THE CO-OPERATIVE GROUP
GEO-ENVIRONMENTAL INVESTIGATION REPORT
SHEFFIELD ROAD, PENISTONE

NOVEMBER 2012

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Geo-Environmental Investigation Report
Sheffield Road, Penistone
November 2012

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DRAWING

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A. FACTUAL INFORMATION

1.0 INTRODUCTION

1.1 Opus Joynes Pike (OJP) were instructed by The Co-operative Group (the Client) in 2008 to carry out a Phase I Desk Study and Phase II intrusive ground investigation at a site off Sheffield Road, Penistone, South Yorkshire. The desk study was reported in the OJP Phase I Desk Study Report Ref. J-S0099_R1_RW dated December 2008 and the Phase II ground investigation was reported in the OJP Geo-Environmental Assessment Report Ref. J-S0099_R2_TPW dated April 2009.

1.2 In November 2012, Opus International Consultants UK Limited (Opus), formerly OJP, were instructed by the Co-operative Group to review the existing reports and combine them in one stand-alone report with the data re-assessed to current standards. This report combines the two original reports with the data has been re-assessed with the current outline proposal of residential houses with gardens in mind.

1.3 At the time of writing, the final design layout of the development has yet to be finalised, however it is understood that the development will be residential housing, with front and rear gardens, off street parking and associated road access.

1.4 The Phase I desk study was carried out to obtain information relating to the environmental setting of the site and the history of the site and surrounding area. This enabled a preliminary assessment of the potential environmental and geotechnical liabilities to be made. This information was then used to form the basis of the subsequent Phase II intrusive investigation.

1.5 The Phase II ground investigation was carried out to obtain appropriate information relating to the soil and groundwater conditions in order to determine the potential presence of contamination due to current and historical land usage, and to obtain sufficient data to allow the design of appropriate foundation and ground slab solutions for the proposed development.

1.6 This report has been prepared by Opus with all reasonable skill, care and diligence within the terms of the Contract with The Client (The Co-operative Group), and taking account of the information made available by The Client, as well as the manpower and resources devoted to it by agreement with the Client. Opus disclaims any responsibility to The Client and others in respect of any matters outside the scope of the above Contract.

1.7 This report has been produced on behalf of The Client and no responsibility is accepted to any Third Party for all or any part. This report should not be relied upon or transferred to any other parties without the express written authorisation of Opus. If any unauthorised Third Party comes into possession of this report, they rely on it at their own risk and the authors owe them no duty of care or skill.

1.8 The findings and opinions conveyed within this report are based on information obtained from a variety of sources, as detailed, which Opus believes are reliable. Nevertheless, Opus cannot and does not guarantee the authenticity or reliability of the information it has relied upon from these sources.

1.9 No asbestos survey or reviews of existing asbestos registers for the site has been undertaken as part of this investigation.

1.10 This report provides preliminary geotechnical and environmental information only. At this stage, no information is available regarding the requirement to dispose of soils off site and as such, the classification of soils for waste disposal purposes and any resulting waste acceptance criteria (WAC) testing required under the Landfill Regulations introduced on 16 July 2005 is beyond the scope of this report.

2.0 THE SITE

2.1 Location and Access

2.1.1 The study site, of approximately 1.7Ha area, is almost triangular in plan and located off Sheffield Road to the immediate northeast of the railway station, in the eastern part of Penistone. The site is centred at approximate National Grid Reference 425250 403260 as shown on the appended Drawing No. J-S0099/401.

2.1.2 Access onto site is gained off Sheffield Road in the north western part of the site via Lairds Way which is a small estate road that slopes steeply up into the site and tracks part way along the western site boundary where it finishes in a dead-end.

2.2 Site Description

2.2.1 A site walkover was carried out by an Opus engineer on 21 November 2008.

2.2.2 The site currently lies derelict with an access road (Lairds Way) passing through the western part. The site is predominantly covered with grasses, brambles and immature Silver Birch trees.

2.2.3 The majority of the site is flat lying however a steep bank is present along the northern boundary where levels slope down by some 7m to Sheffield Road. This slope is highly vegetated with Silver Birch trees. It was noted that a number of the tree trunks were bent which indicates the possibility of the slope moving. In the north eastern corner of the site, at the top of the slope, are the remains of two former brick structures and a number of large concrete/slag boulders.

2.2.4 The site also slopes down towards the south eastern site boundary where a ditch is present, running adjacent to a wooden fence which forms the south eastern boundary.

2.2.5 The northern boundary of the site is formed by a sandstone block retaining wall varying between 1m and 5m in height retaining a slope which at its highest is approximately 7m above the road level adjacent to the northern boundary. A brick retaining wall forms the south western boundary.

2.2.6 Residential properties and associated gardens are present to the immediate east of the site and are situated approximately 5m below main site levels. A Council Depot is located to the north of the site on the opposite side of Sheffield Road. The depot lies 1-2m above the level of Sheffield Road. A derelict works, comprising a metal/concrete structure, is present to the immediate west of the site with a large storage area containing drums and containers. Railway lines run adjacent to the southern part of the southwest boundary with a station present approximately 200m to the northwest.

3.0 DESK STUDY

3.1 Sources of Information

3.1.1 The following sources of information have been consulted as part of the desk study:

(a) Opus International Archives
(b) Landmark Information Group Ltd 'Envirocheck' database report
(c) Selected County Series and Ordnance Survey plans
(d) The British Geological Survey, Keyworth, Nottingham.
(e) Environment Agency Website.
(f) The Law Society's Guidance Notes: Coal Mining Searches 1998.
(g) The Coal Authority Website.
(h) BR 211 Radon; Guidance on Protective Measures for New Dwellings, 2007 Edition
(i) Information Supplied by the Client.

3.2 Site History

3.2.1 A review of the site history has been undertaken in order to identify any previous potentially significant contaminative activities, located either on-site or off-site. This is summarised in Table 1.

3.2.2 Potential on-site contamination sources may present a risk to future site users and underlying and/or adjacent 'controlled waters'.

3.2.3 Neighbouring potential off-site contamination sources may also present a risk to soils and, if present, groundwater underlying the site through cross boundary migration or deposition of waste materials.

3.2.4 The history of the site is recorded over selected periods by inspected maps, copies of which are presented in Appendix 'A'. The account presented in this report is restricted by specific time periods represented by these maps only.

Table 1: Summary of Historical Land Use

Map Edition	Key Features	
	On Site	Off Site
1851	The site predominantly formed a series of fields, with a number of field boundaries crossing the site. Rail tracks appear to cross the southern part of the site.	The site is largely surrounded by agricultural land with Penistone present 500m to the west. A road passes along the northern site boundary and the railway line cutting through the site is shown extending to the northwest and southeast. Penistone Green Beck is indicated 110m to the southeast and the River Don is 110m to the north at its nearest point. A number of quarries are present in the general vicinity of the site, the nearest being approximately 300m to the east.

Map Edition	Key Features	
	On Site	Off Site
1893	The site has been developed by this time and forms part of Yorkshire Steel & Iron Works. A large industrial building dominates the site with railway lines present along the northern and south western boundaries. A slope is indicated part way along the northern boundary, sloping down to Sheffield Road.	Railway lines are situated to the immediate southwest and west of the site. These lines extend to the northwest and southeast. The Yorkshire Steel & Iron Works extends to the southeast of the site, where the land slopes down to two rectangular reservoir type features which were regulated by sluices. Spring Vale Mills (Sawing/Planing) are shown 150m to the east and contained a gasometer. The River Don is indicated 65m to the north at its nearest point, with land sloping upwards to its immediate south. Residential development had occurred to the east of the site by this time off Sheffield Road. Allotment gardens and a tank are shown 170m to the west. Agricultural land remained to the southwest of the railway and to the north in the vicinity of the river.
1894	No significant change.	No significant change, however the development to the west is now recorded as Penistone.
1906	The steel & iron works remained on site with a weighing machine and two cranes indicated on the central and western parts.	Additional industrial buildings associated with the steel & iron works had been constructed to the southeast of the site. Spring Vales Mills to the east is now depicted as a Box Works and an additional gasometer is now indicated.
1907	No significant change.	No significant change.
1931	A number of the buildings in the central part of the site associated with the steel & iron works had been demolished by this time, and a travelling crane is indicated in the north western part. Construction had taken place in the northeast corner.	Increased development associated with the steel & iron works had taken place to the southeast, including new buildings and additional railway lines. The Yorkshire Steel & Iron Works has developed to the south of the site on the opposite side of the main railway lines, where several large industrial units had been constructed. Only one of the rectangular reservoir features is now depicted to the southeast. Spring Vale Box Works, including the gasometers, is no longer shown to the east, presumably being demolished.
1938	All buildings associated with the steel & iron works had been demolished with only a small number of railway lines present in the southwest and western parts of the site.	The Yorkshire Steel & Iron Works is now recorded as Penistone Works. Penistone Sewage Works is indicated 350m to the east, adjacent to the River Don.
1955	Additional railway lines/sidings are shown on the north western part of the site.	Significant development of Penistone is shown to the southwest of the site.
1960	Several railway lines/sidings are shown crossing the site with a weighbridge in the northwest part. St Mary's Catholic Chapel is indicated in the northwest corner of the site, adjacent to Sheffield Road.	Penistone Works to the south is shown to have increased in size considerably. Sports facilities had been built to the southwest, next to Penistone Works. Railway lines/sidings are shown to the immediate southeast. A works is indicated to the immediate north on the opposite side of Sheffield Road.

Map Edition	Key Features	
	On Site	Off Site
1965	No significant change.	No significant change.
1968	No significant change.	Penistone Works to the south is now recorded as a foundry and the works to the north has increased in size and is depicted as a Council Depot. A small garage is indicated 160m to the east off Sheffield Road. A works is shown 180m to the east and a Rubber & Asbestos Works is 360m to the southeast.
1983	The majority of the railway lines crossing the site are no longer shown, presumably being dismantled. Railway lines remain in the southern part, together with a weighbridge in the northwest. The chapel in the northwest corner has also been demolished.	The railway lines and reservoir feature to the southeast are no longer shown with open land indicated in their place. Additional buildings had been constructed at the depot to the north of the site, together with a new access road off Sheffield Road.
1985	The weighbridge is no longer shown on site. The site is generally depicted as open land, which slopes down towards the northern and part of the southwest boundary. The eastern part is shown as being scrubland. Railway lines remain in the southern part.	Scrubland is shown to the immediate southeast of the site. A tank is indicated on the depot to the north.
1989	The railway lines on the southern part of the site are no longer shown.	Fewer railway lines are shown to the southeast of the site and a works is now indicated to the immediate west.
1993 - 2008	No significant change.	No significant change.

Note: Due to the small scale of the 1:10,000 plans much of the detail on these plans, especially those published prior to 1938, is illegible. Therefore, the majority of information prior to this date has been drawn from the 1:2,500 plans.

3.3 Geology, Hydrogeology, Hydrology and Mining

Recorded Geology

3.3.1 Reference has been made to the British Geological Survey Solid with Drift Sheet 86, Glossop, at 1 to 50,000 scale. Geological information provided indicates the site to be directly underlain by Lower Coal Measures strata of the Upper Carboniferous, which include the Penistone Flags.

3.3.2 No superficial deposits are indicated beneath the site and no Made/Worked Ground is shown. No geological faults on or within influencing distance of the site.

Hydrogeology

3.3.2 The bedrock geology of the site is classified by the Environment Agency as a Secondary 'A' Aquifer. Secondary 'A' Aquifers are permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formally classified as minor aquifers.

3.3.3 The site is not located within a Groundwater Source Protection Zone.

Hydrology

3.3.4 The Envirocheck report lists the nearest surface water feature as being the River Don lying 60m to the north. Historical data shows the River Don to flow in an easterly direction.

3.3.5 The Envirocheck report indicates that the site is not situated in an area at risk of floods from rivers, however an area 72m, to the north of the site is. This report should not be regarded as comprising a flood risk assessment. However, given the area of the site, i.e. >1Ha, a flood risk assessment will need to be carried out in accordance with PPS25.

Mining

The site is located within an area listed on the Coal Authority's website (www.coal.gov.uk) as requiring a Coal Mining report. A Coal Mining report (Ref.00073908-08) has been acquired and reviewed by Opus as part of the current assessment, and a copy of that report is included herein as Appendix 'C'. The key points contained in the Coal Mining report are summarised below.

- The property is not within the likely zone of likely physical influence on the surface from past underground coal workings. However, the site is in an area where the Coal Authority believes there is coal at or close to the surface which may have been worked at some time in the past.

- The property is not within the zone of likely physical influence on the surface from any present or future underground coal workings.

- The property is not in an area for which a licence has been granted to remove coal by underground methods, however, reserves of coal exist in the area for which could be worked in the future.

- There are no known coal mine entries within, or within 20 metres of, the boundary of the property.

- The Coal Authority records do not disclose any fault or other line of weakness at the surface caused by coal mining as having affected the stability of the property.

- The site is not located within the geographical boundary of an opencast site within which coal has been extracted by opencast methods.

- The property does not lie within 200m of the geographical boundary of an active opencast coal site or within 800m of a proposed opencast coal site.

- The Coal Authority records do not disclose any damage notice or claim having been given, made or pursued in respect of the property since 1 January 1984.

- The property is not in an area for which a notice of entitlement to withdraw support was published. The property is not in an area for which a notice has been given under Section 41 of the Coal Industry Act 1994 revoking the entitlement to withdraw support.

- The property is not in an area for which an order has been made under the provisions of the Mines (Working Facilities and Support) acts 1923 and 1966 or any statutory modification or amendment thereof.

- There is no record of a mine gas emission requiring action by the Coal Authority within the boundary of the property.

3.4 Environmental Considerations

3.4.1 The environmental sensitivity of the site has been assessed using information contained within the Envirocheck report, including the historical plans. The Envirocheck report, which is included herein as Appendix 'B', states the following:

- There are two recorded discharge consents within 250m of the site. The nearest consent is held by Yorkshire Water Services Ltd and relates to the discharge of sewage effluent at Thurlestone Bridge 189m to the north.

- The nearest Integrated Pollution Control is 322m to the southwest.

- There have been eight recorded pollution incidents to controlled waters within 250m of the site. The nearest incident being 12m to the northeast and involved the release of heavy fuel oil to an unnamed receiving water body. The incident was classified by the Environment Agency as being Category 2 – Significant Incident.

- There are two Local Authority Pollution Prevention and Controls (LAPPCs) within 250m of the site. The nearest of these relates to the blending, packing, loading and use of bulk cement by Readymix (Huddersfield) Ltd, 5m to the northwest of the site.

- There are no registered Registered Radioactive Substances within 1km of the site.

- The river quality of the River Don 16m to the east had a GQA Grade B in 2000. The Cubley Brook 44m to the east had a GQA Grade E in 2000.

- The River Don had a River Quality Biology GQA Grade C (fairly good) in 2006.

- The Cubley Brook had a River Quality Chemistry GQA Grade C (fairly good) in 2006.

- There is one entry on the Substantiated Pollution Incident Register associated with the site, the pollutant being specific waste materials (containers).

- The nearest groundwater abstraction to the site is 342m to the southwest.

- There are no BGS recorded landfill sites within 750m of the site.

- There is one Historical Landfill Site 40m to the southwest at Churchfield Road. The deposited waste included inert and industrial waste.

- There are three entries for Local Authority Recorded Landfill Sites within 1km of the site. The nearest such site is 33m to the southwest however no specific details are given.

- There are two Registered Landfill Sites located within 1km of the site. The nearest being 103m to the southwest, the licence holder being Hi-Tec Integrity Castings Ltd at Churchfield Road. Authorised waste included Chelmsford 50 Sand/7.5% cement mix, and Furane Sand.

- There are forty-six entries in the Contemporary Trade Directory within 1km of the site. The nearest active entry is for Simply Signs of Penistone, a printers, located 50m to the east.

- The nearest fuel station entry is 406m to the southeast off Sheffield Road.

- There are no recorded licensed water abstractions within 1km of the site.

- The Envirocheck report states that the site is located in an area where less than 1% of homes are above the Action Level for radon gas and that no radon protective measures are required in the construction of new dwellings or extensions at the site.

4.0 CONCEPTUAL SITE MODEL

4.1 Potential Sources of Contamination

4.1.1 Historically the site has formed part of a steel and iron works and has had railway lines/sidings crossing it. All construction at the site has now been demolished. Based on the historical use of the site, the following potential onsite contaminants have been identified:

- Possible organic and/or inorganic contaminants in the Made Ground underlying the site, as a consequence of the former site usage.
- Possible organic and/or inorganic contaminants in the materials potentially used to create the embankment on site.
- Possible hydrocarbon/mineral oil contamination in the vicinity of the former railway lines and former site uses.
- Potentially elevated concentrations of ground gas generated by the degradation of any organic material that may be present in the Made Ground underlying the site.
- Possible asbestos containing materials (ACM) entrained in Made Ground underlying the site following the demolition of previously existing structures.

4.1.2 Possible off site sources of contamination include:

- The nearby railway;
- Steel & Iron Works, which later became a foundry;
- The derelict Depot to the immediate west;
- Spring Vale Mills 150m to the east;
- Former backfilled quarries; and
- The Council Depot, including a tank, to the immediate north.

4.2 Receptors of Contamination

4.2.1 Receptors are defined as human or non-human organisms that have the potential to experience adverse effects from direct or indirect exposure to contaminated material. The currently identified receptors, based on the available information, are as follows:

- Future site users;
- Construction/maintenance workers;
- Neighbouring site users; and
- Controlled waters – the underlying Minor Aquifer; nearby surface waters in hydraulic continuity with underlying groundwater.

4.3 Migration Pathways

4.3.1 Migration pathways are defined as the courses chemicals take from a source to an exposed organism or receptor. The exposure pathway can be direct (i.e. stays within the same exposure media) or indirect where transport from one medium to another takes place.

4.2.2 The following potential pathways have been identified at this stage:

- Risk to future site end-users from potentially contaminated Made Ground on the site through direct contact, including inhalation of volatile compounds or contaminated dust, dermal absorption and ingestion;
- Risk to construction/maintenance workers from potentially contaminated Made Ground on the site through direct contact, including inhalation of volatile compounds or contaminated dust, dermal absorption and ingestion;
- Risk to neighbouring site users through inhalation of volatile compounds or contaminated dust;
- Migration of contaminated groundwater through more permeable strata in the underlying Minor Aquifer, and into any surface water bodies that may be in hydraulic continuity with them; and
- Ground gas migration through underlying permeable strata into existing or proposed buildings to be constructed on or near to the site.

4.4 Summary

4.4.1 Based on the findings of the desk study, potential contamination pollutant linkages have been identified. These linkages are summarised in Table 2 in Section 4.5.

4.5 Source-Pathway-Receptor Relationships

4.5.1 The following potential **Source-Pathway-Receptor** relationships have been identified for the site bearing in mind the development proposals.

Table 2 Preliminary Conceptual Site Model.

Source	Pathway	Receptor	Risk
Organic and/or inorganic contaminants in Made Ground beneath the site.	Inhalation or ingestion of contaminated dust, inhalation of volatile compounds, dermal contact.	Site end users, construction and maintenance workers.	In the absence of intrusive investigation data a theoretical risk exists. **Potential Risk.**

Source	Pathway	Receptor	Risk
Organic and/or inorganic contaminants in Made Ground beneath the site.	Inhalation or ingestion of contaminated dust, inhalation of volatile compounds.	Neighbouring site users.	In the absence of intrusive investigation data a theoretical risk exists. **Potential Risk.**
Organic and/or inorganic contaminants in Made Ground beneath the site.	Migration of dissolved contaminants through the vadose zone into the underlying Secondary A Aquifer.	Surface waters or groundwater in hydraulic continuity with perched or mobile water in underlying Minor Aquifer.	In the absence of intrusive investigation data a theoretical risk exists. **Potential Risk.**
Off site sources of organic and/or inorganic contaminants in Made Ground.	Inhalation of windblown dust. Migration of dissolved contaminants through underlying Secondary A Aquifer.	Site end users, construction and maintenance workers.	Dust generation potential from neighbouring sites negligible. In the absence of intrusive investigation data a theoretical risk exists with respect to contaminated groundwater. **Potential Risk.**
Ground gases generated via decomposition of organic materials in underlying Made Ground.	Migration through permeable strata underlying the site. Entry into buildings via service points.	Site end users, construction and maintenance workers, neighbouring site users.	In the absence of intrusive investigation data a theoretical risk exists. **Potential Risk.**
Radon Gas.	Migration through more permeable strata within the underlying Minor Aquifer. Entry into buildings via service points.	Site end users, construction and maintenance workers, neighbouring site users.	Site located in an area where no protection measures required. **Low Risk.**
Asbestos Containing Materials (ACM).	Inhalation of fugitive fibres.	Site end users, construction and maintenance workers, neighbouring site users.	ACM may be present in shallow Made Ground at the site. **Potential Risk.**

5.0 INVESTIGATION METHODOLOGY

5.1 Introduction

5.1.1 Two phases of intrusive ground investigation were carried out at the site as part of the assessment. The first of these, undertaken on 13th February 2009, comprised the drilling of ten boreholes, designated WS1, WS2, WS3, WS3A, WS3B, WS4, WS4A, WS5, WS6 and WS7, using a "Premier Compact 120" tracked window sampler rig.

5.1.2 Prior to the commencement of the ground investigation, it had been intended to progress the boreholes to a depth of at least 4.00m below existing ground level (begl), with gas and groundwater monitoring standpipes being installed in up to four of the borehole locations. However, due to unfavourable ground conditions only one of the boreholes, WS1, was able to be progressed to 4.00m begl, at which point a monitoring standpipe was installed. Of the other nine boreholes, eight were terminated at depths ranging from 1.20m to 2.60m begl after hard obstructions were encountered within the Made Ground, whilst the remaining borehole, WS3B, was abandoned at 3.00m begl after it collapsed back to 1.00m.

5.1.3 Therefore, due to the unfavourable ground conditions encountered during the drilling of the window sample boreholes, a second phase of intrusive ground investigation was undertaken on 2nd March 2009, and comprised the excavation of six trial pits, designated TP1 to TP6, using a JCB 3CX mechanical excavator to depths ranging from 3.20m to 4.60m begl.

5.1.4 Both phases of the intrusive ground investigation were supervised by a suitably qualified and experienced Opus geo-environmental engineer, who positioned the exploratory locations on site, logged all soil arisings, and selected representative soil samples for subsequent laboratory chemical and/or geotechnical testing. All soil arisings were described in accordance with BS EN 14688.

5.1.5 Logs of the exploratory window sample boreholes and trial pits, including information regarding soil descriptions, the soil sampling carried out, monitoring standpipe construction and the results of in situ geotechnical testing, are included as Appendix 'D'.

5.1.6 The positions of all exploratory holes are indicated on the appended Exploratory Hole Location Plan, Drawing No. J-S0099/403.

5.2 In-situ Testing

5.2.1 Standard Penetration Tests (SPTs) were carried out in eight of the window sample boreholes to provide an indication of the in situ strength/density of strata exposed, expressed as an 'N' value.

5.2.2 The test was undertaken by driving a 50mm diameter steel cone into the soil at the base of the borehole by means of an automatic trip hammer, weighing 63.50kg and falling freely through a distance of 760mm.

5.2.3 The penetration resistance is 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.

5.2.4 Where it was not possible to drive the cone the full 300mm of the main drive with 50 blows of the trip hammer, the test was stopped. An extrapolated 'N' value was then derived by calculating how many blows would be required to achieve 300mm of penetration. Extrapolated 'N' values calculated in this way are included on the attached borehole logs.

5.2.5 However, it should be noted that the subsequent trial pit investigation in those areas where the window sample boreholes had been drilled, and where, therefore, the SPTs had been carried out, identified numerous large cobbles and boulders of concrete, brick and fused slag. The interpretation of the SPT results recorded in such material should, therefore, be treated with extreme caution.

5.3 Sampling

5.3.1 During the February 2009 window sample borehole investigation, a total of nineteen samples of shallow Made Ground and natural strata were recovered and placed in appropriate containers for potential laboratory chemical contamination testing. These samples were stored at approximately 4°C using cool boxes and ice blocks pending delivery to the laboratory.

5.3.2 A total of six bulk samples of the underlying natural clays were also recovered during the excavation of the trial pits for potential geotechnical laboratory testing.

5.4 Monitoring Installations

5.4.1 A gas and groundwater monitoring standpipe was installed in WS1 to a depth of 4.00m begl. The standpipe was constructed using 35mm diameter plain and perforated HDPE, with a response zone, surrounded by non-calcareous pea gravel, from 1.00m to 4.00m begl. The uppermost 1.00m of soil was sealed using plain HDPE pipe surrounded by bentonite. The standpipe was fitted with a valve assembly at ground level suitable for connection to portable gas monitoring equipment, and was protected at the surface by the placement of a lockable stopcock cover surrounded by concrete. No gas or groundwater monitoring standpipes were installed in any of the remaining nine boreholes.

5.5 Chemical Laboratory Testing - Soils

5.5.1 Six samples of shallow Made Ground recovered during the drilling of the window sample boreholes were submitted to Derwentside Environmental Testing Services (DETS), a UKAS and MCERTS accredited laboratory, where they were chemically tested for the Opus Basic Soil Suite, comprising the following determinands:

Inorganics

- Arsenic, water soluble boron, cadmium, chromium, copper, lead, nickel, mercury, selenium, zinc, water soluble sulphate, total sulphate, total sulphur, sulphide, total cyanide, free cyanide, soil pH.

Organics

- Speciated (USEPA Priority 16) polycyclic aromatic hydrocarbons (PAH), total phenols, soil organic matter (SOM).

5.5.2 No evidence of significant petroleum hydrocarbon contamination was noted in any of the soil samples recovered. Therefore, no chemical testing was carried out on any of the soil samples for the presence of petroleum hydrocarbons. Copies of the laboratory chemical soil testing certificates are included herein as Appendix 'E'.

5.6 Geotechnical Laboratory Testing

5.6.1 Laboratory geotechnical testing was carried out on four samples of the natural soils, with all four samples being tested for moisture content and Atterberg Limits.

5.6.2 The geotechnical laboratory testing certificates are included as Appendix 'F'.

6.0 RESULTS OF INVESTIGATION

6.1 Introduction

6.1.1 Ground conditions recorded during the investigation were found to be relatively consistent across the site.

6.1.2 Made Ground was encountered at all borehole locations to the full extent of these holes, with the exception of WS1, located in the west of the site where natural Glacial Till was recovered from a depth of 3.4m to 4.0m begl (i.e. the base of the borehole).

6.1.3 Made Ground was also recorded in all six trial pits. At TP1, TP2 and TP5, all located in the eastern part of the site, the Made Ground was present throughout the entire depth of the excavations, which extended to 4.60m, 3.60m and 3.50m respectively.

6.1.4 Glacial Till was recorded beneath the Made Ground at depths of 2.80m begl (TP3), 1.90m begl (TP4) and 1.50m begl (TP6).

6.1.5 The base of the Glacial Till was proven at only one location, namely WS6, where Lower Coal Measures strata were recovered from a depth of 3.00m-3.30m begl.

6.1.6 The occurrence of these strata is summarised in Table 3. Detailed descriptions of the strata encountered are presented below.

Table 3: Summary of Depths to Top of Strata

Stratum	Depth to Top of Stratum (m begl)	Thickness (m) (where proven)
Made Ground	Ground Level	1.50 to >4.60
Glacial Till	1.50 to 2.80	1.50 *(WS6 only)*
Lower Coal Measures	3.00 *(WS6 only)*	Base not proven

6.2 Strata Encountered

Made Ground

6.2.1 The Made Ground across the site was found to be fairly consistent in nature, and generally comprised dark grey, dark brown and black ashy sand and gravel with varying amounts of cobbles and boulders. The gravel typically comprised clinker, fused slag, brick, concrete and sandstone, and locally included glass, metal, coal and pottery.

6.2.2 Cobbles comprised mostly concrete, sandstone masonry, bricks (mostly whole) and fused slag, and locally included fragments of wire, metal pipe and clay pipe. Boulders were mostly recovered in the eastern part of the site, and comprised concrete, sandstone masonry, fused slag and sections of demolished brickwork, i.e. sections of partially demolished wall that had been used as fill.

6.2.3 It was noted during the excavation of the trial pits in the eastern part of the site, and where the majority of the demolition rubble and buried boulders were encountered, that progression of the pits was very slow due to the highly compacted nature of the material, suggesting that it may have been, at least in parts, deposited in a controlled (i.e. engineered) manner.

Glacial Till

6.2.4 Glacial Till was recorded at one borehole location (WS1) and at three trial pit locations (TP3, TP4 and TP6) at depths ranging from 1.40m to 3.40m begl. The base of the Glacial Till was proven at only one location, TP6, where it was found to terminate at a depth of 3.00m and attain a thickness of 1.50m.

6.2.5 At all locations, the Glacial Till comprised silty, sandy, gravelly, intermediate to high plasticity, grey, pale grey, pale brown or orange-brown, occasionally mottled orange, orange-brown and black, stiff consistency clay with variable cobble content. The lithology of the gravel and the cobbles comprised angular to tabular sandstone, mudstone, and coal.

Lower Coal Measures

6.2.6 The Lower Coal Measures were proven at only one location, namely TP6, where these strata were encountered beneath the Glacial Till at a depth of 3.00m. The Lower Coal Measures strata recovered comprised sandy, gravelly, low plasticity, pale brown and yellow-brown, mottled dark grey, black and dark brown, very stiff or hard consistency clay with a high cobble content, and numerous fossilised plant remains, including examples of *Stigmaria* (tree roots). Both gravel and cobbles comprised tabular to angular mudstone and coal.

6.3 Results of Standard Penetration Testing (SPTs)

6.3.1 The results of SPTs carried out in some of the window sample locations are summarised in Table 4. All SPT 'N' values have been corrected to an N60 value in accordance with BS 22476 Part 2 and where appropriate extrapolated for partial penetration.

Table 4: Results of SPTs

Location	Recorded 'N' Values			
	1.00m begl	2.00m begl	3.00m begl	4.00m begl
WS1	52	5	7	86*
WS2	10			
WS3	7	2		
WS3B	31	17	11	
WS4	11	59		
WS4A	7			
WS6	12			
WS7	30			

*Carried out in the Glacial Till

6.4 Groundwater Observations

6.4.1 Perched groundwater was recorded at four of the six trial pit locations, as summarised in Table 5 below.

Table 5: Summary of Groundwater Strikes

Location	Water Strike (m begl)	Comments
TP2	1.50	Slow, continuous, seepage at eastern end of pit.
TP3	2.60	Moderate, continuous inflow at 2.60m, but did not rise. Groundwater level at collapse of pit c.3.10m begl.
TP4	1.90	Slight seepage. Stopped after approximately 10 minutes
TP5	1.60	Moderate, continuous inflow, but did not rise. Groundwater level at collapse of pit c.3.20m begl.

6.4.2 No groundwater was recorded during the drilling of any neither of the window sample boreholes nor in TP1 and TP6.

6.5 Chemical Testing - Soils

6.5.1 The results of the chemical testing on soil samples have been reviewed in accordance with currently accepted methodologies to assess the risk to human health.

6.5.2 The soil sample chemical testing results have been compared to the current Soil Guideline Values (SGV's) where available and Opus's In-House Tier 1 Screening Values (IHSV's) derived using CLEA 1.06 to be protective of human health. A Residential with Home-grown Produce site end use scenario has been adopted.

6.5.3 Where appropriate, the results of the metals and PAH analyses have been statistically assessed in accordance with the CL:AIRE and CIEH document titled 'Guidance on Comparing Soil Contamination with a Critical Land Concentration' published in May 2008. The ESI Contaminated Land Statistical Calculator software has been utilised. Under the planning regime scenario, the objective is to determine the 'suitability for use' of the land under consideration and hence demonstrate that there is a 95% probability that the true population mean (μ) is below the set critical concentration (Cc) such as the SGV's and Opus's IHSV's. The statistical assessment tables are presented in Appendix 'E' of this report.

6.5.4 Under the land use planning system, where the aim is to demonstrate 'suitability for use', the Null and Alternative Hypotheses are as follows:

- Null Hypothesis (H0): "Is the true mean concentration greater or equal to that of the critical concentration?" ($\mu \geq Cc$)
- Alternative Hypothesis (H1): "Is the true mean concentration less than the critical concentration?" ($\mu < Cc$)

6.5.5 The chemical test results from the six samples taken across the site were initially screened against the Opus IHSV's. The initial screen identified elevated concentrations of Arsenic, Chromium and Benzo(a)pyrene. To further quantify the risk posed by the elevated concentration, each of the data sets was subjected to statistical analysis, the results of which are discussed in the following sections.

6.5.6 The analysis results of all the other determinands analysed were not detected at concentrations in excess of their adopted Opus IHSV's and are therefore not considered to pose a risk to identified human health receptors in the context of the proposed residential with home-grown produce end use.

Metals

6.5.7 Statistical analysis of the data sets for Arsenic and Chromium indicates that the true mean exceeds the critical concentrations with no statistical outliers identified. This means that the Null Hypothesis cannot be rejected and that the elevated concentrations recorded indicate site wide contamination within the made ground of both Arsenic and Chromium. The elevated concentrations cannot be attributed to isolated hotspots based on the current data set.

PAHs

6.5.8 Statistical analysis of the data set for Benzo(a)pyrene indicates that the true mean exceeds the critical concentration with no statistical outliers identified. This means that the Null Hypothesis cannot be rejected and that the elevated concentrations recorded indicate site wide contamination within the made ground of Benzo(a)pyrene. The elevated concentrations cannot be attributed to isolated hotspots based on the current data set.

Asbestos

6.5.9 Routine screening undertaken by the laboratory carrying out the chemical soil analyses did not identify asbestos fibres in any of the samples tested.

6.6 Geotechnical Testing

Made Ground

6.6.1 Water soluble sulphate was recorded at concentrations of between 21mg/l and 1800mg/l in the six samples of Made Ground tested. Total sulphate was recorded at levels of between 0.03% and 0.89%, with sulphide being recorded at concentrations of between 15mg/kg and 140mg/kg. The pH range for the soil samples was 7.8 to 8.8, which indicates slightly alkaline soil conditions.

Natural Soils

6.6.2 Atterberg Limit tests were carried out on four samples of natural clays taken from depths of between 1.80m to 3.20m begl. The results of this testing indicated that the liquid limits ranged from 39% to 55%, and plasticity indices ranged from 17 to 31. These results indicate that the clays possess intermediate to high plasticity. However, in accordance with NHBC guidance, modified plasticity indices were reported to range from 7.65% to 28.83%, indicating clays to be either non-shrinkable or of low to medium volume change potential.

6.6.3 The results of moisture content analysis carried out on the four samples of the natural clays ranged from 12% to 36%.

B ASSESSMENT & RECOMMENDATIONS

7.0 REVISED CONCEPTUAL SITE MODEL

7.1 Introduction

7.1.1 Following the completion of the Phase II ground investigation, the environmental risks associated with the site have been qualitatively reassessed. Environmental risk has been assessed using the categories presented in Box 1 below.

Box 1

Qualitative Risk Assessment Categories Used In This Appraisal

Low Risk
There is a finite, low risk to the environment. The presence of residual contaminants does not pose a significant risk to identified receptors.

Medium Risk
There is sufficient evidence to suggest that there may be an unacceptable risk but further work is needed before this can be confirmed or rejected.

High Risk
Action must be taken to reduce the risk because it is judged to be too high. Appropriate actions may reduce the probability of the event occurring or mitigate the effects or consequences.

7.2 Sources of Contamination

7.2.2 The Phase II ground investigation revealed a variable thickness of Made Ground across the site. The Made Ground generally comprised black, dark grey or dark brown ashy sand and gravel of fused slag, clinker, sandstone, brick and concrete, and locally including metal, glass, coal and pottery, with varying amounts of cobbles and boulders comprising concrete, fused slag, brick and sandstone masonry, and locally clay and metal pipe and wire. No visual or olfactory evidence of significant contamination was noted during the ground investigation, including the presence of ACM or petroleum hydrocarbons.

7.2.3 The soil sample chemical testing results have been compared to the current Soil Guideline Values (SGV's) where available and Opus's In-House Tier 1 Screening Values (IHSV's) derived using CLEA 1.06 to be protective of human health. A Residential with Home-grown Produce site end use scenario has been adopted.

7.2.4 The assessments, which are detailed in Section 6.5 of this report, have identified site wide contamination of Arsenic, Chromium and Benzo(a)pyrene within the made ground.

7.3 Receptors of Contamination

7.3.1 The following sensitive receptors have been identified:

- Future site users;
- Neighbouring site users;
- Construction and maintenance workers in close contact with shallow soils; and
- Groundwater within the underlying Minor Aquifer.

7.4 Migration Pathways

7.4.1 The following plausible pathways, by which shallow soil contamination may come into contact with the sensitive receptors, have been identified:

- Risk to site end users from contaminants in the shallow Made Ground through direct contact, including inhalation of contaminated dust, dermal absorption and ingestion;

- Risk to construction/maintenance workers from contaminants in the shallow Made Ground through direct contact, including inhalation of contaminated dust, dermal absorption and ingestion; and

- Risk to groundwater from dissolved contaminants.

7.5 Revised Conceptual Site Model

7.5.1 Following the completion of the Phase II ground investigation, the preliminary Conceptual Site Model has been a revised, as presented in Table 6 below.

Table 6: Revised Conceptual Site Model

Source	Pathway	Receptor	Risk
Organic and/or inorganic contaminants in Made Ground beneath the site.	Inhalation or ingestion of contaminated dust, inhalation of volatile compounds, dermal contact.	Site end users, construction and maintenance workers.	Significantly elevated concentrations of arsenic, chromium and benzo(a)pyrene in shallow Made Ground. **High Risk**
Organic and/or inorganic contaminants in Made Ground beneath the site.	Inhalation or ingestion of contaminated dust, inhalation of volatile compounds.	Neighbouring site users.	Significantly elevated concentrations of arsenic, chromium and benzo(a)pyrene in shallow Made Ground. Granular nature of Made Ground, and the topographical height of site compared to residential properties on much lower ground immediately to the east, means dust generation potential during redevelopment works is high, particularly given UK prevailing (westerly) wind directions. **High Risk**

Source	Pathway	Receptor	Risk
			However, dust generation potential from post-development site is considered negligible. **Low Risk**
Organic and/or inorganic contaminants in Made Ground beneath the site.	Migration of dissolved contaminants through the vadose zone into the underlying Minor Aquifer.	Surface waters or groundwater in hydraulic continuity with perched or mobile water in Secondary A Aquifer.	No groundwater monitoring or groundwater quality testing undertaken at the site to date. Therefore, in the absence of such testing a theoretical risk exists. **Potential Risk**
Ground gases.	Migration through permeable strata underlying the site; Entry into buildings via service points.	Site end users, construction and maintenance workers, neighbouring site users.	No ground gas monitoring or groundwater quality testing undertaken at the site to date. Therefore, in the absence of such testing a theoretical risk exists. **Potential Risk**
Asbestos Containing Materials (ACM).	Inhalation of fugitive fibres.	Site end users, construction and maintenance workers, neighbouring site users.	No asbestos fibres identified during routine laboratory screening of soil samples. No evidence of ACM observed during ground investigation. **Low Risk**

7.5 Discussion and Remediation Options

7.5.1 The requirement for remedial works to be carried out at the site with respect to the underlying soils will largely depend on the nature of any proposed development.

7.5.2 It is proposed that the site be redeveloped, in part or in whole, for a residential end use with gardens. The chemical soil testing results acquired during the February 2009 site investigation indicate that concentrations of arsenic, chromium and benzo(a)pyrene in the shallow Made Ground across the site may pose a significant risk to future site users.

7.5.3 In order to mitigate the identified risks impacting the identified receptors, either the source or receptor would need to be removed, or the pathway broken. In this instance, where the proposed development is for a residential end use with gardens, it is not feasible for the receptor to be removed.

7.5.4 Due to the very large volumes of Made Ground on site, it is considered that removal of the source is neither an environmentally sustainable policy, due to the potential for a large number of vehicle movements and the use of limited landfill resources, nor cost effective.

7.5.5 Therefore, should the Sheffield Road site be redeveloped for a residential end use with gardens it is considered that the most appropriate remedial option is the emplacement of a barrier of demonstrably uncontaminated, inert subsoil and topsoil across all garden areas and other areas of soft landscaping at the site. The thickness of this material should be not less than 600mm in rear garden areas, and 450mm in front garden areas and any proposed areas of public open space. In all areas, it is recommended that the topsoil component should have a minimum thickness of at least 150mm, in order to provide a suitable growing medium for future planting, and for aesthetic purposes.

7.5.6 The requirement for gas protection measures in any buildings, residential or otherwise, at the site is currently unknown. Therefore, further investigation works, to include the installation of a minimum of four additional gas and groundwater monitoring standpipes across the site, will need to be undertaken in order to determine the ground gas regime prevailing at the site.

7.5.7 It is essential that any proposed remedial works are submitted for Regulatory approval (Environmental Health, Environment Agency and the NHBC if required) prior to any irrevocable actions being implemented.

8.0 GEOTECHNICAL ASSESSMENT

8.1 Introduction

8.1.1 At the time of writing, the design of the development had yet to be finalised. However, it is understood that the site is being considered for either residential development. Final design considerations will be dependent upon the final layout of proposed structures.

8.1.2 Foundation loads were unknown at the time of writing, although provisional assumptions have been made based on the type of construction anticipated.

8.2 Summary of Ground Conditions

8.2.1 Made Ground was fully penetrated in WS1 (3.40m), TP3 (2.80m), TP4 (1.40m) and TP6 (1.50m), elsewhere, depths in excess of 4.60m have been encountered. In addition, it was noted during the trial pitting exercise that the Made Ground was highly compacted locally, and several of the window sample boreholes were terminated at depths of between 1.20m and 1.60m on hard obstructions.

8.2.2 Glacial Till deposits were encountered beneath the Made Ground in WS1, TP3, TP4 and TP6, and Lower Coal Measures strata was only encountered in TP6 at a depth of 3.30m.

8.2.3 It should be noted that groundwater and ground gas monitoring was not possible as part of this investigation due to the relatively shallow depth that the window sample boreholes could penetrate.

8.3 Foundation Design

8.3.1 Foundations should not be cast on the Made Ground encountered below this site, which was found to depths of 1.40m and in excess of 4.60m.

8.3.2 All foundations will need to be extended beneath the Made Ground and any former construction to found within adequatly strong natural soils.

Traditional Foundations

8.3.3 Based on the ground investigation carried out to date, it is anticipated that traditional trench fill foundations may be a viable option locally, founding within the Glacial Till deposits where encountered at a sufficiently shallow depth, i.e. TP4 (1.40m) and TP6 (1.50m). It is envisaged that, for economic reasons, the Glacial Till is at too greater depth for trench fill foundations to be constructed elsewhere across the site, assuming site levels are to remain the same.

8.3.4 The Glacial Till deposits have modified plasticity indices ranging between 7.65 and 28.83, which rates it as either being non-shrinkable or having a low to medium shrinkage and heave potential. Based on the Glacial Till being of medium shrinkage potential, a minimum foundation depth of 0.90m will be necessary at this site in accordance with NHBC Standards.

8.3.5 Trees and shrubs, even those off site, can extend the depth affected by seasonal moisture variation, and advice on this is given in the National House Building Council (NHBC) Standards Chapter 4.2, "Building near trees". Appropriate deepening of foundations should therefore be considered as part of the final foundation designs.

8.3.6 The sides of the footings in cohesive material within the range of influence of both recently removed or extant trees will need to be separated from the adjacent clay soil by a suitable void former to accommodate future swelling pressures. A minimum void dimension should be incorporated as detailed by published guidance documents.

8.3.7 The Glacial Till deposits at and below a foundation depth of 1.50m, i.e. at the base of the Made Ground, has a net allowable bearing capacity in the order of 125kN/m² below a 0.60m wide trench fill foundation and 150kN/m² below a 1.2m square pad. The above values incorporate a factor of safety of 3.0 against general shear failure and are based on an assumed minimum shear strength of 65kN/m² for the Glacial Till.

8.3.8 Settlement of such foundations is likely to be in the order of 15-20mm for those footings applying up to 125kN/m² and cast at the minimum foundation depth within the Glacial Till deposits.

8.3.9 The base of foundation excavations should be inspected upon completion 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. Similarly should any live roots be observed in the base of foundation trenches, then excavations should be deepened to at least 0.5m below the last observed root. The excavated surfaces should be protected from deterioration and a blinding layer of concrete used where foundations are not completed without delay.

Foundations in Areas of Deep Made Ground

8.3.10 Based on the available ground investigation information, it has been proven that the majority of the site is underlain by deep Made Ground, i.e. in excess of 2.50m. As such, traditional foundations will not be a viable option for these parts of the site, predominantly for economic reasons.

8.3.11 Alternative foundation options for the site include the following:

- Piled foundations, transferring loads through the Made Ground to the underlying Glacial Till deposits or Lower Coal Measures strata; or
- Shallow reinforced strip foundations in vibro-treated ground.

8.4 Piled Foundations

8.4.1 Due to the significant thickness of Made Ground beneath the majority of the site, it will be necessary to transfer foundation loads to depth using a piled foundation scheme.

8.4.2 The underlying Glacial Till or Lower Coal Measures may, on the basis of this investigation, prove a suitable stratum into which the piles could be installed. However, it should be observed that the solid geology of the Lower Coal Measures was only encountered in one of the exploratory holes, i.e. TP6 at 3.00m, and in this regard it will be necessary to advance a number of cable percussive boreholes in order to determine the deeper soil profile.

8.4.3 Bored or augered piles may be most appropriate for this site. Cost advantages could accompany driven piles, however, in that the amount of spoil for off-site disposal would be reduced. If piling were the preferred option we would recommend early consultation with specialist piling contractors with regard to the most appropriate type of pile for the ground conditions present and the required loadings.

8.4.4 In addition, consideration should be given for the potential for obstructions to be present in the ground which could hinder pile advancement and as such, pre-boring of positions may be required to determine the presence of any obstructions.

8.4.5 Pile cap excavations should remain dry and have stable sides, although the stability of the Made Ground should not be relied upon. Any perched groundwater seepages could be dealt with by pumping from sumps. Safety precautions should not be neglected especially where personnel are to enter deep excavations, when battered side or close support will be required.

8.4.6 Consideration will necessarily need to be given to both the appropriate design of a piling platform, which may in itself require additional ground investigation.

8.4.7 Final pile design and specific construction detail should be undertaken by a suitably qualified specialist contractor, once structural details and layouts are available. It would be necessary to undertake additional boreholes to prove the deeper soil profile below the site, in to which any piles would be installed.

8.5 Ground Improvement

8.5.1 A system of vibro replacement ground improvement may also be considered a suitable way to treat the Made Ground beneath the site. Vibro replacement techniques may be used to treat the Made Ground beneath the proposed structures to provide a suitable medium on which to place traditional strip footings or raft foundations. In addition, vibro replacement will also minimise volumes of spoil for off-site disposal.

8.5.2 Vibro replacement techniques, together with the installation of stone columns beneath strip footings, may not be considered suitable for supporting heavy loads as columns do not transfer the full loads to the soil at depth. Any soft clay may be effectively squeezed into the voids in the column resulting in reduced lateral resistance and efficiency as a drain. Columns to support strip footings would need to be taken down to any stiff Glacial Till.

8.5.3 It should be ensured that all obstructions in the ground, such as those encountered within the exploratory holes, are removed prior to the installation of vibro stone columns.

8.5.4 Vibro stone columns are not always suitable for fine grained soils, due to the lack of lateral constraint on the stone columns as they are installed. Before a final decision is made regarding the most suitable foundation type, the logs should be made available to the relevant contractors for their comments regarding the suitability of the ground to either vibro.

8.5.5 Strip foundations constructed on vibro treated ground will necessarily require reinforcing to guard against residual differential movements.

8.5.6 Future foundation designs will need to take account of existing buried structures and be suitably designed to avoid or span potential soft/hard spots resulting from their removal. Excavation should be backfilled with nominally compacted granular material.

8.6 Slope Stability

8.6.1 It should be noted that a 7m high sloe is located along the northern boundary of the site sloping downwards from the site level to the road level to the north of the site. A slope stability assessment was not commissioned as part of the investigative works. It is likely that the presence of the slope will be a limiting factor on the eventual layout of the site and there is the potential for vibro stone columns to introduce water behind the slope creating the potential for slope stability. Therefore any proposed layout and subsequent vibro improvement layout must be designed in a manner that does not compromise the slope.

8.7 Floor Slab Design

8.7.1 The floor slab design should be confirmed in light of the final development proposal for the site, however at this stage it is assumed that slabs will need to be suspended given the depth of Made Ground present beneath the site.

8.8 Construction

8.8.1 Excavation depths should be readily achieved using conventional plant (JCB or similar). However, higher specification plant (tracked 360^{o} or similar) and breaking equipment may be required to penetrate any foundations, buried floor slabs, basements and obstructions etc., associated with the former structures occupying various parts of the site.

8.8.2 Groundwater monitoring has not been undertaken as part of this investigation, therefore it is not possible to comment on the potential for dewatering excavations at this stage. It is proposed that standpipes are constructed within cable percussive boreholes installed as part of additional works for subsequent monitoring.

8.8.3 Safety precautions should not be neglected, especially where personnel are to enter deep excavations, when battered sides or close support will be required. Monitoring the standpipes within the boreholes immediately before the start of construction will establish the groundwater levels prior to the start of excavation. Excavation shoring, where considered necessary, should be designed in accordance with appropriate guidance documents and best practice.

8.9 Concrete Specification

8.9.1 The geology underlying the site, and the ground conditions recorded during the ground investigation, has been assessed in accordance with the guidelines contained in Part C of BRE Special Digest 1: Concrete in Aggressive Ground (2005), and on that basis the site has been categorised as a brownfield site.

8.9.2 The results of total and water soluble sulphate testing indicate that a concrete Design Sulphate (DS) Class of DS-2, with an ACEC (Aggressive Chemical Environment for Concrete) Class of AC-2, would be appropriate for any buried structures.

8.9.3 The specific concrete mixes (The Design Chemical Class) to be used on site for all the 'in the ground' and 'on the ground' permanent applications should be determined, mindful of the ACEC class, by the site specific concrete requirements, in terms of the required durability and structural performance. These are assessed in terms of the Intended Working Life, and any need for Additional Protective Measures (APM), as detailed in Parts D to F of the BRE Special Digest 1.

8.10 Pavement Design

8.10.1 Table C1 of the TRRL laboratory report 1132 recommends a design CBR value of 3.0% to 4.0% for the near surface Glacial Till, based on a shallow water table, average construction conditions and a thin pavement design. It is recommended that untreated Made Ground is assumed to have a CBR of <2%.

8.10.2 In addition, it is likely that the Made Ground and near-surface Glacial Till could be considered frost susceptible and Road Note 29, Appendix 1 requires that a minimum construction thickness of at least 450mm is used where the sub-grade is a frost susceptible material.

8.10.3 Proof rolling of the formation layer should be carried out prior to construction and any soft or loosely compacted areas should be removed and replaced with a well-graded hardcore or lean-mix concrete.

8.11 Soakaways

8.11.1 Given the presence of a significant thickness of Made Ground beneath the site, soakaway drainage will not be a viable option for this site.

9.0 RECOMMENDATIONS

9.1 The following further works are recommended prior to the development of the site:

(a) Submission of this report to the Local Authority Environmental Health Officer for comment and approval prior to any irrevocable action taking place.

(b) Installation of gas/groundwater monitoring wells with subsequent monitoring and assessment.

(c) Mining investigation.

(d) Tree Survey to provide data which can be used in the assessment of the effect of tree roots on the proposed foundations.

(e) Review foundation options when the final site development proposals are available, including layout, finished site levels, line loads and design details to allow the most cost effective solution to be designed.

(f) Submission of this report to the relevant Water Supply Authority to confirm the required level of protection, if any, for plastic water supply pipes.

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