site was gained via Ings Road to the South.

General site photographs are presented in Figure 2, overleaf.

Figure 2: General Site Photographs

View across the site, facing west

View across the site, facing south west

3.1 Proposed Development

It is understood that the Client intends to build eight residential bungalows on site with associated soft landscaping and off-street parking. An area of public open space is proposed for the land in the southern central portion of the site. Access will be provided from Ings Road to the south and Listing Court to the north.

The proposed development layout details are shown in Figure 3, below.

Figure 3: Proposed Development Plan

4.0 SITE INVESTIGATION

4.1 Exploratory Fieldwork

The fieldwork was carried out by EEG on 15th April 2021 and comprised:

- Five window sample boreholes (designated WS01 to WS06 inclusive) were each sunk to a depth of between 2.00m and 4.00m below existing ground level. The holes were originally proposed to 5.00m bgl but refusals in completely weathered to very weathered sandstone and mudstone were encountered at each location. Window sampler boring is carried out with a small, track-mounted rig, which uses a chain-driven trip hammer to drive sampling tubes or penetrometers into the ground. These tools are coupled to the anvil of the hammer by solid drill rods. Sampling tubes comprise "windowless samplers", which are plain sampler tubes in which a continuous disturbed sample is recovered within a semi-rigid plastic liner. In order to reduce friction within the borehole, sampling tubes of progressively smaller diameter are used as the borehole depth increases. Sampler diameters generally range from between approximately 90mm to 50mm. Standard Penetration Tests (SPTs) were undertaken in the boreholes in accordance with BS EN ISO 22476-3. Groundwater observations were noted where possible. These observations relate to the time of the investigation only, and do not necessarily reflect seasonal fluctuations. Exploratory hole logs are included in Appendix 1.

Exploratory hole locations were selected prior to attending site by an EEG engineer based on the proposed development layout and avoiding known services. Each exploratory location was scanned using a Cable Avoidance Tool (CAT) in order to locate unrecorded underground services, and the exploratory locations were repositioned if necessary.

All locations were surveyed by use of a Trimble GeoXH GPS instrument that has a positional accuracy of less than 50mm depending on proximity to trees, building structures and satellite coverage.

On completion, samples recovered from the site were taken to specialist laboratories for chemical and geotechnical testing.

All site investigation work was supervised full time by a representative of EEG. The logging of soils and rocks has been carried out in accordance with BS5930(2015) except where superseded by the soil and rock description methodology in BS EN14688-1(2002), BS EN 14688-2(2004) and BS EN 14689-1(2003).

An Exploratory Hole Location Plan is presented as Figure 4, overleaf.

Figure 4: Exploratory Hole Location Plan

A summary of exploratory holes undertaken during the investigation are presented in Table 1, below.

Table 1: Summary of Exploratory Holes Undertaken

Hole	Type*	Depth (m)	Date Started	Date Finished	Easting (m)	Northing (m)	Backfill Details**
WS01	WS	2.00	15/04/2021	15/04/2021	420658	424155	A
WS02	WS	2.00	15/04/2021	15/04/2021	420668	424139	A
WS03	WS	2.00	15/04/2021	15/04/2021	420689	424131	A
WS04	WS	4.00	15/04/2021	15/04/2021	420696	424149	A
WS05	WS	2.00	15/04/2021	15/04/2021	420713	424147	A
*WS = Window Sample Borehole **A=Arisings							

4.2 Laboratory Testing

4.2.1 *Geotechnical Testing*

A programme of laboratory testing was carried out on samples taken from the various strata to assist in classification and determine the engineering properties of the materials underlying the site. The tests were scheduled by EEG and carried out by Murray Rix. The test procedures used were generally in accordance with the methods described in BS1377:1990. Details of the specific tests used in each case are given in Table 2, below.

Table 2: Summary of Laboratory Geotechnical Tests Undertaken

TEST	STANDARD	No.
Moisture Content	BS1377:1990 Part 2, Clause 3.2	4
Liquid Limit, Plastic Limit, Plasticity Index	BS1377:1990 Part 2, Clause 4/5	4
Sulphate content of 2:1 soil:water extract	BS1377:1990 Part 3, Clause 5	4
pH value	BS1377:1990 Part 3, Clause 9	4

The results of the laboratory geotechnical tests are discussed in Section 6 and included in Appendix 2.

4.2.2 *Environmental Testing*

The environmental chemistry of the ground was investigated by specialist chemical analysis of selected samples, scheduled by EEG and carried out by DETS.

Chemical analyses were carried out on five soil samples and were submitted for the following suite of determinants:

Asbestos Screen, Arsenic, Barium, Beryllium, Boron, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Vanadium, Zinc, Cyanide, Phenol, Sulphate (SO_4), Sulphide, pH, Soil Organic Matter, Extractable Petroleum Hydrocarbons (EPH), Speciated Total Petroleum Hydrocarbon (TPH) and Speciated Polyaromatic Hydrocarbons (PAH).

The results of the laboratory contamination tests are discussed in Section 8 and included in Appendix 3.

5.0 GROUND CONDITIONS ENCOUNTERED

5.1 Soil Profile Encountered

BGS digital mapping has no records of superficial deposits underlying the site. The solid geology beneath the site is the Pennine Lower Coal Measures Formation, comprising mudstone, siltstone, coal seams and sandstone. The sequence of strata encountered beneath the site was as follows:

- **Made Ground** – Variable Made Ground was encountered in all the exploratory holes, comprising:
    - Sandy gravelly topsoil (containing gravel of concrete, glass, plastic, wood fragments and sandstone).
    - Clayey very gravelly sand (containing gravel of brick, concrete, plastic and sandstone).
    - Sandy gravelly clay (containing gravel of concrete, brick, limestone and sandstone).
    - Cobbles of concrete, brick and limestone.
- **Superficial Deposits** – Clay was encountered in all the exploratory holes, comprising:
    - Silty sandy clay
    - Silty sandy gravelly clay (containing gravel of sandstone and mudstone).
    - Sandy slightly gravelly organic clay
- **Pennine Lower Coal Measure Formation** – This strata with encountered at the base of every borehole and consisted of completely weathered to very weathered mudstone and sandstone.

The depths of the various materials encountered in the exploratory holes are summarised in Table 3, below.

Table 3: Summary of Ground Conditions Encountered

Hole	Depth to Stratum (m bgl)				GROUNDWATER (m bgl)
	MADE GROUND			SUPERFICIAL DEPOSITS	
	TOPSOIL	COHESIVE	GRANULAR	CLAY	
WS01	GL-0.25	0.70-1.00	0.25-0.70	1.00-2.00	-
WS02	GL-0.40	0.85-1.00	0.40-0.85	1.00-2.00	-
WS03	GL-0.35	0.35-1.50	-	1.50-2.00	-
WS04	GL-0.30	0.50-1.40	0.30-0.50	1.40-4.00	2.40
WS05	GL-0.50	0.65-1.00	0.50-0.65	1.00-2.00	-

5.2 Observable Indications of Contamination

During the ground investigation, variable Made Ground gravels were observed in the exploratory holes. These were mostly comprised of inert materials, such as brick and concrete.

No other visual/olfactory evidence of contamination was encountered in any of the exploratory holes during the fieldwork.

5.3 Obstructions

No man-made obstructions were encountered in any of the excavations carried out during the fieldwork.

5.4 Groundwater

Groundwater was only encountered within WS04 and was found at a depth of 2.40m.

6.0 ENGINEERING PROPERTIES OF SOILS ENCOUNTERED

6.1 General

The following sections discuss the engineering properties of the strata encountered, based on results of in situ testing and laboratory testing obtained during this investigation.

The results of laboratory geotechnical testing are summarised in the following table.

Table 4: Summary of Laboratory Geotechnical Test Results

Location	Depth (m)(	Material	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Modified Plasticity Index	Undrained Shear Strength (kN/m²)	pH Value	Water Soluble Sulphate SO_4 (mg/l)
WS01	1.85-2.00	CLAY	17	35	13	22	16	-	7.1	180
WS02	1.85-2.00	CLAY	26	42	18	24	23	-	7.0	320
WS04	3.60-3.80	CLAY	17	43	17	26	21	-	7.1	270
WS05	1.50-1.74	CLAY	17	42	17	25	20	-	7.1	260

6.2 Made Ground

Made Ground was encountered in all exploratory hole locations between ground level and 1.50m below ground level (WS03) and varied from exploratory hole location.

Due to the depth of the Made Ground, **SPT N values** were recorded in this material of between 9 and 22. The results suggest the cohesive Made Ground is firm to stiff.

Made Ground is not typically considered to be a suitable founding material, and as such, no further geotechnical testing was carried out on the material.

6.3 Superficial Deposits

6.3.1 Clay

Clay was encountered in all exploratory hole locations between 1.00m and 4.00m below ground level.

SPT tests carried out in the clay resulted in **SPT N values** of between 10 and 50, as shown on the SPT v Depth Plot in Figure 5 (overleaf). The results suggest the clay is firm to very stiff.

In-situ **hand penetrometer** (HP) tests have given results of shear strength in the range 84kN/m^2 to greater than 215kN/m^2 (the maximum reading of the hand penetrometer used), suggesting the clay is stiff to very stiff.

Figure 6, overleaf, shows the **shear strength** of the clay soils based on in-situ hand penetrometer tests alongside equivalent shear strength from SPT N values based on correlations by Stroud and Butler [(1975)].

Recommended N values and derived design values for the cohesive soils are summarised in Table 5, below.

Table 5: Summary of Design Parameters (Clay)

Depth	SPT N Value Range	Average N Value	Design N Value*	Equivalent Shear Strength** (kN/m^2)	Coefficient of Volume Compressibility** (mv)
1.0	10 - 28	18	12	54	0.17
2.0	14	14	14	63	0.14
*Based on lower quartile N value and correlations by Peck Hanson and Thornburn(1974) **Based on correlation by Stroud & Butler (1975)					

It is recommended that for assessing ultimate bearing capacities, where the lower values are critical, the lower quartile value of N values is used. Based on the N Values in the above table, the equivalent shear strength values were in the range of 54 - 63kN/m^2.

Laboratory testing has given a value of **water-soluble sulphate** in the range 180mg/l to 320mg/l, together with **pH Values** in the range 7.0 to 7.1.

Atterberg Limit tests were carried out on four samples of the clay. Results of the test reported **liquid limit** values in the range 35% to 43% and **plastic limit** values in the range 13% to 18%, resulting in values of **plasticity index** in the range 18% to 23%. These results suggest the samples of clay tested are of **low** to **intermediate plasticity** as shown on the Plasticity Chart in Figure 7, overleaf.

For design purposes, a value of plasticity index = 25% is recommended, based on the upper quartile of the results.

The **coefficient of volume compressibility (mv)** has been estimated using the following correlation by Stroud and Butler (1975): for a clay with a plasticity index of 25%, mv = 1 / (0.50 x N value). This correlation gives values of coefficient of volume compressibility in the range 0.14m^2/MN to 0.17m^2/MN, as shown in Table 5, above. The results suggest the clay has a **medium compressibility** and **medium volume change potential.**

Figure 5: SPT v Depth Plot

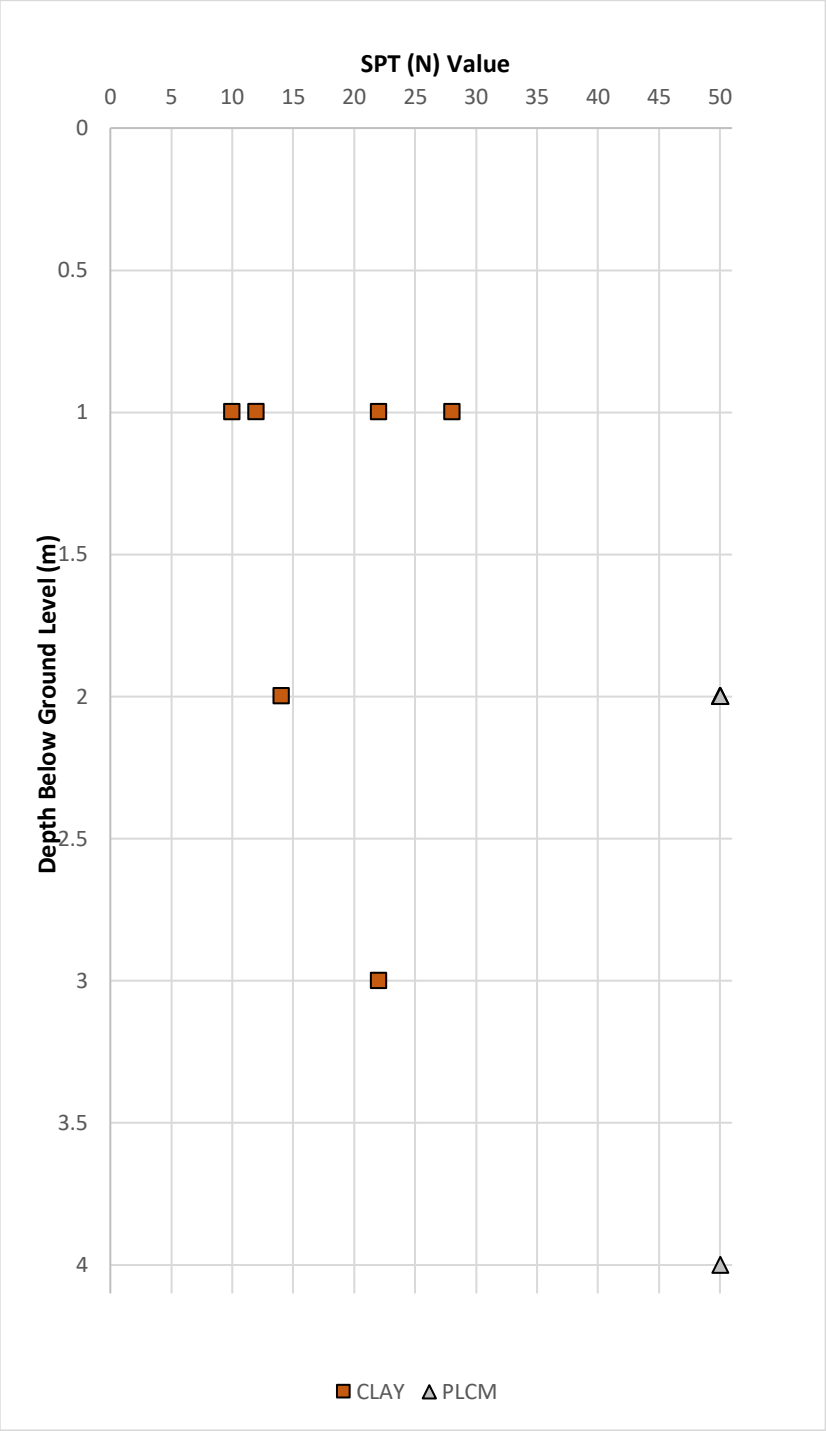
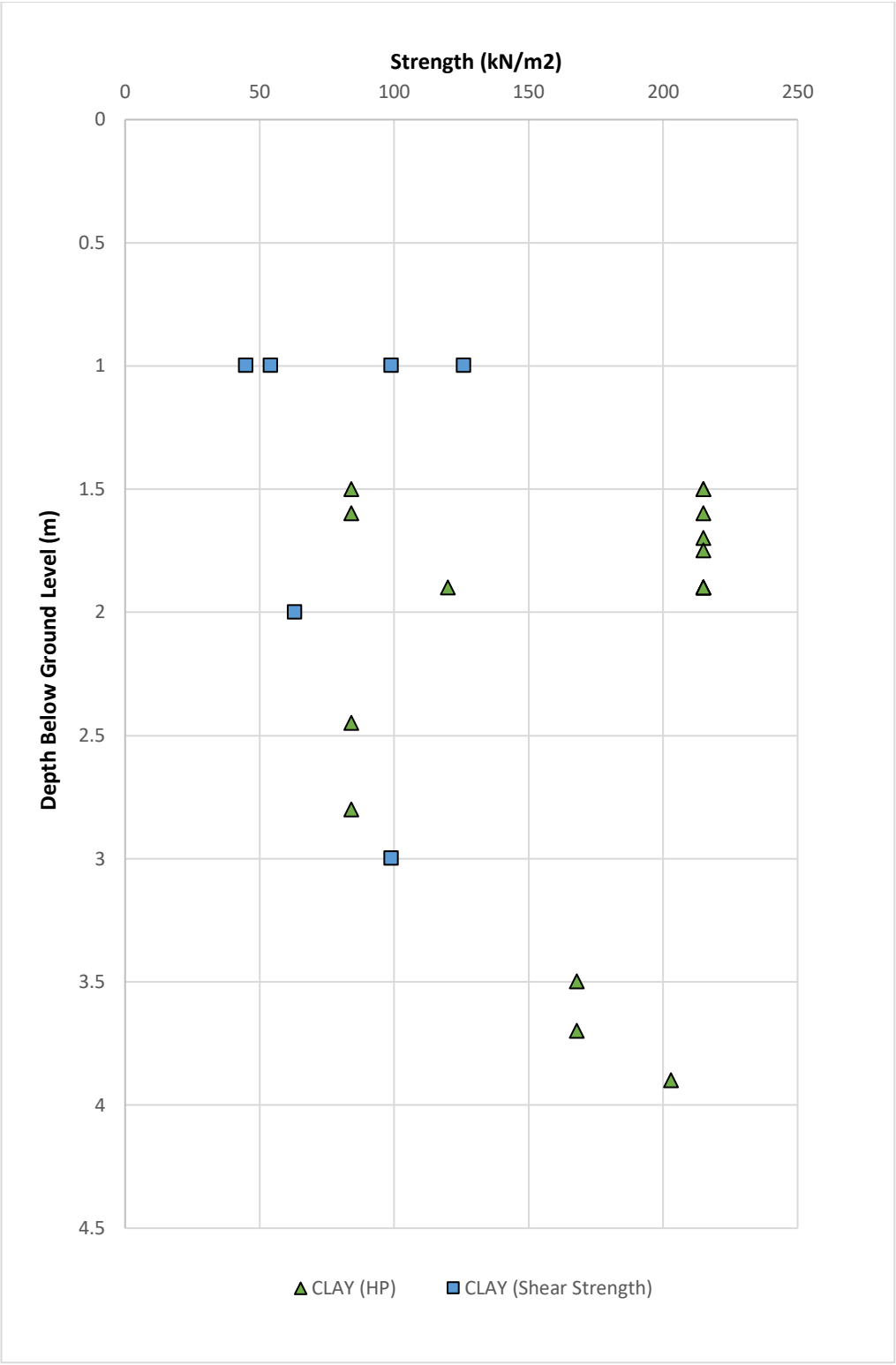


Figure 6: Strength v Depth Plot (Clay)



7.0 GEOTECHNICAL ASSESSMENT

7.1 Proposed Development

It is understood that the client intends to build eight residential bungalows on site with associated soft landscaping and off-street parking. An area of public open space is proposed for the land in the southern central portion of the site. Access will be provided from Ings Road to the south and Listing Court to the north. Detailed information regarding structural loadings and proposed foundation type was not available.

7.2 Ground Conditions Encountered

The exploratory holes generally encountered Made Ground to a maximum depth of 1.50m bgl (WS03). Underlying the Made Ground at all locations were deposits of clay followed by completely weathered to very weathered mudstone and sandstone.

Groundwater was encountered only in WS04 at 2.40m.

7.3 Foundation Considerations

Based on the ground conditions encountered, conventional shallow strip/pad foundations are considered suitable for this site, bearing into the stiff clay, providing the anticipated structural loadings are relatively low and subject to tolerance of structure to settlement. Should the allowable bearing pressure and settlement prove unfavourable, then alternative foundations options will need to be considered, such as ground improvement or piles.

It should be noted that weathered mudstone and sandstone was encountered at the base of every borehole.

7.3.1 *Conventional Shallow Depth Strip/Pad Foundations*

Strip/Pad foundations should be taken down below any Made Ground and placed in the superficial deposits beneath at a minimum depth of 1.00m. If any Made Ground, particularly loose or soft material, is encountered at foundation level this should be excavated and replaced with suitable granular fill or the foundation extended at least 150mm into suitable natural strata.

Foundations should be placed in materials of similar bearing and consolidation characteristics to avoid potential differential settlement occurring. Should foundations cross from cohesive to granular soils, nominal reinforcement should be incorporated to avoid the effects of differential settlement.

Table 6, overleaf, summarises anticipated allowable bearing pressures for strip/pad foundations placed in the superficial deposits. The bearing capacities are calculated based on Hansen's (1978) method and assuming a factor of safety against bearing capacity failure of 3. In order to the simulate a worst-case scenario, for the purposes of the calculations, groundwater has been assumed to be at foundation level.

Table 6: Summary of Allowable Bearing Pressures

Foundation Strata	Design Value (Section 6)	Foundation Depth (m bgl)	Foundation Type	Foundation Size (m)	Allowable Bearing Pressure (kN/m^2)
CLAY	c_u=54kN/m²	1.0	Strip	0.4	139
				0.9	126
			Pad	1.0 x 1.0	148
				2.0 x 2.0	134
	c_u=54kN/m²	1.5	Strip	0.4	145
				0.9	135
			Pad	1.0 x 1.0	158
				2.0 x 2.0	143
	c_u=63kN/m²	2.0	Strip	0.4	173
				0.9	163
			Pad	1.0 x 1.0	192
				2.0 x 2.0	175
	c_u=63kN/m²	2.5	Strip	0.4	176
				0.9	168
			Pad	1.0 x 1.0	197
				2.0 x 2.0	182

Table 7 below summarises anticipated settlements of the above foundations in clay based on design values discussed in Section 6. Settlement in cohesive soils typically comprises a small amount of immediate settlement as loads are applied and a larger proportion of consolidation settlement, which will occur over a longer period of time. For the purposes of the calculations the strata over the depth of influence of the foundation is assumed as the same type and the foundation loading assumed as equal to the above bearing pressures to give a worse-case scenario.

Table 7: Summary of Anticipated Settlement

Foundation Depth (m bgl)	Foundation Strata	Foundation Type	Foundation Size (m)	Pad Foundation Loading (kN/m^2)	Settlement (mm)		
					At Centre	At Corner	Average
1.0	CLAY	Strip	0.4	139	-	-	**10-15**
			0.9	126	-	-	**10-15**
		Pad	1.0 x 1.0	148	20-25	5-10	**15-20**
			2.0 x 2.0	134	25-30	5-10	**20-25**
1.5		Strip	0.4	145	-	-	**5-10**
			0.9	135	-	-	**10-15**
		Pad	1.0 x 1.0	158	20-25	5-10	**15-20**
			2.0 x 2.0	143	20-25	5-10	**15-20**
2.0		Strip	0.4	173	-	-	**5-10**
			0.9	163	-	-	**10-15**
		Pad	1.0 x 1.0	192	15-20	<5	**10-15**
			2.0 x 2.0	175	15-20	<5	**10-15**
2.5		Strip	0.4	176	-	-	**5-10**
			0.9	168	-	-	**5-10**
		Pad	1.0 x 1.0	197	5-10	<5	**5-10**
			2.0 x 2.0	182	5-10	<5	**5-10**

Floor slabs should be designed as suspended if Made Ground of 600mm thickness or greater is present. Made ground is not considered an appropriate bearing stratum due to its variable nature. Floor slabs may be designed as ground bearing where Made Ground is excavated and replaced with suitable granular fill.

The presence of trees within site boundaries indicates that foundations could be within their influence zone. In order to avoid possible excessive settlement due to water removal by trees during dry periods or ground heave due to tree removal, the recommendations of the National House Building Council Practice Standard "Building Near Trees", although not strictly applicable, should be closely followed. In this context clays near surface should be considered as having low to medium volume change potential.

All foundation excavations should be inspected by a suitable qualified engineer to prove that the founding strata is suitable and uniform along the length of the foundation, and capable of taking the anticipated structural loadings. If foundations cross from granular to cohesive soils, nominal reinforcement should be incorporated.

7.4 Pavement Design

The ground investigation identified the soil type at the subgrade level to typically be Made Ground.

A conservative design CBR value of 1% should be adopted in areas where Made Ground is encountered at subgrade level.

Consideration should be given to the potential differing ground conditions near surface, which could cause pavements to be constructed on variable made ground. In this context a flexible pavement design may be required.

Consideration should also be given to the use of geotextiles to allow reduction of capping thickness. For examples biaxial geogrids such as Tensar SSLA20 and SSLA30 are often used to reduce capping thickness. The advice of a suitable contractor should be sought as to the most appropriate type of geotextile to use in the ground conditions encountered at this site. For guidance, the following table gives a comparison of granular layer thickness with and without the use of a geotextile, in accordance with the requirement of HA25/94 Part 2.

It should be noted the type of construction will depend on proposed finished pavement levels across the site and it is recommended the pavement design is reviewed once these levels are known. In this context, it is essential further in situ CBR testing is carried out once formation levels are known to confirm design CBR values.

Table 8: Comparison of Capping Thickness with and without Geotextile

CBR	Unreinforced			Reinforced with Tensar Geogrid				
	Sub-base	Capping	Total	Sub-base	Capping	No. of grids	Total	Thickness saving
0.5%	Design not suitable			200mm	400mm	2	600mm	-
1.0%	150mm	600mm	750mm	400mm	0	1	400mm	350mm
1.5%	150mm	600mm	750mm	310mm	0	1	310mm	440mm
2.0%	150mm	600mm	750mm	260mm	0	1	260mm	490mm
3.0%	150mm	350mm	500mm	210mm	0	1	210mm	290mm
4.0%	150mm	300mm	450mm	175mm	0	1	175mm	275mm
5.0%	150mm	250mm	400mm	160mm	0	1	160mm	240mm
These figures are suitable for light access roads and car parks, based on 1000 standard axles. For heavier loaded pavements the advice of specialist contractor should be sought.								

All formation excavations should be examined by a suitably experienced engineer or inspector to check for soft or unsuitable material, which should be removed and replaced with compacted granular fill. Also, to ensure good compaction and remove unevenness, the formation should be compacted with equipment suitable for use in the ground conditions encountered. Careful inspection of this work will also help identify any soft spots at or just below formation level.

7.5 Chemical Attack on Buried Concrete

Chemical tests (see Appendices) show low levels of water-soluble sulphates and near neutral conditions. Based on these conditions, it is recommended that for concrete placed in natural strata the Design Sulphate Class for the site, as defined in BRE Special Digest 1(2005), be taken as DS-1, and the Aggressive Chemical Environment for Concrete (ACEC) site classification be taken as AC-1s. The recommendations of BRE Special Digest 1 should be followed for concrete foundations and ground bearing floor slabs.

7.6 Suitability of Excavated Materials

Acceptability criteria and testing, and methods of compaction/placement will depend on the type of contract and specification used for the construction of the proposed development and it is recommended that earthworks specifications are reviewed by a suitably qualified engineer, once these have been prepared by the relevant parties.

Near surface natural clays are unlikely to be suitable as structural fill and should be used for landscaping purposes only, providing they are not contaminated.

Granular Made Ground and natural sand could be suitable for re-use as structural fill, providing it is not contaminated and does not contain excessive amounts of clay and providing moisture contents are controlled during placement. The control of moisture contents will be important as the cohesive content of this stratum is likely to be sensitive to moisture content changes.

7.7 Temporary Works

Formations will be susceptible to damage both by weather and trafficking, and should be protected immediately on exposure, particularly in areas where construction plant will access the site.

Excavations in Made Ground are likely to be unstable and should be battered back to an angle of 1 in 2, or a system of close sheeting and shoring adopted to ensure stability, and in particular where personnel are required to enter excavations. All excavations should be adequately supported where personnel are required to enter.

Groundwater seepages could be encountered near surface within excavations, particularly during the wetter months of the year. Pumping of excavations from a suitable located sump is likely to be required to keep excavations dry.

All natural materials on site should be capable of being excavated using conventional excavating machinery.

8.0 SOIL CONTAMINATION RISK ASSESSMENT

8.1 Tier I Human Health Soil Risk Assessment – Groundworkers During Development

To assess the risk of soil contamination to construction and ground workers during development, guidelines from the HSE Document 'Protection of workers and the general public during development of contaminated land'(1991) are used. The document assesses soil contamination test results and classifies the site as being uncontaminated or contaminated with varying degrees of contamination from 'slight' to 'unusually heavy'. The guideline values and laboratory test results are summarised in the following table:

Table 9: Summary of Guideline Values for Protection of Workers and the General Public During Development of Contaminated Land

Contaminant	Typical Values* for:					Test Results	Class
	Uncontaminated Soils	Slight Contamination	Contaminated	Heavy Contamination	Unusually Heavy Contamination		
	Class A	Class B	Class C	Class D	Class E		
pH (alkaline)	7 - 8	8 - 9	9 - 10	10 - 12	12	7.5 - 8.3	A - B
Arsenic	0 - 30	30 - 50	50 - 100	100 - 500	500	9 - 27	A
Cadmium	0 - 1	1 - 3	3 - 10	10 - 50	50	< 0.2 - 0.9	A
Chromium	0 - 100	100 - 200	200 - 500	500 - 2500	2500	12 - 89	A
Copper	0 - 100	100 - 200	200 - 500	500 - 2500	2500	21 - 146	A - B
Lead	0 - 500	500 - 1000	1000 - 2000	2000 – 1%	1.0%	28 - 225	A
Mercury	0 - 1	1 - 3	3 - 10	10 - 50	50	< 1	A
Nickel	0 - 20	20 - 50	50 - 200	200 - 1000	1000	14 - 24	A - B
Zinc	0 - 250	250 - 500	500 - 1000	1000 - 5000	5000	86 - 512	A - C
Boron	0 - 2	2 - 5	5 - 50	50 - 250	250	< 1	A
Selenium	0 - 1	1 - 3	3 - 10	10 - 50	50	< 3	A
Barium	0-500	500-1000	1000-2000	2000-1.0%	1.0%	58 - 211	A
Beryllium	0 - 5	5 - 10	10 - 20	20 - 50	50	0.6 – 1.1	A
Vanadium	0 - 100	100 - 200	200 - 500	500 - 2500	2500	16 - 34	A
Sulphate	0 - 2000	2000 - 5000	5000 – 1%	1% - 5%	5.05%	573 - 980	A
Sulphide	0 - 10	10 - 20	20 - 100	100 - 500	500	< 5	A
Cyanide (free)	0 - 1	1 - 5	5 - 50	50 - 100	100	< 2	A
Phenol	0 - 2	2 - 5	5 - 50	50 - 250	250	< 2	A

Based on the above results it is considered there is a moderate to low potential risk from soil contamination to construction workers, ground workers and members of the public during construction. Appropriate measures, such as PPE, site health plans, and appropriate disposal of material arisings will be required to mitigate any risk.

8.2 Tier I Human Health Soil Risk Assessment – Future Site Users

The following section provides a Human Health Soil Assessment for future site users. Based on the proposed development type, the following section compares the results of contamination analyses to residential types of end development as specified by Defra/LQM/CIEH. As part of the contamination assessment, the chemical results obtained by EEG have been screened against accepted compliance criteria, namely:

- Defra C4SL Health Criteria Values (March 2014), where available; and
- Tier 1 assessment values - based on LQM/CIEH Suitable 4 Use Levels(2015) (S4ULs).

The soil chemical testing results are summarised in Table 10, overleaf.

Table 10: Soil Results Comparison with C4SL/S4UL Values

Determinand	C4SL/S4UL Levels Residential (mg/kg)	WS01 0.20m MG	WS02 0.60m MG	WS03 0.30m MG	WS04 0.40m MG	WS05 0.70m MG	No of Exceedances
Metals							
Arsenic	37	27	12	26	21	9	0
Beryllium	1.7	0.7	0.6	1	1.1	0.7	0
Boron	290	< 1	< 1	< 1	< 1	< 1	0
Cadmium	22	0.7	0.6	< 0.2	0.9	< 0.2	0
Chromium	910	26	12	17	89	17	0
Chromium VI	21	< 2	< 2	< 2	< 2	< 2	0
Copper	2400	57	26	36	146	21	0
Lead	200	**225**	39	74	**203**	28	2
Mercury	40	< 1	< 1	< 1	< 1	< 1	0
Nickel	180	18	14	21	24	17	0
Selenium	250	< 3	< 3	< 3	< 3	< 3	0
Vanadium	410	25	16	27	34	21	0
Zinc	3700	512	117	97	373	86	0
Petroleum Hydrocarbons							
Benzene	0.087	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0
Toluene	130	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0
Ethylbenzene	47	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0
o-xylenes	60	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0
m-xylenes	59	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0
p-xylenes	56	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0
Aliphatic EC >5-6	42	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0
Aliphatic EC >6-8	100	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0
Aliphatic EC >8-10	27	< 2	< 2	< 2	< 2	< 2	0
Aliphatic EC >10-12	130 (v)	< 2	< 2	< 2	< 2	< 2	0
Aliphatic EC >12-16	1100 (s)	< 3	< 3	< 3	< 3	< 3	0
Aliphatic EC >16-21	65000 (s)	10	< 3	< 3	< 3	< 3	0
Aliphatic EC >21-35	65000 (s)	25	< 10	< 10	12	< 10	0
Aromatic EC >5-7	70	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0
Aromatic EC >7-8	130	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0
Aromatic EC >8-10	34	< 2	< 2	< 2	< 2	< 2	0
Aromatic EC >10-12	74	< 2	< 2	< 2	< 2	< 2	0
Aromatic EC >12-16	140	< 2	< 2	< 2	< 2	< 2	0
Aromatic EC >16-21	260	15	< 3	< 3	14	< 3	0
Aromatic EC >21-35	1100	33	< 10	< 10	30	< 10	0
Polycyclic Aromatic Hydrocarbons							
Naphthalene	2.3	0.84	< 0.1	< 0.1	0.13	< 0.1	0
Acenaphthylene	210	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Acenaphthene	170	0.59	< 0.1	< 0.1	0.25	< 0.1	0
Fluorene	170	0.44	< 0.1	< 0.1	0.15	< 0.1	0
Phenanthrene	95	3.22	0.13	0.43	1.84	< 0.1	0
Anthracene	2400	0.75	< 0.1	0.12	0.5	< 0.1	0
Fluoranthene	280	4.01	0.25	0.75	3.29	< 0.1	0
Pyrene	620	3.54	0.24	0.68	3.05	< 0.1	0
Benzo(a)anthracene	7.2	1.93	0.11	0.31	1.81	< 0.1	0
Chrysene	15	1.82	0.15	0.38	1.95	< 0.1	0
Benzo(a)pyrene	5	2.26	0.14	0.32	2.32	< 0.1	0
Benzo(b)fluoranthene	2.6	**2.69**	0.14	0.39	**2.74**	< 0.1	2
Benzo(k)fluoranthene	77	0.88	< 0.1	0.2	0.89	< 0.1	0
Indeno(1,2,3-cd)pyrene	27	0.91	< 0.1	0.16	1.23	< 0.1	0
Dibenz(a,h)anthracene	0.24	0.22	< 0.1	< 0.1	0.24	< 0.1	0
Benzo(ghi)perylene	320	0.84	< 0.1	0.14	1.09	< 0.1	0
Phenols							
Phenol	280	< 2	< 2	< 2	< 2	< 2	0
Concentrations in **red** are above the assessment criteria based on Residential End Use with Plant Uptake. MG = Made Ground							

Elevated concentrations of contaminants of concern, with respect to the long-term protection of human health, have been identified at two locations across the site when compared to residential end use (with plant uptake) assessment criteria of soils with above 1% organic matter. The contaminants identified were lead and benzo(b)fluoranthene in both WS01 (0.20m) and WS04 (0.40m).

Borehole WS04 is located within an area of public open space and therefore should be compared to the relevant assessment criteria for residential public open space. When the correct assessment criteria are used, no exceedances of any contaminants are present.

The sample from WS01 at 0.20m can also be compared to alternative assessment criteria due to the sample's elevated organic matter content of 5.5%. When using the relatively conservative assessment criteria relevant to residential (with plant uptake) in soils of above 2.5% organic matter content, the contaminant exceedance of benzo(b)fluoranthene is no longer present.

Asbestos was not identified in any of the samples tested during this investigation.

8.3 Soil Waste Assessment

An assessment of the disposal characteristics of the soil in accordance with Environment Agency guidance WM3.1, edition of June 2018, "Guidance on the classification and assessment of waste" has been carried out on soils recovered from the site, using HazWasteOnline.

The results are summarised in Table 11 below and presented in full in Appendix 4.

Table 11: Waste Classification of Soils

Location	Depth (m bgl)	WM3.1 Classification	Comments
WS01	0.20	Non-Hazardous	-
WS02	0.60	Non-Hazardous	-
WS03	0.30	Non-Hazardous	-
WS04	0.40	Non-Hazardous	-
WS05	0.70	Non-Hazardous	-

The above table shows that the eight soils samples collected during the course of this investigation were classified as **Non-Hazardous** in accordance with WM3.1.

Further Waste Acceptance Criteria (WAC) testing may prove that his material is acceptable as inert waste.

9.0 CONCLUSIONS & RECOMMENDATIONS

9.1 Soil Contamination

There is a moderate to low potential risk from soil contamination to construction workers and ground workers during development, and appropriate measures such as PPE, site health plans, appropriate disposal of material arisings will be required to mitigate any risk. The groundworks contractor must provide a soil management plan including methods of dealing with unanticipated soil contamination encountered during groundworks.

Based on the results of the chemical testing, when compared to the most relevant assessment criteria, an exceedance of lead was detected in WS01 at 0.20m. This poses a moderate to low risk to future residential end users within the vicinity of contamination hotspot.

In order to break potential pollutant linkages to future residential end users, it is recommended that landscaped areas in the vicinity of the contamination should be capped with clean cover soils.

Additional contamination testing may allow for further delineation of the contaminated “hot-spot”.

A Remediation Strategy is recommended to specify the design of the capping system and any following validation work.

The presence of higher levels of contamination on areas of the site not covered by the current exploratory holes should not be discounted and additional spot checks would be prudent, particularly during groundworks. This testing can be carried out as part of the Soil Management Plan for the site.

9.2 Asbestos

Asbestos was not identified in any of the samples tested during the course of this investigation.

9.3 Foundations

Shallow strip/pad foundation placed in the stiff natural clay at a minimum depth of approximately 1.00m bgl or below are considered appropriate for the current proposed development, dependent on allowable bearing pressures and tolerance of structures to settlement.

It should be noted that weathered mudstone and sandstone was encountered at the base of every borehole.

The presence of trees within site boundaries indicates that foundations could be within their influence zone. In order to avoid possible excessive settlement due to water removal by trees during dry periods or ground heave due to tree removal, the recommendations of the National House Building Council Practice Standard “Building Near Trees”, should be closely followed.

9.4 Soil Disposal

Soils should be disposed of at a suitable site, registered to take the levels of contamination encountered. The soils collected from all borehole locations have been classified as Non-Hazardous for the purpose of off-site disposal in accordance with Environment Agency guidance WM3.1.

9.5 Risk to Buried (Water) Services

It is considered that standard materials may not be acceptable for new water pipes. Further advice should be sought from the local water company.

Previous guidance on buried water pipes was contained in Water Regulations Advisory Scheme (WRAS) Guidance Note No. 9-04-03(2002), however this has been superseded by the UK Water Industry Research Report 'Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites' Ref 10/WM/03/21 (January 2011).

9.6 Site Personnel

As with all construction sites, personnel working on the site during the construction period should be encouraged to maintain a high standard of personal hygiene and on-site washing facilities should be available.

9.7 Other Matters

Due diligence is required during the construction period, and should any further evidence of contamination be found, appropriate investigation and / or action should be taken. The significance of any contamination not discovered by this investigation is outside the scope of this report.

APPENDIX 1

EXPLORATORY HOLE LOGS

APPENDIX 2

GEOTECHNICAL TESTING RESULTS

APPENDIX 3

CHEMICAL TESTING RESULTS

APPENDIX 4

SOIL WASTE ASSESSMENT

APPENDIX 5

REPORT LIMITATIONS

REPORT LIMITATIONS

This contract was completed by Earth Environmental & Geotechnical Ltd on the basis of a defined programme and scope of works and terms and conditions agreed with the client. This report was compiled with all reasonable skill, and care, bearing in mind the project objectives, the agreed scope of works, the prevailing site conditions, the budget and staff resources allocated to the project.

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It is Earth Environmental & Geotechnical Ltd understanding that this report is to be used for the purpose described in the introduction to the report. That purpose was an important factor in determining the scope and level of the services. Should the purpose for which the report is used, or the proposed use of the site change, this report will no longer be valid and any further use of, or reliance upon the report in those circumstances by the client without Earth Environmental & Geotechnical Ltd review and advice shall be at the client's sole and own risk.

The report was written in 2021 and should be read in light of any subsequent changes in legislation, statutory requirements and industry best practices. Ground conditions can also change over time and further investigations or assessment should be made if there is any significant delay in acting on the findings of this report. The passage of time may result in changes in site conditions, regulatory or other legal provisions, technology or economic conditions which could render the report inaccurate or unreliable. The information and conclusions contained in this report should not be relied upon in the future without the written advice of Earth Environmental & Geotechnical Ltd. In the absence of such written advice of Earth Environmental & Geotechnical Ltd, reliance on the report in the future shall be at the client's own and sole risk. Should Earth Environmental & Geotechnical Ltd be requested to review the report in the future, Earth Environmental & Geotechnical Ltd shall be entitled to additional payment at the then existing rate or such other terms as may be agreed between Earth Environmental & Geotechnical Ltd and the client.

The observations and conclusions described in this report are based solely upon the services that were provided pursuant to the agreement between the client and Earth Environmental & Geotechnical Ltd. Earth Environmental & Geotechnical Ltd has not performed any observations, investigations, studies or testing not specifically set out or mentioned within this report.

Earth Environmental & Geotechnical Ltd is not liable for the existence of any condition, the discovery of which would require performance of services not otherwise contained in the services. For the avoidance of doubt, unless otherwise expressly referred to in the introduction to this report, Earth Environmental & Geotechnical Ltd did not seek to evaluate the presence on or off the site of electromagnetic fields, lead paint, radon gas or other radioactive materials.

The services are based upon Earth Environmental & Geotechnical Ltd observations of existing physical conditions at the site gained from a walkover survey of the site together with Earth Environmental & Geotechnical Ltd interpretation of information including documentation, obtained from third parties and from the client on the history and usage of the site. The findings and recommendations contained in this report are based in part upon information provided by third parties, and whilst Earth Environmental & Geotechnical Ltd have no reason to doubt the accuracy and that it has been provided in full from those it was requested from, the items relied on have not been verified.

No responsibility can be accepted for errors within third party items presented in this report. Further Earth Environmental & Geotechnical Ltd was not authorised and did not attempt to independently verify the accuracy or completeness of information, documentation or materials received from the client or third parties, including laboratories and information services, during the performance of the services. Earth Environmental & Geotechnical Ltd is not liable for any inaccurate information, misrepresentation of data or conclusions, the discovery of which inaccuracies required the doing of any act including the gathering of any information which was not reasonably available to Earth Environmental & Geotechnical Ltd and including the doing of any independent investigation of the information provided to Earth Environmental & Geotechnical Ltd save as otherwise provided in the terms of the contract between the client and Earth Environmental & Geotechnical Ltd.

Where field investigations have been carried out these have been restricted to a level of detail required to achieve the stated objectives of the work. Ground conditions can also be variable and as investigation excavations only allow examination of the ground at discrete locations. The potential exists for ground conditions to be encountered which are different to those considered in this report. The extent of the limited area depends on the soil and groundwater conditions, together with the position of any current structures and underground facilities and natural and other activities on site. In addition, chemical analysis was carried out for a limited number of parameters [as stipulated in the contract between the client and Earth Environmental & Geotechnical Ltd] based on an understanding of the available operational and historical information, and it should not be inferred that other chemical species are not present.

The groundwater conditions entered on the exploratory hole records are those observed at the time of investigation. The normal speed of investigation usually does not permit the recording of an equilibrium water level for any one water strike. Moreover, groundwater levels are subject to seasonal variation or changes in local drainage conditions and higher groundwater levels may occur at other times of the year than were recorded during this investigation.

Any site drawing(s) provided in this report is (are) not meant to be an accurate base plan but is (are) used to present the general relative locations of features on, and surrounding, the site.