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EXECUTIVE SUMMARY

This executive summary contains an overview of the key findings and conclusions. No reliance should be placed on any part of the executive summary until the whole of the report has been read. Other sections of the report may contain information that puts into context the findings that are summarised in the executive summary.

BRIEF

This report describes the findings of a ground investigation carried out by Geotechnical and Environmental Associates Limited (GEA), on the instructions of Stephen Howard Homes, with respect to the construction of two new three storey blocks of flats together with associated basement parking and landscaping areas. The purpose of the investigation has been to identify the ground conditions, to assess the extent of any contamination and to provide information to assist with the design of suitable foundations. A desk study has previously been carried out by GEA (report ref J07229, dated August 2007).

GROUND CONDITIONS

Beneath a generally moderate thickness of made ground, extending to a maximum depth of 1.5 m, variably silty sandy clay soils graded into clayey sandy gravel of the Glacial Sand and Gravel which extended to depths of between 2.0 m and 5.3 m. Beneath this stratum, Upper Chalk was encountered and was proved to the maximum depth investigated of 20.0 m.

A hydrocarbon odour was noted within the made ground at a single location and grey staining and a malodour was noted within the glacial deposits at two locations and the chalk below a depth of 9.0 m.

Ground water was encountered within the Glacial Sand and Gravel at two locations at a depth of 3.5 m and within the chalk at depths of between 6.1 m (93.75 mTBM) and 8.4 m (91.24 m TBM) during the investigation and was subsequently measured at depths of 2.4 m (97.4 mTBM), 3.0 m (97.01 m TBM) and 2.6 m (96.89 m TBM) during the monitoring of the standpipes.

Results of chemical analysis have identified hydrocarbon contamination to be present within the made ground, glacial deposits and Upper Chalk and the groundwater has also been significantly impacted by hydrocarbon contamination. Results of soil gas monitoring have revealed anomalous soil gas conditions around the location of the tank farm in the southern part of the site.

RECOMMENDATIONS

A basement raft foundation placed in the clay, chalk or gravel may be the most appropriate foundation solution as this would result in a reduced net applied foundation pressure and provide a reduced risk of being affected by any possible solution features. Alternatively, should a raft foundation not be considered structurally appropriate for the proposed buildings, consideration could be given to the use of reinforced strip foundations designed to span a notional 5 m diameter void which should be also extended at the corners of each building to provide a similar spanning capability. A piled foundation would also make a suitable alternative.

Elevated concentrations of hydrocarbons have been identified within the made ground, gravel and chalk and ground water. Remedial measures will therefore be required and are likely to involve the removal of tanks that are present below the southern part of the site and the treatment of the ground water. Further investigation will however be required to allow the required remediation to be determined.

Gas protection measures are unlikely to be required unless the proposals change.

Part 1: INVESTIGATION REPORT

This section of the report details the objectives of the investigation, the work that has been carried out to meet these objectives and the results of the investigation. Interpretation of the findings is presented in Part 2.

1.0 INTRODUCTION

Geotechnical and Environmental Associates (GEA) has been commissioned by Stephen Howard Homes to carry out a ground investigation at 253 Watford Road, Croxley Green. A desk study was previously carried out by GEA (report ref: J07229, dated August 2007) and has been referred to where appropriate.

1.1 Proposed Development

Consideration is being given to the construction of two new three storey apartment blocks with basement car parking, together with the provision of soft landscaping. This report is specific to the proposed development and the advice herein should be reviewed if the development proposals are amended.

1.2 Purpose of Work

The principal technical objectives of the work carried out were as follows.

- to determine the ground conditions and their engineering properties;
- to provide information on the design of spread and piled foundations;
- to investigate the soil gas conditions; and
- to provide an assessment of the presence of contamination.

1.3 Scope of Work

In order to meet the above objectives, a ground investigation was carried out which comprised, in summary, the following activities:

- a series of small diameter boreholes advanced using window sampling equipment;
- a series of dynamic probes;
- three cable percussion boreholes drilled to a maximum depth of 20.0 m;
- installation and monitoring of three gas and ground water monitoring standpipes;
- a soil vapour survey;
- laboratory testing of selected soil samples for geotechnical purposes and for the presence of contamination; and
- provision of a report presenting and interpreting the above data, together with our advice

and recommendations with respect to the proposed development.

1.4 Limitations

The conclusions and recommendations made in this report are limited to those that can be made on the basis of the investigation. The results of the work should be viewed in the context of the range of data sources consulted, the number of locations where the ground was sampled and the number of soil, gas or groundwater samples tested; no liability can be accepted for information in other data sources or conditions not revealed by the sampling or testing. Any comments made on the basis of information obtained from the client or other third parties are given in good faith on the assumption that the information is accurate; no independent validation of such information has been made by GEA.

2.0 THE SITE

The site is located between Rickmansworth and Watford approximately 200 m to the west of Croxley Green railway station. It is bounded by Watford Road to the south, houses to the west, a public house car park to the east and a railway embankment and car sales and vehicle repair garage to the north. It can additionally be located by National Grid Reference 508610, 195900.

Whilst the history and description of the site has been discussed in the previous report, the salient points are included below.

The site is occupied by a used car sales garage with a showroom in the western part of the site and some workshop / garages in the northern and eastern parts. A hand car wash is present in the northeastern corner and the remainder of the site is occupied by cars. An above ground oil tank is located adjacent to the northern boundary and the local petroleum officer has revealed the presence of five buried fuel tanks in the southern part of the site, one in the west and four in the east. The site is devoid of vegetation.

2.1 Site History

The site was first developed at some time between 1914 and 1939 with a garage and electrical engineers. The site remained unchanged until the 1970s when the layout and usage of the site changed to include a book manufacturer and a service station. The site has most recently been used as a used car sales centre and workshop. The desk study revealed that there are five underground fuel storage tanks which have reportedly been decommissioned and filled with cement slurry. There are also two additional disused tanks present below the site although no further information was available on the condition of these.

The Geological Survey map of the area shows the site to be underlain by Glacial Sand and Gravel over the Upper Chalk. Information obtained during the desk study revealed that the site is located in an area where solution features are prevalent.

2.2 Preliminary Risk Assessment

The ongoing use of the site as a garage which sold petrol and regularly serviced and maintained motor vehicles indicates a risk of a range of potential contaminants. Reference to the relevant DoE Industry Profile[1] indicates the main following potential contaminants:

[1] Department of the Environment Industry Profile (1996) *Road vehicle fuelling, services and repair: garages and filling*

- engine and lubricating oils;
- lighter oils from machining operations;
- lead from fuels;
- copper from engine bearings and other metals from engine parts:
- petroleum hydrocarbons from spillages and leakages;
- glycols and ethers from brake fluids;
- a range of solvents used in degreasers, thinners, fillers, adhesives, strippers and paints.

On the basis of the above it is considered that there is a moderate risk of there being contamination beneath this site as a result of former activities.

3.0 EXPLORATORY WORK

In order to meet the objectives described in Section 1.2, three cable percussion boreholes were drilled in accessible locations to a maximum depth of 20.0 m to provide information on the strength of the chalk and to facilitate the installation of gas and ground water monitoring standpipes. A series of 14 window sampler boreholes was advanced to a maximum depth of 6.0 m to investigate the shallow ground conditions and facilitate sample collection across the site for contamination purposes. A soil vapour survey was also carried out using a Photo-ionisation Detector (PID). Nine dynamic probes were advanced to check for the presence of loose zones indicating solution features. All of the work was supervised and coordinated by a geotechnical engineer from GEA.

3.1 Sampling Strategy

The borehole locations were chosen on site with due regard to the proposed layout and to investigate the presence of any contamination. The window sampler boreholes and dynamic probes were located to provide a good coverage of the site, whilst additional window sampler boreholes were concentrated around the tank farm. Insitu Standard Penetration Tests (SPTs) were carried out at regular intervals in the cable percussion boreholes and disturbed samples were recovered for subsequent geotechnical and contamination testing.

Gas and ground water monitoring standpipes were installed in the cable percussion boreholes to depths of between 7.0 m and 9.5 m and have been monitored on a single occasion, approximately two weeks after installation.

The analytical suite of testing was selected to investigate for the presence of the contaminants identified by the desk study. For this investigation the analytical suite included a range of metals, speciated total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAH), total cyanide, and monohydric phenols, and a range of specific fuel related hydrocarbons and fuel additives including VOCs and SVOCs. Samples of ground water were also analysed for a range of metals and speciated hydrocarbons. The contamination analyses were carried out at an

stations, HMSO

MCERTs accredited laboratory with the majority of the testing suite accredited to MCERTS standards. A summary of the MCERTs accreditation and test methods are included with the attached results and further details are available upon request.

The borehole and probe records and results of the laboratory analyses are appended, together with a site plan indicating the exploratory positions. The Ordnance Datum (OD) levels shown on the cable percussion borehole records were measured on site and relative to a manhole cover which was assigned a temporary benchmark value of 100 m TBM.

4.0 GROUND CONDITIONS

The investigation has encountered the expected ground conditions in that, beneath a moderate thickness of made ground, initially clay soils of the Glacial Sand and Gravel were encountered and underlain by Upper Chalk.

4.1 Made Ground

Beneath a concrete or tarmac surface, a generally moderate thickness of made ground was found to extend to depths of between 0.1 m and 1.5 m and comprised a mixture of rubble and brown silty sandy clay with gravel, brick, concrete and clinker. Some of the boreholes were terminated on concrete obstructions within the made ground towards the southern part of the site.

Visual and olfactory evidence of hydrocarbon contamination was observed at a single location in Borehole No 7 upstream of the tanks and selected samples of the made ground were analysed for a range of contaminants as a precautionary measure and the results are summarised in Section 4.5.

4.2 Glacial Sand and Gravel

This stratum was proved to depths of between 2.0 m and 5.3 m and initially comprised firm brown occasionally sandy clay with occasional gravel which graded into brown clayey gravel. SPTs indicated the gravel to be in a generally medium dense condition. A loose zone was encountered in Borehole No 3b at a depth of around 4.45 m.

Results of laboratory tests have indicated the clay to be of low volume change potential.

Some evidence of hydrocarbon contamination was identified within the gravel below a depth of 3.8 m in Borehole Nos 16 and 17, located upstream from the tanks in the southern part of the site and in Borehole No 7 below a depth of 3.5 m. Four samples of this material were analysed for speciated hydrocarbons and three for VOCs and SVOCs and the results are summarised in Section 4.5.

4.3 Upper Chalk

On the basis of the inspection of recovered samples, the chalk has been classified in accordance with CIRIA Report C574 (2002), *Engineering in Chalk*, with the chalk generally comprising gravel sized clasts of chalk in a comminuted chalk matrix, which was proved to the full depth of investigation of 20.0 m. The chalk was initially assessed as Grade Dc in the boreholes, although the sampling will have resulted in disturbance of the material and the recovered samples will not be indicative of the insitu condition.

In Borehole No 2, immediately to the west of a tank, a grey discolouration and a malodour was noted from a depth of around 9.0 m and the driller noted, that during drilling, the casing appeared to be scraping alongside an obstruction, probably a tank. Grey discolouration and a hydrocarbon odour was also noted below a depth of 4.0 m in Borehole No 6 in the northern part of the site and Nos 10a and 11 upstream of the tanks.

The results of the insitu testing carried out in the boreholes have been used to provide additional information on the material properties of the chalk. With reference to the table below, the results of SPTs indicate that the chalk is generally moderately sound becoming sound.

SPT 'N' Value (spoon)	Classification
<10	Highly Weathered
10 to 20	Weathered
20 to 30	Moderately sound
30 to 50	Sound
>50	Very Sound

The results of laboratory analysis of a single sample has identified the chalk to be of low density with a measured intact dry density of 1.54 Mg/m^3.

Four samples of chalk were analysed for speciated hydrocarbons and a single sample for VOCs and SVOCs and the results are summarised in Section 4.5.

4.4 Ground Water

Groundwater was encountered in Borehole Nos 7 and 9 within the Glacial Sand and Gravel at a depth of 3.5 m and ground water was encountered during drilling at depths of between 6.1 m (93.75 mTBM) and 8.4 m (91.24 m TBM) within the chalk. Water levels were measured in the standpipes installed in Borehole Nos 1, 2 and 3b at depths of 2.4 m (97.4 mTBM), 3.0 m (97.01 m TBM) and 2.6 m (96.89 m TBM) respectively.

The borehole levels indicate groundwater to be flowing in a southeasterly direction towards the River Gade.

Three samples of ground water were analysed for speciated hydrocarbon analysis and the results are discussed in Section 4.6.

4.5 Soil Contamination

Part IIA of the Environmental Protection Act 1990, which was inserted into that Act by Section 57 of the Environment Act 1995, provides the main regulatory regime for the identification and remediation of contaminated land. The determination of contaminated sites is based on a "suitable for use" approach which involves managing the risks posed by contaminated land by making risk-based decisions. This risk assessment is carried out on the basis of a source-pathway-receptor approach.

The use of a risk-based approach, which is presented in Part 2 of this report, means that it is not appropriate to determine the significance of contamination test results by simply comparing individual contaminant concentrations to a single "trigger" or "target" concentration. The significance of the results is therefore considered in more detail in Part 2, whilst the table below sets out the range of values measured within 15 samples of made ground tested for a general suite of contaminants and indicates the statistically weighted average concentrations.

Determinant	Maximum concentration recorded (mg/kg)	Minimum concentration recorded (mg/kg)	Number of samples below detection limit	Normalised upper bound US_{95}
Arsenic	12	7.9	0	10
Cadmium	1.3	<0.5	1	0.8
Chromium	33	17	0	25
Copper	540	17	0	134
Lead	140	27	0	101
Mercury	<0.6	<0.6	all	-
Nickel	31	<4	3	21
Selenium	<2.5	<2.5	all	-
Zinc	600	57	0	182
Total Cyanide	<1	<1	all	-
Total Phenols	<1	<1	all	-
PAH	63.2	<2	4	25
TPH	610	<25	4	239
Total Organic Carbon (TOC) %	14	0.7	0	4.3
Sulphide	88	<10	8	30

Note: The use of the normalised upper bound for 95[th] percentile confidence aims to remove some of the uncertainty associated with calculation of an arithmetic sample mean of a relatively small number of samples. The US95 value is the upper bound of the range within which it can be stated with 95% confidence that the true mean concentration of the data set will fall.
Figure in bold indicates concentration in excess of risk-based soil guideline values, as discussed in Part 2 of this report

A sample of made ground from Borehole No 1 recorded a TPH concentration of 3100 mg/kg although statistical analysis has revealed this result to be a statistical outlier and as such it has been omitted from the above table.

Nine samples were additionally selected for speciated hydrocarbon analysis and a maximum TPH concentration of 4500 mg/kg was identified within a sample of made ground from Borehole No 7. The speciation revealed the higher concentrations to be in the C21-C35 range which indicate diesel range organics or some form of heating or lubrication oil.

The highest total concentration recorded within the sand and gravel was 2000 mg/kg in Borehole No 7 and was also in the same range. The samples of the chalk that were tested did not reveal any elevated concentrations to be present although it is apparent from visual examination of the samples that they had been impacted by hydrocarbons to some extent.

4.6 Ground Water Contamination

Three samples of ground water were collected during the monitoring visit. The results have been compared to the Environmental Quality Standards for surface water (EQS)[2] and the Drinking Water Standards. No concentrations of metal contaminants were recorded above EQS levels although elevated concentrations of hydrocarbons were recorded above the drinking water standards at depths of 2.4 m (97.4 mTBM) and 3.0 m (97.0 mTBM). Concentrations of 0.58 mg/l and 15.91 mg/l upstream in Borehole Nos 1 and 2 in the north of the site and immediately adjacent to the tank farm respectively. Speciation of the results shows the higher concentrations to be in the C6 to C10 range which is indicative of petrol range organics.

4.7 Soil Gas

The soil vapour survey around the location of the tanks recorded a maximum reading of 312 ppm although this exercise was severely hampered by the presence of shallow obstructions in this area. A single round of gas monitoring has been carried out and has revealed elevated concentrations of methane and carbon dioxide and depleted concentrations of oxygen to be present in Borehole No 2. A nominal flow rate was also recorded in Borehole No 3b.

2 Water Framework Directive, *European Commission*, December 2000

Part 2: DESIGN BASIS REPORT

This section of the report provides an interpretation of the findings detailed in Part 1, in the form of a ground model, and then provides advice and recommendations with respect to foundation options and contamination issues.

5.0 INTRODUCTION

Consideration is being given to the redevelopment of the site through the construction of two new three storey blocks of flats together with basements, areas of car parking and soft landscaping. Loads are not known at this stage but are expected to be moderate and thus typical for this type of development.

6.0 GROUND MODEL

The desk study revealed that the site has had a potentially contaminative history having been occupied by a garage and having a tank farm present on site. On the basis of the fieldwork, the ground conditions at this site can be characterised as follows.

- A generally moderate thickness of made ground was proved to a maximum depth of 1.5 m;
- the underlying Glacial Sand and Gravel generally comprised firm brown clay which graded into clayey gravel and extended to depths of between 2.0 m and 5.3 m;
- weathered Upper Chalk was encountered which became moderately sound and was proved to the maximum depth investigated of 20.0 m;
- groundwater was encountered during the investigation at levels of between 93.75 mTBM and 91.24 m TBM and was subsequently measured at levels of 97.4 mTBM and 96.89 m TBM
- the results of the soil contamination analyses indicate that elevated concentrations of hydrocarbons are present in the made ground and natural soil; and
- the results of the ground water contamination analysis has identified that it has been significantly impacted by hydrocarbons.

6.1 Contaminants of Concern

The use of a risk-based approach has been adopted to provide an initial screening of the test results to assess the need for subsequent site specific risk assessments. To this end the table below indicates those contaminants of concern that have US95 values in excess of a generic human health risk based guideline value which is either that of the CLEA[3] Soil Guideline Value where available, or is a Generic Guideline Value calculated using the CLEA UK Beta Version 1.0

3 CLR 7 (2002) *Assessment of risks to human health from land contamination: an overview of the development of soil guideline values and related research*; CLR8 (2002) *Priority contaminants for the assessment of land*; CLR 9 (2002) *Contaminants in soil: collation of toxicological data and intake values*; CLR10 (2002) *The contaminated land exposure model (CLEA): technical basis and algorithms*, and reports CLR TOX1-25 and CLR SGV1-10, 15 and 16; all DEFRA and Environment Agency.

software assuming a residential end use. Where contaminant concentrations are measured in excess of these values it is considered that there is a potential for there to be some risk to human health and hence site specific risk assessment, soil remediation or risk management may be required. Values measured at concentrations below these values are not deemed to require further consideration with regard to human health.

The proposed development of the site comprises the construction of a new block of flats with associated areas of soft landscaping and therefore the site will have a "residential" end use.

The tables of generic screening values derived by GEA and an explanation of how each value has been derived are included in the Appendix.

Within the made ground elevated concentrations of TPH have been recorded in Borehole Nos 1 and 7 and are likely to be attributable to a localised spillages located towards the north of the site. In Borehole No7, a TPH concentration of 2000 mg/kg was also noted within the natural soils, which is approximately five times the guideline value.

The ground water contains TPH concentrations of 0.58 mg/l and 15.91 mg/l in Borehole Nos 1 and 2 respectively which significantly exceed the acceptable Drinking Water levels of 0.01 mg/l. Borehole No 2 was advanced adjacent to a tank and it is likely that the water recorded at this location is more representative of water perched within the tank excavation rather than reflecting the general ground water concentrations, particularly as Borehole No 3b, located downstream of the tanks did not record an elevated TPH concentration. As Borehole No 1 is located upstream of the tanks, the concentrations measured at this location may be originating from the garage immediately to the north or from other former source on the site. Inspection of the carbon bandings indicates that the sources of the contamination identified in Borehole Nos 1 and 2 are likely to be different.

In determining the significance of soil gas concentrations both the gas concentrations and borehole flow rates are used to define a characteristic situation for a site based on the limiting borehole gas volume flow, renamed as the Gas Screening Value (GSV) for methane and carbon dioxide. In this case the following GSVs have been determined, in accordance with guidance provided by CIRIA.[4]

Gas	Max concentration % vol.	Ave flow rate l/hr	GSV
Methane	0.9	0.3	0.003
Carbon dioxide	1.2	0.3	0.036

On the basis of the above the site is therefore defined as Characteristic Situation 1 and as having a very low risk. On the NHBC "traffic light" system[5] the site may be considered to be Green.

The implications of these results are discussed in Section 7.6.

4 Wilson, S, Oliver, S, Mallett, H, Hutchings, H and Card, G (2006) *Assessing risks posed by hazardous ground gases to buildings* CIRIA Report C659

5 Boyle, R and Witherington, P (2006) *Guidance on evaluation on development proposals on sites where methane and carbon dioxide are present, incorporating 'traffic lights'.* Report Ref 10627-R01-(02) for National House-Building Council

7.0 ADVICE AND RECOMMENDATIONS

Although the proposed loads are not known, it is likely that the proposed three storey building could be supported by spread foundations bearing in the firm clay or medium dense granular soils of the Glacial Sands and Gravels. Some remedial measures will be required with respect to the hydrocarbon contamination identified by this investigation.

7.1 Basement Construction

Monitoring of the standpipes has indicated that groundwater is likely to be encountered within the 3.0 m depth of basement excavation, although monitoring should be continued to confirm this and to identify any significant seasonal fluctuation in the level. The water levels measured in standpipes may not however be as significant as the volume of water that may flow into the excavation. For example, a high level of water measured in a standpipe may not be significant if this represents only a small volume of water which may for example be trapped around the buried tanks. It would therefore be prudent to carry out a number of trial excavations, to depths as close to the full basement depth as possible, to provide an indication of the likely ground water conditions.

The design of basement support in the temporary and permanent conditions needs to take account of the need to maintain the stability of the excavation and surrounding structures and to protect against ground water inflows. In order to achieve these aims a secant bored pile wall will be the most appropriate solution if continued standpipe monitoring or trial excavations indicate that groundwater inflows will affect the excavation and could have the advantage of being incorporated into the permanent works and may be able to provide support for structural loads.

The ground movements associated with the basement excavation will depend on the method of excavation and support and the overall stiffness of the basement structure in the temporary condition. Thus, a suitable amount of propping will be required to provide the necessary rigidity. In this respect the timing of the provision of support to the wall will have an important effect on movements. The railway embankment is close to the proposed block of flats in the north of the site and a check should be made once proposals have been finalised that the embankment will not be adversely affected by the basement excavation.

7.1.1 Basement Retaining Walls

The following parameters are suggested for the design of the permanent basement retaining walls.

Stratum	Bulk Density (kg/m³)	Effective Cohesion (c' – kN/m²)	Effective Friction Angle (ϕ' – degrees)
Made Ground	1800	Zero	25
Glacial Sand and Gravels (clay soils)	1900	Zero	25

The investigation has indicated that ground water is likely to be present within the 3 m deep basement excavation. Reference to Clause 3.4 of BS BS8102:1990 "Protection of Structures Against Water from the Ground" Clause 3.4 indicates that, for basements less than 4 m deep, it would be advisable to assume a design water level of three-quarters the full depth below ground, subject to a minimum of 1 m below ground level. Whereas, for basements that are deeper than 4 m a design water level of three-quarters the full depth below ground should be adopted.

7.1.2 Basement Heave

The basement excavation will lead to some heave movements, but any movements within the Glacial Sand and Gravel are likely to occur as immediate movements and are unlikely to be of a significant magnitude. It is however recommended that analysis is undertaken on the potential magnitude of heave once final levels and loads are known.

7.2 Spread Foundations

Although the site is located in an area which is prone to solution features, none have been identified during this investigation. A basement raft foundation placed in the clay, chalk or gravel may be the most appropriate foundation solution as this would result in a reduced net applied foundation pressure and provide a reduced risk of being affected by any possible solution features. It must be designed to span a notional 5 m diameter void and additional settlement analyses should be carried out, although at this stage it is considered that the loads associated with the proposed buildings, when applied across a raft foundation, are unlikely to result in excessive settlements.

Alternatively, traditional trench fill strip foundations may be appropriate to support the anticipated relatively light to moderate foundations loads which are envisaged. Moderately sized strip foundations bearing within the firm clay, chalk or medium dense granular soils of the Glacial Sand and Gravels at a depth of 3.0 m may be designed to apply a net allowable bearing pressure of 150 kN/m^2. This value incorporates an adequate factor of safety against bearing capacity failure and should ensure that settlements remain within tolerable limits. Foundations spanning both cohesive and granular layers should be suitably reinforced.

In order to mitigate the risks associated with possible solution features, strip or pad foundations should be suitably reinforced and designed to span a 5 m diameter void; the foundations should be extended beyond the corners of each building to provide a similar spanning capability.

7.3 Piled Foundations

For the ground conditions at this site some form of driven pile is likely to be the most appropriate. A conventional rotary augered pile is unlikely to be practical in view of the inflows of ground water within the gravel and high risk of consequent instability of pile bores. A continuous flight auger (cfa) pile would however be suitable.

The following parameters, based upon the guidance provided by CIRIA[6,7] for piles in chalk, are considered suitable for the preliminary design of straight-shafted bored piles installed using cfa techniques. The Glacial Sands and Gravel have been assumed to be predominately gravel for the purposes of these calculations in order to provide more conservative pile design parameters.

Ultimate Skin Friction

		kN/m^2
Basement Excavation	GL to 3.0 m	Ignore
Glacial Sands and Gravel (assuming gravel)	3.0 m to 5.0 m	5
Upper Chalk	5.0 m to 20.0 m	40

6 *Engineering in Chalk* CIRIA C574 (2002)
7 *Shaft Friction of cfa piles in chalk*, CIRIA Project Report 86 (2003)

Ultimate End Bearing		**kN/m²**
Upper Chalk	At 20 m	8000

On the basis of the above coefficients it has been estimated that a 450 mm diameter pile founding at a depth of 20.0 m below existing ground level should provide a safe working load of about 830 kN. These examples are based upon an overall factor of safety of 2.5.

Care should be taken in the construction of cfa piles in these types of soils. Careful control of concrete pressures and drilling rate will be required to maintain the pile shaft integrity in the made ground and care will need to be taken in the granular soils to avoid excessive overbreak, particularly if a pile diameter of 300 mm or less is adopted. In addition, as with any situation where bored piles are constructed in chalk, consideration will need to be given to the possibility of variations in the level and quality of the chalk and the possibility of undetected significant variations between borehole positions.

Prospective contractors should be consulted to determine how they intend to control and monitor the pile installation and with regard to their experience in similar ground conditions. The contractors should be provided with all of the exploratory data.

7.4 Excavations

Accurate assessment of the likely ease and stability of shallow excavations for foundations, pile caps and services is not readily available from the investigation techniques used; however on the basis of the borehole findings it is considered likely that it will be feasible to form relatively shallow excavations terminating within the made ground without the requirement for lateral support, although localised instabilities may occur.

Perched water may be encountered within the made ground, particularly in the vicinity of existing foundations and other buried structures although these occurrences should be adequately dealt with by sump pumping.

7.5 Basement Floor Slabs

The formation level of the basement floor slab will be within the firm clay and the formation level should therefore be proof rolled and any soft spots filled with a suitably compacted granular material prior to forming a ground bearing floor slab.

7.6 Effect of Sulphates

Chemical analyses of selected soil samples have revealed generally low concentrations of soluble sulphate, corresponding to Class DS-1 and DS-2 and AC-1s of Table C2 of BRE Special Digest 1: 2005. The guidelines contained in the above digest should be followed in the design of any new foundation concrete.

7.7 Contamination Risk Assessment

One of the requirements of the Environment Act (1995) is that local authorities carry out inspections of their area with a view to identifying sites that may be contaminated. When assessing whether a site is contaminated the local authority will attempt to establish the presence of a 'pollution linkage'. A pollution linkage requires there to be a source of contamination, a sensitive receptor that can be adversely affected by the contamination and a pathway via which contamination can reach the target. At this site, hydrocarbon contamination has been found within the natural soils and groundwater beneath the site. The highest recorded concentration is likely to be representative of water perched around the tank and the borehole which is downstream of the tanks has not recorded elevated concentrations of TPH. Borehole No 1, which is approximately 40 m upstream from the tanks, has identified a slightly different TPH composition, suggesting that it is not associated with the tanks and could have originated from another source of from the site to the north.

The following table provides a summary of the risk assessment and indicates where a pollution linkage has been established for which remedial action will be required. The linkages are based on the existing ground model and the comments indicate how remediation of the site will break the linkages.

SOURCE	RECEPTOR	PATHWAY	COMMENTS
Hydrocarbon contamination within natural soils and ground water	end users	vapours	provision of gas protection measures for the proposed buildings in the immediate vicinity depending upon the post remediation gas regime
		plant uptake	Importation of clean topsoil
	ground water	ground water	the groundwater has been found to be impacted by fuel related hydrocarbons to an unacceptable level. Remedial action will be required.
		percolation	Until recently, percolation has been restricted by existing buildings and hardstandings Introduction of landscaped areas may introduce a new pathway
	adjacent sites	ground water	Source removal and remedial measures will reduce liability
	site workers during construction	ingestion of contaminated soil or dust, skin contact, inhalation	protection from hydrocarbon contaminants during site works will be provided by adherence to normal high standards of site safety
	plastic services	direct contact	protection from residual hydrocarbon contaminants after remediation or non plastic pipes required should it not be possible to divert services away from the area of concern

Each of the potential pollution linkages is considered in more detail below and remedial measures to address each linkage are discussed in Section 8.

7.8 Protection of End Users

7.8.1 Direct Contact

New areas of landscaping are proposed at ground floor level and clean topsoil and subsoil will be required in these areas to provide a suitable growing medium for plants. At this stage it is recommended that a cover thickness of imported subsoil and topsoil of 450 mm in thickness should be specified to ensure successful plant growth, in accordance with recommendations from BRE[8]. It may be possible to reduce the final thickness of cover required, but this will need to be determined once final levels have been established and the concentrations of potential contaminants within the imported material is known. Any soil brought onto the site should be

[8] BRE (2004) *Cover systems for land regeneration. Thickness of cover systems for contaminated land.* BRE pub 465

certified as clean with appropriate documentation.

The remaining areas of the site will be covered with hardstanding, thus preventing a pathway from being formed.

7.8.2 Vapours

The precautions required to prevent a build-up of noxious fumes and vapours within the proposed basement car park should provide sufficient protection against the risk of vapours from any residual hydrocarbons following removal of the tanks and surrounding contaminated soils. If the proposed use of the basement changes this advice will need to be reviewed.

7.9 Ground Water

TPH concentrations of 0.54 mg/l and 15.91 mg/l have been recorded in Borehole Nos 1 and 2 respectively although the later is likely to be representative of water perched within the tank excavation. Aliphatic / aromatic speciation of the ground water results has identified some carbon chains to be present in excess of their solubility thresholds which indicates the presence of free product which is likely to be present as a smear zone above the water; however the majority of the recorded concentrations are within solubility limits and therefore likely to be present in the ground water. On the basis of these results, the Environment Agency may require a Detailed Quantitative Risk Assessment (DQRA) to be carried out and further sampling is likely to be required in this respect. Nevertheless, the downstream borehole has not revealed elevated concentrations to be present and therefore further sampling is recommended following the removal of the tanks and contaminated groundwater to re-assess the impact on the groundwater. If contamination is shown to be entering the site from the north, a physical barrier may also be required to protect the site from further contamination.

7.10 Site Workers

High concentrations of potentially carcinogenic hydrocarbons have been measured in the soils and ground water beneath the site.

Site workers should be made aware of the possible presence of contamination and a programme of working should be identified to protect workers handling any soil. The method of site working should be in accordance with guidelines set out by HSE[9] and CIRIA[10] and the requirements of the Local Authority Environmental Health Officer. If any suspicious substances are encountered during site work, these should be assessed by a geoenvironmental engineer.

7.11 Waste Disposal

Any spoil arising from excavations or landscaping works may need to be disposed of to a licensed tip. Under the European Waste Directive landfills are classified as accepting Inert, Non-hazardous or Hazardous wastes in accordance with Waste Acceptance Criteria (WAC) which, for Hazardous and Inert wastes are based upon the results of CEN method bulk leaching tests or percolation tests.

Based upon the results of the analyses carried out and the technical guidance provided by the

9 HSE (1992) HS(G)66 *Protection of workers and the general public during the development of contaminated land* HMSO

10 *A guide for safe working on contaminated sites*, Report 132, Construction Industry Research and Information Association

Environment Agency[11] it is considered likely that the made ground will be classified as a Non-Hazardous waste and the natural soils may be classified as an Inert waste. Soils that have been significantly impacted by the hydrocarbon contamination and are stained or have a hydrocarbon odour are likely to attract a more onerous classification. However, these classifications should be confirmed by the receiving landfill once the soils to be discarded have been identified. In order to finalise this classification it will probably be necessary to carry out further analyses including WAC CEN method bulk leaching tests if a classification of Inert waste is to be considered. Such tests should be carried out upon representative samples from the waste stream once the extent of the materials to be discarded has been established.

Non-hazardous and hazardous wastes will need to be pre-treated prior to disposal. The pre-treatment process must be physical, thermal, chemical or biological, including sorting. It must change the characteristics of the waste in order to reduce its volume, hazardous nature, facilitate handling or enhance recovery. The waste producer can carry out the treatment but they will need to provide documentation to prove that this has been carried out. Alternatively, the treatment can be carried out by an approved contractor. The local waste regulation department of the Environment Agency (EA) should be contacted to obtain details of tips that are licensed to accept the soil represented by the test results. The tips will be able to provide costs for disposing of this material and may require testing to be carried out.

8.0 FURTHER WORK

This investigation has indicated the presence of contamination and preliminary recommendations have been made for the mitigation of this contamination in light of the current development proposals. This report should be viewed as the first stage in a process which culminates in the provision of a Completion Report confirming that the remediation has been carried out satisfactorily. The next stage in this process should be consultation with the Local Environmental Health Officer (EHO) and Environment Agency (EA) and the provision of Remediation Proposals that can be agreed with these parties as a basis for the remediation of the contamination.

The EA may require further investigation and analysis to allow a detailed quantitative risk assessment to be carried out The results of the investigation carried out to date should therefore be used to as the basis of a discussion with the EA and EHO in order to determine their concerns with regard to the impact of this contamination upon the underlying soils and groundwater.

The removal of the tanks and excavation of the basements should be monitored and validated by a geoenvironmental engineer to ensure that any potential sources of soil or ground water have been removed. Further ground water treatment may also be required and if an off-site source is identified, additional protective measures may be required.

8.1 Outline Remediation Proposals

On the basis of the discussion of pollution linkages in the preceding section the following possible remedial objectives can be identified:

- protect end users in landscaped areas;

11 Environment Agency 2003. *Hazardous Waste: Interpretation of the definition and classification of hazardous waste.* Technical Guidance WM2

- remove potential hydrocarbon contamination;
- improve ground water conditions both on and off-site;
- protect site workers

The nature and scope of any soil and groundwater remediation will need to be agreed with the EA prior to the adoption of any particular remediation scheme. It is likely however that the EA will require at least the removal of the underground fuel storage tanks and any associated significantly contaminated soils. The excavation of the basement and the removal of the tanks will need to be monitored and validated.

Depending upon the outcome of the discussion with the regulatory authorities, some additional ground water treatment may be required. The most appropriate method of ground water treatment will probably be the installation of a sump from which ground water and can be pumped and treated. This treatment may be carried out using on-site plant by a specialist contractor, under the supervision of a suitably experienced environmental engineer, which would minimise the disruption to the proposed development programme. Monitoring of the ground water will need to be carried out to determine the efficacy of the system and hence the point at which the hydrocarbons concentrations within the ground water have been reduced to an acceptable level, as determined in conjunction with the EA.

Whilst the excavation of the basement and the removal of the tanks will remove the majority of the contaminated soil, a watching brief should be maintained in these areas and there may be a requirement for further investigation and removal of contaminated soil. It is understood that the design of the proposed scheme will only include limited areas of soft communal landscaping and it is only in these areas where precautions will be required to protect end users.

APPENDIX

Borehole Records

Dynamic Probe Records

SPT Results

Geotechnical Laboratory Test Results

Chemical Analyses (Soil)
(Gas)
(Groundwater)

Generic Guideline Values

Site Plan