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REPORT ON A SITE INVESTIGATION AT FORMER PLANT HIRE YARD CROSS STREET FARCET CAMBRIDGESHIRE

Report Reference C15737

On behalf of:

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October 2022

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INTRODUCTION

The client, Formation Developments Limited, proposes to build a new residential development of approximately eighteen dwellings at a former plant hire yard, Cross Street, Farcet in Cambridgeshire.

The scope of the site investigation comprised desk study research and trial pits and window sample boreholes with laboratory testing on recovered samples to determine the nature of the underlying soil.

This report provides the findings of the investigation and makes recommendations for the design of shallow foundations together with comments on the risk of soil contamination being present beneath the site.

LOCATION, TOPOGRAPHY AND GEOLOGY OF THE SITE

The site of the proposed development is located at the former Philip Hall Plant yard, Cross Street, Farcet in Cambridgeshire and shown in Figure 1. The site is bounded by Cross Street and No.9 Cross Street to the west; by Main Street to the south; by houses and gardens to the north and east; and by the Black Swan public house to the south-east. Farcet is approximately 4km south of Peterborough city centre and the National Grid Reference for the centre of the site is TL 2068 9456.

The approximately 0.5 hectare, irregular shaped site is located directly to the east of a residential property No.9 Cross Street, which was previously annexed to the Philip Hall Plant yard. A 15m wide entrance off Cross Street is located directly to the north of No.9 and a second entrance is located midway along the 50m site curtilage of the site on Main Street to the south-east of No.9. The main body of the site occupies a 55m by 50m area between the two entrances.

The site contains a dilapidated, 15m wide by 20m long, steel portal frame building with cement bonded asbestos sheet roofing and side cladding, centrally located within the site, together with small derelict outbuildings and portacabins. The south-eastern part of the garden of No.9 is included within the site and this contains a prefabricated concrete double garage. Directly to the south-east of the garage were two steel box (3.0m by 1.5m by 1.5m) surface mounted fuel tanks, which stood on a plinth over a 1.5m high and 2m wide by 8m long block constructed bund. Two small surface mounted heating oil tanks were observed off site adjacent the residential property No.9 Cross Street.

The former plant hire yard, which surrounds the central building included an asphalt surfaced area to the front/south with the remaining areas partly overgrown and covered by bare earth. A 1m to 2m high overgrown earth mound was located to the rear/north of the portal frame building and there were other earth mounds scattered across the site.

Trees including mature Weeping Willow, Sycamore and Silver Birch were present within and around the boundaries of the site.

The site stands at an elevation of approximately 4.5mOD, on ground that gently slopes down eastwards towards the old course of the River Nene, which is about 40m distant.

The geological map for the area, sheet 172 at 1:50,000 scale, shows the eastern part of the site to be covered by superficial Nordelph Peat, and the western part of the site to be underlain by Glaciolacustrine Deposits. The superficial deposits are indicated to rest on the solid geology of the Oxford Clay Formation, which crops out across the central part of the site.

SITE HISTORY

Research into the site history involved reference to historical Ordnance Survey (OS) maps, aerial photographs, and internet research. Selected extracts are presented in Appendix 1 and described below:

OS Map Extract	*Description*
1887 OS County Series Scale 1:10,560 **Figure A** **1889** OS County Series Scale 1:2500 **Figure B**	The site is shown on the eastern outskirts of the Fenland village of Farcet and is situated within fields and gardens to the east of properties along Cross Street and Bridge Street. The properties appear to be a mixture of residential and commercial including the Anchor Inn and a smithy. The southward flowing River Nene (old course) is situated about 50m to the east of the site and there is a pond located adjacent a rectangular mound 100m to the north.
1901 OS County Series Scale 1:2500 **Figure C** **1902** OS County Series Scale 1:10,560 **Figure D**	The site appears as shown previously.
1924 OS County Series Scale 1:10,560 **Figure E** **1926** OS County Series Scale 1:2500 **Figure F**	The site and immediate surroundings appear as shown previously. There is a sewage works located about 100m south of the site.
1938 OS County Series Scale 1:10,560 **Figure G**	The site and immediate surroundings appear as shown previously.
1950 OS County Series Scale 1:10,560 **Figure H**	The site and immediate surroundings appear as shown previously.

OS Map Extract	*Description*
1958 OS Sheet TL29SW Scale 1:10,560 **Figure I**	The site and immediate surroundings appear as shown previously.
1982 OS Sheet TL29SW Scale 1:10,000 **Figure J**	With the exception of the Anchor Inn building, which appears to be a dwelling, the other buildings along the western side of the site are no longer present. The site, which has been sub-divided into two, remains for the most part as open land with the exception of a new building and an outbuilding to the south-east of the former Anchor Inn. A small works is shown directly to the north of the site.
1989 OS Sheet TL2094 Scale 1:2500 **Figure K**	The site and immediate surroundings appear as shown previously. To the west of the small works to the north of the site is a working men's club.
1994 OS Sheet TL2094 Scale 1:2500 **Figure L**	The main building has been extended two-fold with an open sided structure. The works to the north is no longer shown. Otherwise the site and immediate surroundings appear as shown previously.
1999 Aerial Photograph On Page 12, Appendix 2	The site layout appears as shown in the 1994 map. There are numerous vehicles parked in the yard.
2003 OS Sheet TL2094NE Scale 1:1250 **Figure M**	The site and immediate surroundings appear as shown previously.
2010 OS Sheet TL29SW Scale 1:10,000 **Figure N**	The site and immediate surroundings appear as shown previously. There is new residential development shown along George Alcock Way directly to the north.
2011 Aerial Photograph On Page 11, Appendix 2	The site layout remains unchanged. The land directly to the north and north-east appears to be undergoing residential development.
2013 Aerial Photograph On Page 10, Appendix 2	The site layout remains unchanged. The land directly to the north and north-east is occupied by dwellings.

OS Map Extract	*Description*
2018 Aerial Photograph On Page 9, Appendix 2	The site layout remains unchanged.
2022 OS Sheet TL29SW Scale 1:10,000 **Figure O**	The site and immediate surroundings appear as shown previously.
2022 OS Mastermap On Page 13, Appendix 2	The site and immediate surroundings show the current site layout.

Historical Summary

The 1887 first edition of the OS County Series maps shows the undeveloped site to lie within farmland on the eastern outskirts of Farcet. The site appears to have remained unchanged through to 1967 when it is understood that Philip Hall established his plant and machinery hire business on the site. With the exception of a twofold extension of the central building the site lay out has remained unchanged through to the time of this investigation in October 2022.

SUMMARY OF ENVIRONMENTAL DATA

Appendix 2 contains information derived from Environmental Databases for a radius of up to 2000m from the site. The information covers datasets held by the Groundsure with contributors including the local authority, the Environment Agency, British Geological Survey, Ordnance Survey and the Coal Authority and the results, within a radius of 250m, are summarised below:

Historical Industrial Sites	**On Site**	**0-50m**	**51 - 250m**
Historical Industrial Land Uses	1	2	6
Historical Tanks	0	0	2
Historical Energy Features Database	0	0	4
Historical Petrol and Fuel Site Database	0	0	0
Historical Garages	0	0	0
Historical Military Land	0	0	0
Landfill and Other Waste Sites	**On Site**	**0-50m**	**51 - 250m**
Landfill Sites	0	0	0
Waste Sites	0	0	0
Waste exemptions	2	6	1
Current Industrial Land Uses	**On Site**	**0-50m**	**51 - 250m**
Recent Industrial Land Uses	0	2	2
Current or Recent Petrol Stations	0	0	0
Electricity Cables	0	0	0
Gas Pipelines	0	0	0
Sites Determined as Contaminated Land	0	0	0
Permits/Authorisations	0	0	0
Pollution Discharge	0	2	5
Dangerous Substances	0	0	0
Pollution Incidents	0	1	1
Pollutions Inventories	0	0	0
Hydrogeology	**On Site**	**0-50m**	**51 - 250m**
Superficial Aquifer	Identified (within 500m)		
Bedrock Aquifer	Identified (within 500m)		
Groundwater Vulnerability	Identified (within 50m)		
Groundwater Abstractions	0	0	0
Surface Water Abstractions	0	0	0
Potable Abstractions	0	0	0
Source Protection Zones	0	0	0
Hydrology	**On Site**	**0-50m**	**51 - 250m**
Water Network (OS MasterMap)	0	1	11
Surface Water Features	0	2	9

Groundwater	0	-	-
River and Coastal Flooding	**On Site**	**0-50m**	**51 - 250m**
Risk of Flooding from Rivers and Sea	None (within 50m)		
Historical Flood Events	0	0	0
Flood Defences	0	0	0
Areas Benefiting from Flood Defences	0	1	0
Flood storage areas	0	0	0
Flood Zone 2	Identified (within 50m)		
Flood Zone 3	Identified (within 50m)		
Surface Water Flooding			
Surface Water Flooding	1 in 30 year, 0.3m-1.0m (within 50m)		
Groundwater Flooding			
Groundwater Flooding	Negligible (within 50m)		
Designated Environmentally Sensitive Sites	**On Site**	**0-50m**	**51 - 250m**
Environmentally sensitive sites	2	0	0
Natural Hazards			
Hazard			
Shrinking or Swelling Clay	Moderate (within 50m)		
Running Sand	Very Low (within 50m)		
Compressible Ground	High (within 50m)		
Collapsible Deposits	Very Low (within 50m)		
Landslides	Very Low (within 50m)		
Ground Dissolution of Soluble Rocks	Negligible (within 50m)		
Mining, Ground Workings & Natural Cavities	**On Site**	**0-50m**	**51 - 250m**
Natural Cavities	0	0	0
Surface Ground Workings	0	0	9
Underground Mining	0	0	0
Radon			
The property is in an area where less than 1% of properties are above the radon action level. The site lies within an area where no radon protection measures are necessary.			

Database Summary

There is one on-site historical land use record (1978) relating to an unspecified works. There are a further eight records within a 250m radius of the site that relate to unspecified works, heaps, sewage works and a pump between 1887 and 1978.

There are two historical tanks (1926) within 116m and 128m to the south and four electricity substations (1974 to 1994) within a radius of 250m.

There are no current landfill or waste sites within a 250m radius of the site. Two waste exemptions are recorded for processes relating to the storage and the use of waste in construction. There are a further seven waste exemptions within the premises of Anchor House, which neighbours the site.

There are four current industrial uses recorded within 250m of the site. These relate to Philip Hall Plant Hire Limited (on-site) and a pumping station and two electricity substations.

There are no permits or authorisations recorded on the site address.

There are seven licenses relating to licensed discharges to controlled waters and two pollution incidents (dated 2001/2002) within 250m of the site.

The site is indicated to be underlain by the solid geology of the Oxford Clay Formation, which is an Unproductive Aquifer. The eastern half of the site is covered superficial deposits comprising the Nordelph Peat and the western margin is covered by a Glaciolacustrine Deposits, both of which are Unproductive Aquifers.

The southward flowing River Nene (old course) is located 44m to the south-east of the site. There is a 1 in 30 year chance that the site will flood with water levels between 0.30m and 1.00m. There is a negligible risk of surface water flooding.

The property is in an area where less than 1% of properties are above the radon action level. The site lies within an area where no radon protection measures are necessary.

PRELIMINARY RISK ASSESSMENT

Potential sources of contamination present on or beneath the site would relate primarily to; the historical use of the site; the presence of contaminated soil; and the potential presence of soil gas beneath the site.

In order to assess the risks associated with the presence of ground contamination the linkages between the sources and potential receptors to contamination need to be established and evaluated. This is in accordance with the Environmental Protection Act 1990, which provides a statutory definition of Contaminated Land. To fall within this definition it is necessary that, as a result of the condition of the land, substances may be present on or under the land such that

- *Significant harm is being caused or there is a significant possibility of such harm being caused; or*
- *Pollution of controlled waters is being, or is likely to be, caused*

There are three principal factors that are assessed whilst undertaking a qualitative risk assessment for any site. These are the presence of a contamination source, the existence of migration pathways and the presence of a sensitive target(s). It should be noted that it is necessary for each element of source, pathway and target to be present in order for exposure of a human or environmental receptor to occur.

UK Government guidance on the assessment of contaminated land, requires risk to human health and the environment to be reviewed using source – pathway – target relationships. If each of these elements is present, the linkage provides a potential risk to the identified targets.

Contaminants or ***potential pollutants*** identified as ***sources*** in relation to the identified previous uses are listed overleaf in Table 1.

Table 1: Identified Potential Contaminant Sources

Contaminant Source	*Comments*
Existing Buildings	The existing buildings may include asbestos containing materials (ACM).
Fuel Tanks	Fuel tanks present because historical refuelling of vehicles took place
Soil Beneath Site	Contamination may be present within any made ground materials on the site.
Soil Gas	Potential soil gas generated from made ground.
Ground Contamination Outside Site Boundary	Ground contamination migrating from adjoining sites

A ***Pathway*** is defined as one or more routes through which a receptor is being, or could be, exposed to, or affected by, a given contaminant.

Potential ***Target or Receptors*** fall within the categories of Human Health, Water Environment, Flora and Fauna, and Building Materials.

There are a number of possible pathways for the contaminants identified on the site to impact human and/or environmental receptors and these are summarised in Tables 2 and 3.

Table 2: Human Receptors and Pathways

Human Receptor-Mechanism	*Typical Exposure Pathway*
Human Inhalation	Breathing Dust and Fumes Breathing Gas emissions
Human Ingestion	Eating -contaminated soil, for example by small children -produce grown on contaminated soil Ingesting dust or soil on vegetables Drinking contaminated water
Human Contact	Direct skin contact with contamination Direct skin contact with contaminated liquids

Table 3: Water Receptors and Pathways

Receptor-Water Environment	*Typical Exposure Pathway*
The site is indicated to be underlain by the solid geology of the Oxford Clay Formation, which is an Unproductive aquifer. The eastern half of the site is covered superficial deposits comprising the Nordelph Peat and the western margin is covered by a Glaciolacustrine Deposit, both of which are Unproductive Aquifers.	Surface infiltration of atmospheric waters into the soils beneath the site could wash or dissolve potential contaminants and migrate to underlying groundwater. Contamination leads to restriction/prevention of use as a resource, for example, drinking water, and can have secondary impacts on other resources, which depend on it.
The southward flowing River Nene (old course) is located 44m to the south-east of the site.	Surface infiltration of atmospheric waters into the soils beneath the site could wash or dissolve potential contaminants and laterally migrate. Contamination leads to a restriction/prevention of use: -as drinking water resource -for amenity use Effects on aquatic life

Preliminary Conceptual Model

Assessment of the potential linkage between ground contamination sources, human and environmental receptors have been assessed based on the desk study research documented in the preceding sections of this report.

A generalised preliminary conceptual model is presented below in Table 4.

Table 4: Preliminary Conceptual Model Relative to Proposed Development

Receptors	Pathway	Estimated Potential for Linkage with Contaminant Sources			
		Fuel Tanks	Soil Beneath Site	Soil Gas	Ground Contamination Outside Site Boundary
Human Health – site and ground workers	Ingestion and Inhalation of contaminated Soil, Dust and Vapour	Likely	Low likelihood	Low likelihood	Low likelihood
Human Health – users of completed development	Ingestion and Inhalation of contaminated Soil, Dust and Vapour	Likely	Low likelihood	Low likelihood	Low likelihood
Water Environment	Migration through ground into surface water or surrounding groundwater	Likely	Low likelihood	Low likelihood	Low likelihood
Flora	Vegetation on site growing on contaminated soil	Low likelihood	Low likelihood	Unlikely	Unlikely
Building Materials	Contact with contaminated soil	Low likelihood	Low likelihood	Unlikely	Unlikely

Key to Table 4 Estimated Potential for Linkage with Contaminant Source	Definition
High likelihood	There is a pollution linkage and an event that either appears very likely in the short term and almost inevitable over the long term, or there is evidence at the receptor of harm or pollution.
Likely	There is a pollution linkage and all the elements are present and in the right place, which means that it is probable that an event will occur. Circumstances are such that an event is not inevitable, but possible in the short term and likely over the long term.
Low likelihood	There is a pollution linkage and circumstances are possible under which an event could occur. However, it is by no means certain that even over a longer period such an event would take place, and is less likely in the shorter term.
Unlikely	There is a pollution linkage but circumstances are such that it is improbable that an event would occur even in the very long term.
NA	Not Applicable

SITE WORK

The site work was carried out on 26 August 2022 and comprised five window sample boreholes (WS1 to WS5) and seven trial pits (TP1 to TP7) at locations shown in Figure 2.

The exploratory hole records have been produced in accordance with British Standard BS5930:2015+A1:2020 'Code of Practice for Site Investigations' and are given in Appendix 3. The records provide the descriptions and depths of the various strata encountered, details of standpipe installations, samples taken, and the groundwater conditions observed during excavation, boring and on completion. The results of hand vane testing have also been presented as applicable on the exploratory hole records.

Service plans were consulted and a cable avoidance tool (CAT) was used to check for the absence of buried services prior to boring.

Window Sample Boreholes (WS1 to WS5)

The boreholes, WS1 to WS5, were started by the excavation, using hand tools, of service inspection pits to a depth of 1.20m in order to ensure the absence of buried services. Representative small disturbed small and bulk samples of soil were taken from each starter pit.

The window sample boreholes were formed by a small track-mounted window sampling and super heavy dynamic probing rig and taken to depths of 3.45m and 4.45m. The window sampling equipment consisted of drive-in sample tubes of specially constructed and strengthened steel, lined with a plastic core-liner. The barrels were initially of up to 87mm internal diameter and were reduced in diameter with successive barrels with increasing depth. Upon extraction, a continuous 'undisturbed' profile of the soil was obtained within the plastic liners.

The standard penetration test (SPT) was carried out at regular intervals in order allow the assessment of the relative in-situ density or stiffness of the ground. The test was made by driving a split-barrel sampler (SPT(S)) into the soils at the base of the borehole by means of an automatic trip hammer weighing 63.50kg falling freely through 750mm. The penetration resistance was determined as the number of blows required to drive the tool the final 300mm of a total penetration of 450mm into the soil ahead of the borehole.

On completion a soil gas and groundwater monitoring installation was fitted into boreholes WS2, WS3 and WS4 to a depth of 3.00m. The installations comprised a standpipe fitted to 3.00m depth with a silica gravel surround to a depth of 1.00m. A bentonite seal was inserted between 0.50m and 1.00m depth, above which the tube was sealed by a gas valve and a surface protective cover was fixed in concrete.

Trial Pits (TP1 to TP7)

The trial pits were excavated to depths of 2.10m to 3.10m using a JCB 3cx type machine.

The exposed strata in the trial pits were sampled and logged by a geotechnical engineer, and representative small and bulk disturbed samples were taken throughout the depth of each pit. Following completion the pits were backfilled with compacted layers of the arisings.

Return Visits to Site

Return visits to site was undertaken on 13, 21 September and 4 October 2022 to monitor the standpipe installations WS2, WS3 and WS4 for depth to groundwater and the concentrations of methane, carbon dioxide and oxygen. Measurement was carried out using a Gasdata GFM430, which also recorded the atmospheric pressure and flow rate. The monitoring results are presented on and following the borehole records in Appendix 3.

GEOTECHNICAL LABORATORY TESTING

Samples recovered from the exploratory holes were tested in accordance with the recommendations of British Standard BS1377:1990 & 2016 ‘Methods of Tests for Soils for Civil Engineering Purposes’ and other industry standards. The results of testing are presented on Laboratory Summary Sheets in Appendix 4.

Soil Moisture Content

The moisture content of selected samples was determined, and the results are reported as the percentage water content with respect to the dry mass of soil.

Atterberg Limit Tests

The liquid and plastic limits, and plasticity index, were determined for selected specimens for the purpose of engineering soil classification. The results are quoted as the percentage water with respect to the dry weight of soil.

CBR Tests

California Bearing Ratio (CBR) tests were performed on selected samples recompacted using a 2.5kg rammer. The test consisted of jacking into the soil a cylindrical plunger with a cross sectional area of 1935mm^2. A force of 50N was applied initially to seat the plunger on the soil surface and then the plunger was made to penetrate the soil at a uniform rate of 1mm/min. Readings of force were taken at intervals of penetration of 0.25mm to a penetration not exceeding 7.50mm. The CBR value is the ratio of the force required to achieve 2.50mm or 5.00mm penetration to standard forces expressed as a percentage.

Sulphate and pH Testing

Selected soil samples were tested to determine their pH-values and aqueous sulphate contents in order to provide advice on assessing the aggressive chemical environment in relation to buried concrete.

CHEMICAL LABORATORY TESTING

Selected soil and water samples were submitted to a UKAS Accredited Laboratory who carried out a suite of tests, which encompassed a wide range of potential contaminants outlined by the Environment Agency (EA) and National House Building Council (NHBC) document R&D 66; 2008 'Guidance for the Safe Development of Housing on Land Affected by Contamination'.

Tests were carried out to screen the samples for the following potential contaminants: total arsenic, total cadmium, total chromium, hexavalent chromium, total lead, total mercury, total selenium, water soluble boron, total copper, total nickel, total zinc, total cyanides, free cyanides, soluble sulphate, sulphides and pH-value, phenols and polyaromatic hydrocarbons (PAH), including benzo[a]pyrene, and petroleum hydrocarbons (TPH). Selected samples were also screened for asbestos. Waste acceptance criteria (WAC) testing was also carried out on selected soil samples.

The results of chemical testing are presented in Appendix 5.

GROUND CONDITIONS

The strata encountered in the exploratory holes comprised between 0.90m and 2.10m thickness of made ground, which over the majority of the site rested on Glaciolacustrine Deposits. The underlying solid geology of the Oxford Clay Formation was present at depths between 2.00m and 2.90m.

Along the south-eastern margin of the site, within TP1, TP2 and WS3, the made ground overlay the Nordelph Peat and Alluvium, which was present with a thickness of between 0.20m and 0.90m.

A schematic cross-section across the site is provided in Appendix 3 following the borehole and trial pit records.

Made Ground

The exploratory holes encountered a capping layer of made ground, which had a thickness between 0.90m and 2.10m. The made ground comprised brown, red brown, dark brown, grey brown, grey and black mixed layers of sandy gravel; gravelly sand; and soft and firm, slightly sandy, slightly gravelly clay. The gravel fraction typically comprised angular to sub-rounded brick, concrete, asphalt, mortar, ash, bone, flint, limestone, igneous rock and ironstone. A 0.10m to 0.20m thick layer of asphalt was encountered within the yard areas and locally a 0.20m to 0.30m thick layer of brick rubble was encountered close to the surface. Locally in trial pit TP1 a fragment of cement bonded asbestos sheet was observed in the made ground between 0.30m and 0.80m depth.

Nordelph Peat & Alluvium

Along the south-eastern margin of the site, within TP1, TP2 and WS3, the made ground overlay Nordelph Peat and Alluvium, which was present with a thickness of between 0.20m and 0.90m. The Nordelph Peat was encountered as soft, dark brown and black, silty, organic clay and fibrous peat. A 0.20m thick layer of soft, grey, silty clay Alluvium was locally encountered overlying the Nordelph Peat in WS3.

The base of the Nordelph Peat was met at 2.10m, 2.30m and 2.45m respectively in TP1, TP2 and WS3.

Glaciolacustrine Deposit

The Glaciolacustrine Deposit was encountered underlying the made ground at depths of between 1.00m and 2.00m in the majority of the exploratory holes across the site.

Along the south-eastern margin of the site, within TP1, TP2 and WS3, the Nordelph Peat overlay Glaciolacustrine Deposit at depths between 2.10m and 2.45m.

The Glaciolacustrine Deposit was absent in WS1 where the made ground rested on the Oxford Clay Formation at 1.70m depth.

The Glaciolacustrine Deposit comprised variable intebedded layers or lenses of soft and firm, brown grey, orange brown, light brown and grey, silty clay; slightly gravelly clay; and slightly sandy, slightly gravelly clay. The gravel fraction comprised angular to sub-rounded flint, quartzite and fossil shell fragments.

Trial pits TP4 TP5, TP6 and TP7 were completed within the Glaciolacustrine Deposit at depths between 2.00m and 2.20m.

The base of the Glaciolacustrine Deposit was encountered at between 2.00m and 2.90m depth in WS2, WS3,WS4, WS5, TP1, TP2 and TP3.

Oxford Clay Formation

The underlying solid geology of the Oxford Clay Formation was present at depths between 2.00m and 2.90m and comprised firm, locally stiff, fissured, brown, orange brown and grey, silty clay. Locally it contained occasional sand size selenite crystals and pyrite nodules. Boreholes WS2, WS3,WS4 and WS5, and trial pits TP1, TP2 and TP3 were completed at depths between 3.10m and 4.45m depth within the firm or stiff Oxford Clay Formation.

Groundwater

Groundwater was encountered in TP1 and TP3 at 1.30m and 2.80m depth respectively. The remaining trial pits and the boreholes were all dry on completion at depths of 2.00m and 4.45m.

Return visits undertaken on 13 and 21 September and 4 October 2022 recorded standpipe water levels of between 1.50m and 2.14m in WS2, WS3 and WS4.

Evidence of Contamination

Visual and olfactory evidence of petroleum fuel pollution was observed within the made ground in WS2 at depths between 0.10m and 2.00m; and in TP3 at depths between 0.30m and 1.80m. The source of pollution is believed to be related to the historical refueling of vehicles and the storage of fuel on site. Locally in trial pit TP1 a fragment of cement bonded asbestos sheet was observed in the made ground between 0.30m and 0.80m depth.

Live Roots

Live roots were observed to depths between 1.20m and 3.00m within WS1, WS3, TP3, TP4, TP6 and TP7.

COMMENTS ON THE GROUND CONDITIONS IN RELATION TO FOUNDATION DESIGN AND CONSTRUCTION

The client proposes the construction of approximately eighteen dwellings with associated garden areas.

The strata encountered in the exploratory holes comprised between 0.90m and 2.10m thickness of made ground, which over the majority of the site rested on Glaciolacustrine Deposits. The underlying solid geology of the Oxford Clay Formation was present at depths between 2.00m and 2.90m.

Along the south-eastern margin of the site, within TP1, TP2 and WS3, the made ground overlay the Nordelph Peat and Alluvium, which was present with a thickness of between 0.20m and 0.90m.

The made ground, Nordelph Peat and Alluvium are all considered unsuitable as a founding stratum and spread foundations should be taken through these strata and placed within the underlying Glaciolacustrine Deposits or Oxford Clay Formation.

Depth of Strip and Pad Foundations

The depth of the footings would need to be deep enough to protect against the effects of soil desiccation or soil heave within clay layers of Glaciolacustrine Deposits or the Oxford Clay Formation.

Laboratory testing the near surface clay within the Glaciolacustrine Deposits and Oxford Clay Formation gave modified plasticity indices of between 14% and 64%, which indicates low to high volume change potential, according to the National House Building Council (NHBC) Standards Chapter 4.2 "Building near Trees" (2022). Guidance on the necessary foundation depths relating to tree species, distance and soil plasticity can be determined from the latter document, which should also be consulted where new planting is proposed.

In order to address any potential future shrinkage or heave effects, a high volume change potential has been assumed for the clay beneath the site. At an open position well away from the influence of trees and shrubs a minimum foundation depth of 1.00m below ground level or finished floor level, whichever is deepest, would be required for foundations in order to avoid the zone of seasonal volume change in accordance with the above document.

The following minimum foundation depths, presented in Table 5 would be considered appropriate for footings located at specified distances from trees such as mature Silver Birch, Sycamore and Willow.

Table 5	**NHBC Appendix 4.2 Foundation depth at specified distance from mature tree**					
	1m	**7m**	**12m**	**17m**	**20m**	**30m**
Minimum foundation depths for low water demand trees such as Birch	1.70m	1.00m	1.00m	1.00m	1.00m	1.00m
Minimum foundation depths for medium water demand trees such as Sycamore	2.35m	1.85m	1.40m	1.00m	1.00m	1.00m
Minimum foundation depths for high water demand trees such as Willow	>2.50m	>2.50m	2.50m	1.10m	1.85m	1.00m

The specified design depths are for footings placed within the Glaciolacustrine Deposits and Oxford Clay Formation. It is recommended that a full survey of tree species is completed prior to final foundation design and also appropriately deepened foundations should be adopted in areas where trees have been removed. Foundations should be suitably designed to prevent excessive movement due to heave.

It is recommended that the depth of footings is scheduled on a plot by plot basis.

Traditional Foundation Bearing Pressures

Foundation options comprise the construction of traditional footings, which could be placed within the Glaciolacustrine Deposits and Oxford Clay Formation. The following allowable bearing pressures (Table 6), which incorporate a factor of safety of 3.0 against general shear failure in clay, should be considered for foundations taken through the made ground, Nordelph Peat and Alluvium, and placed within the soft or firm Glaciolacustrine Deposits or firm or stiff Oxford Clay Formation at depths between 1.00m and 3.00m. Settlements would be expected to be less than 25mm at these pressures.

Table 6: Allowable bearing pressures for settlement of less than 25mm

Stratum	Foundation Depth	Pad Footing		Strip Footing
		1.0m wide	2.0m wide	1.0m wide
Glaciolacustrine Deposit	1.00m-2.50m	75kN/m^2	70kN/m^2	65kN/m^2
Oxford Clay Formation	2.00m-3.00m	110kN/m^2	100kN/m^2	90kN/m^2

If the anticipated loads for the proposed dwellings are in excess of the available bearing properties within the near surface soils, the loads will need to be transferred to the soils at greater depth using bored, CFA or driven piles. Further ground investigation in the form of a deep borehole would be necessary in order to provide information to inform the design of piled foundations.

Floor Slabs

All topsoil, uncontrolled or untreated fill, organic matter, soft, disturbed soil should be removed from beneath proposed floor slab areas. The exposed surface should be proof-rolled to expose any excessively soft or compressible zones, which should also be removed. Coarse-granular backfill should then be placed in layers and subjected to controlled compaction.

In the parts of the site where the made ground is less than 1m thick, consideration could be given to ground bearing floor slabs. In areas where an increased thickness was present consideration should be given to suspending the floors on foundations.

It is recommended that all areas, which lie within the zone of influence of trees, should be inspected and any root infested clay is removed and replaced with well graded, compacted coarse grained fill material in accordance with the recommendations in NHBC Standards Chapter 4.2. Suspended floors with voids, in accordance with Table 7 of the latter document, should also be used in situations where heave could occur within the area bounded by the foundations.

Foundation Excavations and Groundwater

Following preparation, the base of foundation excavations should be inspected to ensure that the condition of the soil complies with that assumed in design. Should pockets of inferior material be present, they should be removed and replaced with well graded hardcore or lean mix concrete. Water should be excluded from foundation excavations, otherwise rapid and significant loss of bearing capacity may occur. The excavated surface should be protected from deterioration and a blinding layer of concrete used where foundations are not completed without delay.

Groundwater was encountered in TP1 and TP3 at 1.30m and 2.80m depth respectively. The remaining trial pits and the boreholes were all dry on completion at depths of 2.00m and 4.45m. Return visits undertaken on 13 and 21 September and 4 October 2022 recorded standpipe water levels of between 1.50m and 2.14m in WS2, WS3 and WS4.

The observations indicate that whilst excavations may be initially dry, when left open groundwater should be expected to stand at depths between 1.50m and 2.20m. It is expected that shallow excavations could encounter water seepages due to surface infiltration, which would be more prevalent following periods of wet weather.

It is likely that water ingress within excavations in the short term could be controlled by screened sump pump techniques.

Buried Concrete

Test results from samples of made ground, Nordelph Peat, Glaciolacustrine Deposits and Oxford Clay Formation to determine the risk of sulphate attack on buried concrete, indicate levels that fall into Classes DS-1 and DS-2, as defined by Table C2 of BRE Special Digest 1, 2005. The pH results indicate slightly acidic to slightly alkaline ground conditions with pH values ranging between 6.2 and 8.3.

For the purposes of design an Aggressive Chemical Environment for Concrete (ACEC) Class of AC-2 should be considered when specifying a Design Chemical Class (DC Class) for concrete used within footings on this site.

Peat and Oxford Clay Formation are listed in the latter publication as being a stratum that may contain sulphides, such as pyrite, hence oxidation due to disturbance during the excavation of foundations may increase the total potential sulphate content. Arisings from the Oxford Clay should not be re-used under the buildings as there would be a potential for oxidation of any pyrite present and, in the long term, possible thaumasite formation.

An extract of Table C2, Aggressive Chemical Environment for Concrete (ACEC) site classification, from BRE Special Digest 1, 2005 is presented in Appendix 6.

COMMENTS ON SOIL CHEMICAL TESTING

The results of the laboratory chemical testing on near surface soil samples have primarily been compared to soil screening values (SSVs) produced by Land Quality Management Limited (LQM) and the Chartered Institute for Environmental Health (CIEH) presented in their document 'The LQM/CIEH S4ULs for Human Health Risk Assessment: 2015 (Publication Number S4UL3608)'. The LQM/CIEH S4ULs are intended for use in assessing the potential risks posed to human health by contaminants in soil and are transparently-derived and cautious 'trigger values' above which further assessment of the risks or remedial action may be needed. The S4ULs (Suitable for Use Levels) have been derived, in accordance with UK legislation and Environment Agency policy, using a modified version of the Environment Agency CLEA 1.06 software.

Reference has also been given to ATRISKsoil soil screening values produced by Atkins Limited and provided under licence to Ground Engineering Limited. Atkins SSVs have been derived in line with the Environment Agency 2009 guidance using the CLEA 1.071 software. With the absence of a S4UL for cyanide the ATRISKsoil SSV has been used as the soil screening criteria within this report.

In 2014 the Department for Environment Food and Rural Affairs (DEFRA) published, in their document SP1010, Category 4 Screening Levels (C4SL) for several contaminants including lead. The C4SL represent screening levels below which the land could be considered suitable for a specified use and definitely not contaminated land in respect of those determinands. With the absence of S4UL for lead the C4SL has been used as the soil screening criteria within this report.

For each contaminant the adopted soil screening criteria have been calculated for the following land uses:

- Residential use with home grown produce
- Residential use without home grown produce
- Public Open Spaces Near Residential Housing

The intended purpose of the SSVs are as "intervention values" in the regulatory framework for assessment of human health risks in relation to land use. These values are not binding standards but are intended to inform judgements about the need for action to ensure that a new use of land does not pose any unacceptable risks to the health of the intended users.

Tables 7 & 8 compare the test results for the made ground with the SSVs in relation to the specified uses. The number of test results, which exceed these values, are also provided.

Residential usage values are considered appropriately conservative screening values for the proposed housing development.

Table 7: Comparison of Chemical Test Results for Near Surface Soil with Soil Screening Values (SSV)

Determinand	Number of Samples	Min Value (mg/kg	Max Value (mg/kg)	Number of Samples Exceeding SSV for:			Measured 95th Percentile (mg/kg)	Soil Screening Values (SSV) (1% SOM)			
				Residential with home grown produce	Residential without home grown produce	Public Open Spaces Near Residential Housing		Assessment Method	Residential with home grown produce (mg/kg)	Residential without home grown produce (mg/kg)	Public Open Spaces Near Residential Housing (mg/kg)
Organic matter	12	1.5%	16%	-	-	-	-	-	-	-	-
Arsenic	12	4.5	18	0	0	0	12.70	S4UL	37	40	79
Cadmium	12	<0.10	0.32	0	0	0	0.23	S4UL	11	85	120
Total Chromium	12	5.7	24	0	0	0	17.93	S4UL	910	910	1500
Hexavalent Chromium	12	<0.50	<0.50	0	0	0	<0.50	S4UL	6	6	7.7
Lead	12	21	1100	2	2	1	139.31	C4SL	200	310	630
Mercury	12	0.05	6.1	0	0	0	1.73	S4UL	11	15	40
Selenium	12	0.25	0.76	0	0	0	0.60	S4UL	250	430	1100
Nickel	12	6.4	25	0	0	0	17.73	S4UL	130	180	230
Phenols	12	<0.10	<0.10	0	0	0	0.10	S4UL	120	440	440
Copper	12	8.2	50	0	0	0	33.60	S4UL	2400	7100	12,000
Zinc	12	52	290	0	0	0	169.80	S4UL	3700	40,000	81,000
Free Cyanide	12	<0.50	0.70	0	0	0	0.55	ATRISK	34	34	34

Notes
S4UL and C4SL for metals were derived using 6% SOM. These values are not sensitive to SOM and would also be applicable for 1% SOM and 2.5% SOM

ATRISKsoil SSVs produced by Atkins Limited and provided under licence to Ground Engineering Limited

Table 8: Comparison of PAH Chemical Test Results for Near Surface Soil with Soil Screening Values (SSV)

Determinand	Number of Samples	Min Value (mg/kg)	Max Value (mg/kg)	Number of Samples Exceeding SSV for:			Measured 95th Percentile (mg/kg)	Assessment Method	Soil Screening Values (SSV) (1% SOM)		
				Residential with home grown produce	Residential without home grown produce	Public Open Spaces Near Residential Housing			Residential with home grown produce (mg/kg)	Residential without home grown produce (mg/kg)	Public Open Spaces Near Residential Housing (mg/kg)
Acenaphthene	12	<0.10	0.29	0	0	0	0.15	S4UL	210	3000	15,000
Acenaphthylene	12	<0.10	0.28	0	0	0	0.14	S4UL	170	2900	15,000
Anthracene	12	<0.10	4.1	0	0	0	1.16	S4UL	2400	3100	74,000
Benzo[a]anthracene	12	<0.10	9.7	1	0	0	3.33	S4UL	7.2	11	29
Benzo[a]pyrene	12	<0.10	11	2	2	1	3.78	S4UL	2.2	3.2	5.7
Benzo[b]fluoranthene	12	<0.10	12	4	2	1	4.37	S4UL	2.6	3.9	7.1
Benzo[g,h,i]perylene	12	<0.10	6.2	0	0	0	1.62	S4UL	320	360	640
Benzo[k]fluoranthene	12	<0.10	4.7	0	0	0	1.71	S4UL	77	110	190
Chrysene	12	<0.10	7.3	0	0	0	2.82	S4UL	15	30	57
Dibenzo[a,h]anthracene	12	<0.10	1.8	2	1	1	0.51	S4UL	0.24	0.31	0.57
Fluoranthene	12	<0.10	23	0	0	0	7.49	S4UL	280	1500	3100
Fluorene	12	<0.10	0.68	0	0	0	0.24	S4UL	170	2800	9900
Indeno[1,2,3-cd]pyrene	12	<0.10	6.0	0	0	0	1.58	S4UL	27	45	82
Naphthalene	12	<0.10	0.52	0	0	0	0.20	S4UL	2.3	2.3	4900
Phenanthrene	12	<0.10	12	0	0	0	3.68	S4UL	95	1300	3100
Pyrene	12	<0.10	26	0	0	0	8.27	S4UL	620	3700	7400

Notes

ATRISKsoil SSVs produced by Atkins Limited and provided under licence to Ground Engineering Limited

Discussion of Results

With exception of lead and several PAHs, none of the determinand concentrations in the twelve near surface soil samples exceeded the respective SSV for residential with home grown produce, residential without home grown produce end use, or for public open spaces near residential housing usage.

In five of the twelve made ground samples one or more of the determinands, lead, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene and dibenzo[a,h]anthracene, exceeded the respective SSV for residential with home grown produce, and residential without home grown produce end use. Benzo[a]pyrene, benzo[b]fluoranthene and dibenzo[a,h]anthracene, exceeded the respective SSV for public open spaces near residential housing usage.

Visual and olfactory evidence of petroleum fuel pollution was observed within the made ground in WS2 between 0.10m and 2.00m depth; and in TP3 between 0.30m and 1.80m depth. The source of pollution is believed to be related to the historical refueling of vehicles and the storage of fuel on site. Visual and olfactory evidence of petroleum fuel pollution was not noticed in the remaining boreholes.

A summary of the TPH results is provided below in Table 9.

Table 9: Summary of Petroleum Hydrocarbon Test Results in Soil

Depth m	Concentration of Total Petroleum Hydrocarbons (TPH) in soil mg/kg (s) and water µg/l (w)				
	WS1	WS2	WS3	WS4	WS5
0.30	<10s	1400s	<10s		
0.50				<10s	
0.60	140s	260s			<10s
0.90	<10s	110s			
1.65			<10w		
1.90-1.95	130000w			<10w	
2.00		<10s			

Depth m	Concentration of Total Petroleum Hydrocarbons (TPH) in soil mg/kg (s) and water µg/l (w)						
	TP1	TP2	TP3	TP4	TP5	TP6	TP7
0.20				<10s			
0.40						<10s	<10s
0.60		<10s			<10s		
0.70	<10s			<10s			
0.80			<10s				

Whilst asbestos was not encountered in the screened soil samples, a fragment of cement bonded asbestos sheet was observed in the made ground between 0.30m and 0.80m depth in trial pit TP1.

GROUNDWATER QUALITY ASSESSMENT

Water samples were recovered from the standpipes in WS2, WS3 and WS4 and tested for a wide range of potential contaminants including metals, phenols, PAHs and TPH. The primary assessment tool employed for the generic screening of samples for the protection of 'Controlled Waters' comprised the Statutory Instrument 2016 No.614, which supersedes Statutory Instrument 2000 No.3184 'The Water Supply (Water Quality) Regulations 2000'. The latter document amends the 1991 version, which provides a standard of 10µg/l for dissolved or emulsified hydrocarbons represented by total petroleum hydrocarbons (TPH) in the chemical analysis. There is no amendment indicated in Statutory Instrument 2000 No.3184 and consequently with the absence of an amendment or update we refer to the 1991 standard, which is generally accepted within the industry. In summary Table 10 compares the chemical test results on water samples with the adopted water screening criteria (WSC). The number of test results, exceeding the WSC are also provided.

Table 10: Comparison of Chemical Test Results, on water recovered from borehole WS2, WS3 and WS4 with Water Supply Regulations

Determinand	**No of Samples**	**Min. Value**	**Min. Value**	**No of Samples Exceeding WSC**	**WSC** **The Water Supply (Water Quality) Regulations 1989-2016 Maximum Concentration/Value for Consumers Taps**
pH value	3	7.2	7.3	0	6.5 minimum 9 maximum
Arsenic (total) µg/l	3	0.89	6.6	0	10 µg/l
Boron (Water Soluble) µg/l	3	440	680	0	1000 µg/l
Cadmium (total) µg/l,	3	<0.11	<0.11	0	5.0 µg/l
Chromium (total) µg/l	3	0.53	1.9	0	50 µg/l
Copper (total) µg/l	3	<0.50	1.1	0	2000 µg/l
Cyanide (total) mg/l	3	<0.050	<0.050	0	0.05 mg/l
Lead (total) µg/l	3	<0.50	<0.50	0	10 µg/l
Mercury (total) µg/l	3	<0.50	<0.50	0	1.0 µg/l
Selenium (total) µg/l	3	2.3	5.1	0	10 µg/l
Nickel (total) µg/l	3	4.7	46	0	20 µg/l
Zinc (total) µg/l	3	4.4	11	0	5000 µg/l
Sulphate (soluble) mg/l	3	93	1500	2	250 mg/l
Phenols mg/l	3	<0.030	0.38	1	0.0005 mg/l
PAHs µg/l	3	<0.20	<0.20	-	0.10 µg/l
TPH µg/l	3	<10	130000	1	10 µg/l

Discussion of Results of Water Analysis

Concentrations of sulphate and petroleum were encountered exceeding the drinking water standards. The remaining determinands all had concentrations less than the drinking water standards.

A significant presence of petroleum hydrocarbons was measured within the water sample taken from WS2, which was located next to the surface mounted diesel tanks. The TPH fell mainly in the C12 to C35 diesel range.

SOIL GAS

Soil gas and water monitoring of the standpipe in boreholes WS2, WS3 and WS4 was conducted on 13, and 21 September and 4 October 2022.

Within WS3 and WS4 concentrations of less than 0.1% by volume methane was encountered with carbon dioxide concentrations of 2.8% and 6.5% by volume. Oxygen levels of between 15.2% and 17.6% were measured.

Within WS2 concentrations of between 1.6% and 6.9% by volume methane was encountered with carbon dioxide concentrations of 13.3% and 15.4% by volume. Very low oxygen levels of between less than 0.1% and 0.3% were measured.

The results indicate a Gas Screening Value (GSV) of 0.0069l/hr for methane and 0.0156l/hr for carbon dioxide.

The GSV fall into Characteristic Situation 2 as defined by BS8485:2015+A1:2019 'Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings'.

UPDATED CONCEPTUAL MODEL

A generalised conceptual model, updated following the intrusive works, monitoring and testing, is presented below in Table 11 and follows the comparison of consequence against probability presented in CIRIA 552.

Table 11: Updated Conceptual Model & Risk Assessment Relative to Construction and Future Development

Source	Pathway	Receptor	Probability of risk being realised	Consequence of risk being realised	Risk Classification
Asbestos in Existing Buildings	Inhalation of Dust	Human Health Demolition/ Construction Workers	High	Severe	Very High Risk
Petroleum Impacted made ground, natural soil & groundwater beneath site (in vicinity of fuel tanks and fuel lines)	Ingestion and Inhalation of contaminated Soil, Dust and Vapour	Human Health Groundworkers	Likely	Medium	Moderate Risk
		Human Health Site Users if exposed at surface	Likely	Medium	Moderate Risk
		Human Health Site Users if present beneath permanent hardstanding/roads	Likely	Medium	Moderate Risk
	Migration through ground into surface water or groundwater	Water Environment	Likely	Medium	Moderate Risk
Made Ground Soil Beneath Site	Ingestion and Inhalation of contaminated Soil, Dust and Vapour	Human Health Groundworkers	Likely	Minor	Low Risk
		Human Health Site Users if exposed at surface	Likely	Minor	Low Risk
		Human Health Site Users if present beneath permanent hardstanding/roads	Unlikely	Minor	Very Low Risk
	Migration through ground into surface water or groundwater	Water Environment	Unlikely	Minor	Very Low Risk

Source	Pathway	Receptor	Probability of risk being realised	Consequence of risk being realised	Risk Classification
Natural Soil Beneath Site	Ingestion and Inhalation of contaminated Soil, Dust and Vapour	Human Health Groundworkers	Unlikely	Minor	Very Low Risk
		Human Health Site Users if exposed at surface	Unlikely	Minor	Very Low Risk
		Human Health Site Users if present beneath permanent hardstanding/roads	Unlikely	Minor	Very Low Risk
	Migration through ground into surface water or groundwater	Water Environment	Unlikely	Minor	Very Low Risk
Soil Gas	Inhalation of Soil Gas	Human Health Groundworkers	Likely	Minor	Low Risk
		Human Health Site Users	Likely	Minor	Low Risk
Ground Contamination Outside Site boundary	Ingestion and Inhalation of contaminated Soil, Dust and Vapour	Human Health Groundworkers	Unlikely	Minor	Very Low Risk
		Human Health Site Users	Unlikely	Minor	Very Low Risk
	Migration through ground into surface water or groundwater	Water Environment	Unlikely	Minor	Very Low Risk

Key to Table 11 **Risk**	**Definition**
Very High risk	There is a high probability that severe harm could arise to a designated receptor from an identified hazard, or there is evidence that severe harm to a designated receptor is currently happening. The risk, if realised, is likely to result in a substantial liability. Urgent investigation (if not undertaken already) and remediation are likely to be required.
High risk	Harm is likely to arise to a designated receptor from an identified hazard. Realisation of the risk is likely to present a substantial liability. Urgent investigation (if not undertaken already) and remedial works may be necessary in the short term and likely over the long term.
Moderate risk	It is possible that harm could arise to a designated receptor from an identified hazard. However, it is either relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that the harm would be relatively mild.
Low risk	It is possible that harm could arise to a designated receptor from an identified hazard, but it is likely that this harm, if realised, would at worst normally be mild.
Very Low risk	There is a low possibility that harm could arise to a receptor. In the event of such harm being realised it is not likely to be severe.

COMMENTS ON GROUND CONTAMINATION IN RELATION TO PROPOSED RESIDENTIAL DEVELOPMENT

The ground investigation works have been carried out in advance of proposed development, which comprises the construction of approximately eighteen dwellings with associated garden areas.

This investigation may not have revealed the full depth or extent of made ground or contamination on the site and appropriate professional advice should be sought if subsequent site works reveal materials that appear to be contaminated.

Anticipated exposure scenarios relating to the site and future use, in the context of the conceptual model, are discussed as follows.

Asbestos in Existing Buildings

The site contains a dilapidated, 15m wide by 20m long, steel portal frame building with cement bonded asbestos sheet roofing and side cladding centrally located within the site together with small derelict outbuildings and portacabins. It would be recommended that an asbestos survey is conducted prior to any demolition or building works. Asbestos presents a very high risk and consequently suitable precautions, in line with current best practice, should be put in place to protect workers from the effects of asbestos material, during demolition or building works. Care should be taken to during demolition to ensure that asbestos fragments or fibres are not spread onto other areas of the site or get mixed into the soil.

Contamination Risk – Oil/Petroleum Pollution

About 15m to the north-east of the site entrance off Main Street there were two steel box (3.0m by 1.5m by 1.5m) surface mounted fuel tanks, which stood on a plinth over a 1.5m high and 2m wide by 8m long block constructed bund. There is significant evidence that leakage or a spillage of fuel oil has occurred within this area impacting both the underlying soil and groundwater.

It is recommended that all the sources of pollution are established and removed. Further investigation would be necessary to establish the extent of oil pollution and when redevelopment is considered, the removal of all such sources would be recommended in order to eliminate future risk. This would include the decommissioning and removal from across the whole site of all buried or surface fuel/oil tanks, fuel lines, drums, chemicals and oil interceptors. The latter measures should reduce the future risk to human health and water environment from moderate/high to low.

Contamination Risk - Near Surface Soil

The exploratory holes encountered a capping layer of made ground, which had a thickness between 0.90m and 2.10m. The made ground encountered across the site comprised brown, red brown, dark brown, grey brown, grey and black mixed layers of sandy gravel: gravelly sand, and soft and firm slightly sandy, slightly gravelly clay. The gravel fraction typically comprised angular to sub-rounded brick, concrete, asphalt, mortar, ash, bone, flint, limestone, igneous rock and ironstone.

The presence of elevated lead and PAH concentrations, associated with the presence of ash and clinker means that the made ground would be considered unsuitable at the surface within garden areas. Additionally a fragment of cement bonded asbestos sheet was observed in the made ground between 0.30m and 0.80m depth within TP1.

Human Health - Construction Workers

No special precautions would be required during the development of the site by workers who may come into contact with the soil during groundworks, providing standard precautions are adopted, which should generally include the procedures given by the Health and Safety Executive (The Blue Book).

For the protection of these workers during groundworks the following is recommended:

a) Limit repeated or prolonged skin contact with soils by wearing gloves with sleeves rolled down.

b) Washing facilities should be made available to groundworkers, so as to minimise the potential for inadvertent ingestion of soil.

c) If any soils are revealed, which are different to those encountered by this ground investigation, the advice of a specialist should be sought in view of classifying the material and ascertaining its risk to groundworkers.

d) Suitable precautions should be implemented if asbestos containing materials are encountered in the ground.

e) Suitable precautions should be implemented if workers are to enter deep excavations as reduced oxygen levels are present in the ground.

<u>Human Health – Residential Usage</u>

The made ground should be considered unsuitable for use at the surface within landscape or residential garden areas. Unsuitable soil at the surface within gardens or landscaped areas should be replaced with a suitably thick, clean capping layer.

- For front garden areas it would be recommended that the underlying natural ground be exposed, or in deeper areas the made ground should be removed to a minimum depth of 0.60m and replaced with an equivalent thickness of clean inert soil.
- For rear gardens it is recommended that the underlying natural ground should be exposed, or in deeper areas the made ground should be removed to a minimum depth of 1.00m and replaced with an equivalent thickness of clean inert soil.

All garden/landscaped areas should be inspected prior to final capping to ensure that unsuitable materials have not been inadvertently placed in the garden or landscaped areas during the preceding stages of redevelopment works.

All imported soils should be certified ‘clean’ fill and should be suitable for use in accordance with UK legislation and Environment Agency policy.

Methane and Carbon Dioxide Soil Gas

The presence of elevated methane (of up to 6.9% by volume) and carbon dioxide (of up to 15.4% by volume) concentrations combined with the observed low flow/emission rate indicates that for design purposes it would be prudent to adopt a CS2 soil gas categorisation as defined by BS8485:2015+A1:2019 ‘Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings’.

Tables 3 to 7 within this British Standard identify a points-based method for defining the need for gas precaution measures. Based on this method and on the basis of a Type A building (representative of a private dwelling), a minimum gas protection score of 3.5 would be required and could be achieved using a ventilated underfloor void, a low permeability gas membrane, and minimal penetration of the ground slab by services.

Off-Site Disposal of Soil Arisings

The results of chemical analysis are provided in Appendix 5 and can be used within the suite of information necessary for basic characterisation of the soil destined for landfill. Excavated material and excess spoil should always be classified prior to removal from site as required by 'Duty of Care' (Environmental Protection Act, 1990) legislation. This means that material has to be given a proper description and waste classification prior to removal. Basic characterisation is the responsibility of the waste producer and compliance checking and on-site verification are generally the responsibility of the landfill operator. The landfill operator will need to liaise with the waste producer as the approach relies on the information from basic characterisation.

The clean arisings from the underlying natural soils, excluding peat and topsoil, across this site should fall under the EWC code 17 05 04 inert category.

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