Land South of Church Street, Church Gresley

Preliminary Geo-environmental Assessment Report

St. Modwen Developments Limited

July 2013

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1. Introduction

1.1. General

St Modwen Developments Limited (SMD) propose to submit a planning application for the proposed residential development at Land South of Church Street, Church Gresley. The application will be submitted for a residential development of up to 306 dwellings, access, parking, public open space, landscaping and associated infrastructure (outline with all matters reserved other than principle means of vehicular access).

Atkins Limited has been commissioned to prepare a Preliminary Geo-environmental Assessment of the proposed development site, in order to provide the Local Planning Authority with information on ground conditions and proposals.

This report aims to provide a summary of the desk study information and findings of the ground investigation including a description of ground conditions and identified ground abnormals and constraints.

The findings of chemical testing are discussed, concluding with a Conceptual Site Model. Ground engineering considerations are outlined for the redevelopment, based the proposed residential end use.

Outline recommendations for options to mitigate the geo-environmental constraints to the proposed redevelopment are presented, where appropriate.

1.2. Limitations

This report has been prepared based on the data from sources listed herein. All reasonable endeavours have been made to source information from reputable organisations. However, no warranty over the accuracy of this information can be given.

In accordance with Atkins' procedures and due to insurance purposes, this report does not advise on measures to deal with asbestos. Detailed advice should be sought from a specialist contractor, where required.

2. Site Area

2.1. Site Location

The site is located in Church Gresley, south of Swadlincote in South Derbyshire. The Ordnance Survey National Grid Reference for the approximate centre of the site is SK 297 181.

The site location plan is enclosed as Figure 1.

2.2. Site Description

The site is irregular in shape and covers an area of approximately 12 hectares. The site comprises an area of open space / grass land with several well trodden paths transecting the site. A drain and hedgerow (or line of trees) bisects the site from northeast to southwest roughly through its centre. The western boundary of the site is densely covered with vegetation and trees. The northern tip of the site (south of Rockcliffe Close) is densely covered in trees and vegetation.

The site is bounded by trees and areas of densely planted woodlands.

Pedestrian access can be gained at various locations around the perimeter of the site. Restricted vehicular access can be gained from Mount Pleasant Road adjacent to the south-western corner of the site.

A site plan is presented as Figure 2.

2.3. Surrounding Area

The area immediately predominantly comprises residential development with some light industrial / commercial properties to the north and west and a mix of open grassland / woodlands to the east and south.

A watercourse/drain is present close to the southern boundary. Church Gresley Woods is located to the south. A large lake is located approximately 420m east with opencast further south and east.

2.4. Historical Development

The following summary of history of the site and surroundings is based upon available historical maps presented in the Envirocheck Report (Ref. 1).

Table 1. Summary of Historical Development

Date	Land Use On-site	Land Use Off-site
1881 – 1883 (1:2,500) 1883 – 1887 (1:2,500) 1884 – 1885 (1:10,560)	The site comprises fields with trees along the field boundaries. A path extends through the site from the west to east (later identified as Railwayside). A mineral railway follows the eastern boundary encroaching into the north-eastern and south-eastern corners of the site.	Church Gresley is to the north. A mineral railway is located close to the southern boundary serving the Church Gresley Colliery approximately 100m west. An old shaft is adjacent the central-western boundary (no longer shown by 1901). Sloping ground (probable spoil mounds), 4No. shafts and 2No. air shafts are recorded at the main colliery Old shaft 340m west. Sewerage tanks 160m north. Albert (brick and tile) Works 340m north-east.
1901 (1:2,500) 1902 – 1904 (1:10,560)	A football ground encroaches into the central-western section of the site Additional railway spur constructed within the north-eastern corner of the site to service Donington Works	Donington (fire brick) Works established adjacent the north-eastern boundary with an aerial railway extending eastwards to a clay mine (320m east). Church (sanitary earthenware) Works established adjacent the western boundary (redeveloped into housing by 1923).

Date	Land Use On-site	Land Use Off-site
	beyond. No other significant changes identified.	The Railway (sanitary pipe) Works established 60m south of the site. The main building is surrounded by numerous circular structures (chimneys). Clay pit established south of the mineral railway (30m south). Church Gresley colliery expanded - number of colliery buildings and spoil mounds increased. A reservoir and a small pond are shown 220m and 280m south-west. A number of clay mines and Tile works 400m north-east, brick works, pipe works and clay pit 400m west.
1923 (1:2,500) 1925 (1:10,560)	A small clay pit is shown in the central-northern area of the site. Allotment gardens area present within the north-western section of the site. The football ground is no longer marked.	Donington Works (renamed Church Gresley Works) extended - several chimneys and a reservoir. A second reservoir identified 30m south. Clay pit 30m south extended significantly, tramway established between the pit and the Railway works. (clay pit no longer shown by 1937). The colliery extended significantly - new condenser and clay pit shown. Further away, a mine or air shaft and pumping house recorded 200m north-east and east.
1937 (1:2,500) 1938 (1:10,560)	Clay pit extended (approx. 0.4 ha). No other significant changes are noted.	There is an absence in detail on the 1:2500 maps. The 1:10,000 indicates no significant changes in the surroundings since 1925.
1955 (1:10,560) 1960 – 1961 (1:2,500) 1967 (1:10,560)	The clay pit is now shown as sloped ground with a small pond. A football ground and two features (labelled air raid shelters in 1972) are recorded encroaching onto the north-western edge of the site The allotments are no longer shown	Church Gresley Works and clay pit extended towards the north-eastern boundary of the site. The clay pit 30m south extended significantly, with extensive areas of sloped ground shown. South of the main colliery redeveloped into commercial / industrial uses (200m south-west).
1972 -1975 (1:2,500) 1974 (1:2,500) 1976 – 1977 1:10,00	The football ground is no longer shown. The air raid shelters are recorded as disused. The railway line and mineral railway lines have been dismantled. A clay pit is shown throughout the majority of the site. The 1975 and 1989 maps show (active) opencast coal and clay workings. A cliff/highwall is shown on the western side of the site. A second area of clay pit is possibly indicated in the extreme eastern boundary (relating to an offsite opencast area).	Church Gresley Works disused by 1972 and no longer shown by 1975. A confectionary works is shown adjacent the northern boundary. Spoil heaps and an electricity substation shown beyond the northern boundary. Opencast coal and clay works shown north-east of the site. Clay pit shown beyond the eastern boundary. By 1974 the majority of land to the east of the site comprised opencast workings Spoil heaps are shown beyond the southern boundary. The 1975 map shows these areas as opencast workings and clay workings. The line of a surface water course appears to follow the clay pit outline. This water course disappears in 1974. The colliery is shown as disused by 1972. The

Date	Land Use On-site	Land Use Off-site
	The line of a surface water course appears to follow the clay pit outline. This water course disappears in 1974. .	buildings have been demolished. .
1988 – 1989 (1:2,500) 1980 – 1991 (1:2,500 1986 (1:1,250) 1993 (1:1,250) 1995 (1:1,250) 1996 (1:1,250) 1990 (1:10,000)	The cliff within the opencast is no longer mapped by 1980 suggesting restoration works took place since 1978. The north-western and north-eastern corners of the site are covered with trees. It appears that the site had been restored to current condition by 1986, Paths are shown within the site and along the northern boundary. A drain is shown running north to south through the centre of the site.	By the 1980s, further works, a depot and later a factory (1986) established in the eastern side of the former colliery. A culverted drain/watercourse is present to the east of the site. Drains are shown adjacent the southern boundary. Adjacent the site the workings are shown as disused.
2006 (1:10,000) 2011 (1:10,000)	No changes are shown.	The plan shows the site located on the south-eastern side of Church Gresley, surrounded to the north and west by the village and the east by open space. To the south is Church Gresley Wood. Further disused workings are shown east and a lake 400m south-east.

3. Geo-environmental Setting

3.1. Solid and Drift Geology

Reference to the 1:50,000 BGS Geological Map for Loughborough Sheet 141 (Ref. 2) indicates that drift deposits are absent below the site. The solid geology comprises Pennine Middle Coal Measures Formation typically comprising mudstone, siltstone and sandstone.

A geological fault is shown running through the eastern section of the site trending north-west to south-east with a down-throw to the south-east.

Significant thicknesses of Made Ground deposits are anticipated within the site due to its previous opencast use.

3.2. Mineral Extraction

A coal mining report has been obtained from the Coal Authority and is included in the Desk Study report prepared by Atkins. The findings of the report are summarised below:

- The property is within the boundary of an opencast site from which coal has been removed by opencast methods.
- The property is in the likely zone of influence from workings in 9 seams of coal at 150m to 460m depth, last worked in 1977. The report states that any movement from these coal workings should have now ceased.
- The property 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 in the likely zone of influence of any present underground coal workings.
- The property is not in an area for which the Coal Authority is determining whether to grant a licence to remove coal.
- The property is not in an area for which a licence has been granted to remove coal using underground methods. However, reserves of coal exist in the local area which could be worked at some time in the future.
- There are two mine entries recorded adjacent the boundary of the site. Record 429318-005 and 429318-023 are shown adjacent the western and eastern boundaries respectively. There is no record of treatment however, records may be incomplete and further entries may be present.

No reference is made within the report as to the depth of the opencast, or the measures undertaken to restore the site.

3.3. Hydrology

The closest surface water feature is the drain running north to south through the centre of the site and the drain adjacent the southern boundary. A watercourse is present approximately 180m east of the site flowing in a southerly direction. The water course is likely to be Hooborough Brook.

3.4. Hydrogeology

3.4.1. Groundwater Vulnerability Map

The Environment Agency groundwater vulnerability map in the Envirocheck Report (Ref. 1) classifies the underlying bedrock as a Secondary ‘A’ Aquifer. The Environment Agency defines Secondary ‘A’ Aquifers as 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.

Environment Agency information indicates that the site does not lie within a Groundwater Source Protection Zone.

3.4.2. Groundwater and Surface Water Abstractions

There are no groundwater or surface water abstractions listed within 1km of the site.

4. Ground Investigation Proposals

4.1. Investigation Requirements

The Atkins desk study report (Ref. 1) highlighted possible pollutant linkages with respect to the proposed future development. The preliminary ground investigation was designed to provide environmental information to explore these potential pollutant linkages to facilitate a preliminary contamination assessment and to provide outline mitigation measures. The objectives of the preliminary investigation were therefore to:

- Characterise the Made Ground and Middle Coal Measures,
- Identify potential ground abnormals, such as existing or historical structures, foundations and basements which may remain at the site and assess their impact upon the proposed re-development,
- Establish a preliminary understanding of the geo-environmental regime (soil, leachate and groundwater),
- Establish the groundwater conditions beneath the site,
- Establish the soil borne gas regime,
- Identify the geotechnical properties of the Made Ground and Middle Coal Measures, and
- Assess the materials encountered in terms of the suitability of materials for re-use in earthworks.

4.2. Scope of Ground Investigation Works

The ground investigation scope comprised the following:

- 5No. Cable percussion boreholes,
- 16No. Trial pits,
- 5No. Gas and groundwater monitoring installations,
- *In situ* Standard Penetration Tests,
- Gas and groundwater level monitoring (six monitoring visits following site works), and
- Geotechnical and chemical analytical testing of soil, leachate and groundwater.

5. Ground Investigation Works

5.1. Investigation

Ground Investigation and Piling (GIP) were appointed as the specialist ground investigation contractor for the works, which were carried out between 24th September and 10th in October 2012. 5No. cable percussive boreholes (CP1, CP2, CP4, CP5 & CP6) were advanced at the site to depths of between 14.5m and 29.32m below ground level (bgl). 16No. trial pits were excavated to depths of between 3.0m and 4.5m bgl. Six cable percussion boreholes were originally proposed, however, due to slow progress CP3 was abandoned.

The ground investigation was carried out in accordance with 'Site Investigation in Construction, UK Specification for Ground Investigation' (Ref. 2). Attendance was provided on site on a part time basis by a GIP Engineer and an Engineer from Atkins during the site operations. A factual report has been prepared by GIP (Ref. 3).

The design of the investigation took into account the development proposals for the site. The investigation was undertaken in general accordance with BS:10175 'Code of Practice: Investigation of Potentially Contaminated Sites' (Ref. 4) and BS:5930 'Code of practice for site investigations' (Ref. 5).

The sampling strategy was designed to obtain representative soil and water samples from each stratum encountered. Soil samples were obtained from the first metre for human health assessment. Additional samples were collected at depth to assess the chemical regime for waste classification purposes. Groundwater samples were obtained as part of the monitoring exercise. Geotechnical testing was undertaken on samples from each stratum to identify the engineering properties.

Cable detection searches were carried out and hand-dug inspection pits excavated at the location of each borehole to check for the presence of services.

Representative soil samples were stored in containers under appropriate conditions prior to onward transmission to the laboratory, with chain of custody documentation for environmental samples.

The Exploratory Hole Location Plan is presented on the GIP drawing 20359 and exploratory hole logs are presented in Appendix A.

5.2. Instrumentation and Monitoring

35mm diameter gas and groundwater monitoring standpipes were installed within the five boreholes to monitor groundwater levels and concentrations of soil borne gas.

Table 2. Standpipe Installation Details of Exploratory Holes

Location	Response Zone (mbgl)		Response Zone (mAOD)		Stratum Monitored
	Top	Bottom	Top	Bottom	
CP1	5.0	26.0	116.54	95.54	Made Ground
CP2	1.0	10.0	117.77	108.77	Made Ground
CP4	1.0	7.0	105.67	99.64	Made Ground
CP5	1.0	10.0	107.20	98.20	Made Ground
CP6	1.0	10.0	112.62	103.62	Made Ground

A total of six monitoring visits have been carried out between October 2012 and February 2013.

Measurements of oxygen, methane, carbon dioxide, carbon monoxide and hydrogen sulphide together with groundwater levels, barometric pressure and gas flow rates were made within each of the installations. The results of the monitoring are presented within the ground investigation GIP factual report (Ref. 3).

Samples of groundwater were obtained from the boreholes during the second monitoring visit.

Groundwater and gas monitoring data is presented in Appendix B.

6. Ground Investigation Findings

6.1. Ground Conditions Encountered

During the investigation works only one of the cable percussion boreholes was advanced into the natural ground (at a depth of 28.5m bgl in CP1). The four other cable percussion boreholes terminated within the Made Ground at depths of between 14.5m bgl (CP4) and 24.9m bgl (CP2) due to the presence of siltstone boulders. The trial pits were extended to depths of between 3.0m and 4.5m bgl, the depth of excavation was largely dictated by ground conditions (presence of perched groundwater and the difficulty of digging through stiff Made Ground).

The site is surfaced with grass overlying a thin (generally <0.1m thick) band of clayey topsoil underlain by Made Ground described as cohesive colliery spoil. The shallow colliery spoil generally comprised firm to stiff grey brown occasionally orange and yellow mottled slightly sandy to sandy gravelly clay to depths of generally between 0.65m and 1.0m bgl. This is in turn underlain by firm to very stiff pale grey, grey and dark grey friable slightly sandy gravelly clay with occasional to frequent cobbles and rare boulders.

Gravel within the cohesive colliery spoil is fine to coarse and comprised predominantly grey mudstone, siltstone and occasional weathered coal fragments, sandstone, quartz and rare ironstone. Lenses and discrete pockets of weathered coal were present in various locations (TP2, TP3, TP4, TP8, TP11, TP15 and TP16) and depths (0.1m to 3.6m). Rare to occasional fragments of brick, ceramic, metal and timber were also encountered. Cobbles and boulders were predominantly of grey siltstone. The colliery spoil was in several locations very friable and was often recovered as sand and gravel with clay lumps.

Bands of granular colliery spoil; recovered as grey clayey and silty gravel and grey silty and clayey sand and gravel with cobbles was encountered in CP5, CP6, TP1, TP5, TP6, TP7, TP9 and TP12. Trial pits terminated in this material at the locations of TP1, TP5, TP7 and TP9. Generally these deposits were proven at various depths ranging between 0.7-1.4m (TP1) to 7-10m (CP6) and thicknesses ranging between 0.7m (TP1) and 3m (CP6). The locations and depths of 'granular' deposits do not indicate any clear area or depth of granular material (i.e. continuous layers). It should be noted that whilst recovered as granular materials the results of the particle size distribution (PSD) testing indicates the material is predominantly cohesive in nature (>35% fines) possibly as a result of low moisture content and very high friability, hence is effectively fragmented mudstone or siltstone.

The natural bedrock was proven at one location (CP1 located in the west of the site) at a depth of 28.5m bgl but was not proven beyond 29.32mbgl. The Middle Coal Measures is described as comprising weak grey mudstone.

SPT results within the boreholes indicate that the Made Ground / colliery spoil is firm (and occasionally stiff) becoming stiff from depths of between 3.0m (CP1) and 6.0m bgl (CP2, CP6) and very stiff from depths of between 6.0m (CP1) and 17.0m bgl (CP5). SPT results within the granular Made Ground (CP5 & CP6) indicate it to be medium dense. Various refusals occurred on encountering cobbles.

The sides of the trial pits were generally stable within the cohesive Made Ground unless groundwater was encountered, which caused the sides to collapse, or where significant gravels/cobbles and boulders were encountered.

No evidence of hydrocarbon or significant organic contamination was recorded, although coal fragments have been recorded within the Made Ground. An organic (not hydrocarbon) odour was noted in TP11 in a band of damp clays encountered below 3.6m bgl. Where perched water accumulated within trial pits, a black film was noted on the water, however this did not appear to be hydrocarbon sheen and there was no associated odour.

6.2. Groundwater

Groundwater was encountered at various depths and locations. Borehole records show that groundwater was encountered in CP2 at 23.0m rising to 22.5m, CP4 at 3.0m rising to 2.9m, CP5 at 6.0m rising to 2.0m and CP6 at 13.5m.

Groundwater was encountered in TP9 at 1.6m, significant water entry caused the sides to collapse and inhibited progress below 3.0m. Groundwater was encountered entering TP14 at 2.4m, water entry and accumulation of water in the pit caused the sides to collapse. Damp conditions and seepages were encountered in TP11 (2.5m – damp), TP12 (seepage at 2.0m) and TP16 (seepage at 4.0m).

Based on field observations and exploratory hole logs, the groundwater identified is considered likely to be pockets of perched water present within gravel layers and in gravelly/ cobbly clays at varying depths.

Groundwater monitoring within the borehole standpipes has recorded groundwater levels between a maximum of 15.1m bgl (CP1 located in west of site at highest elevation) and a minimum of 1.33m bgl (CP4 located in east of site at lowest elevation). The results obtained to date suggest the groundwater flow within the Made Ground is in a south-easterly / easterly direction.

Table 3. Groundwater Monitoring

Borehole	Groundwater Levels Monitored (mbgl)		Groundwater Levels Monitored (mAOD)		Stratum Monitored
	Range	Average	Range	Average	
CP1	14.26 – 15.00	14.79	107.28 – 106.44	106.75	Made Ground
CP2	11.00 – 11.20	11.09	107.77 – 107.57	107.68	Made Ground
CP4	1.33 – 1.42	1.37	105.31 – 105.28	105.27	Made Ground
CP5	1.36 – 1.60	1.56	106.70 – 106.62	106.71	Made Ground
CP6	7.92 – 8.20	8.09	105.70 – 105.42	105.53	Made Ground

7. Contamination Assessment

7.1. Soil Assessment

To assess potential risks to redevelopment associated with contamination within the Made Ground and the potential pollutant linkages identified in the Preliminary Conceptual Site Model (Ref. 1), 35No. samples taken during the ground investigation works were selected and sent to a UKAS/MCERTS accredited laboratory (Chemtest) for analysis. The following analyses and number of tests were carried out:

Table 4. Chemical Laboratory Analysis

Analysis	Number of Samples
Heavy metals (arsenic, boron, chromium, hex chromium, cadmium, copper, lead, mercury, nickel, selenium and zinc)	35
PAH – USEPA 16 Speciated	35
TPH CWG (Aromatic Aliphatic split) including BTEX	35
BRE SD1 Suite	14
Asbestos (identification)	35
Loss of Ignition	4
Calorific Value	3
Organic Matter	35

The contamination assessment has been based on the proposed residential development of the site, with areas of open space.

Detailed guidance on human health risk assessment is available within a number of documents, published by the Environment Agency and DEFRA, which comprise the *Contaminated Land Exposure Assessment (CLEA) Model* (Refs. 6 and 7).

Human Health

A Tier 2 generic quantitative risk assessment has been carried out for the potential human health pollutant linkages, based on the screening of soil contamination data against relevant Generic Assessment Criteria (GAC) where available, including Environment Agency Soil Guideline Values (SGVs) and Atkins' Soil Screening Values (SSVs).

The GAC for a residential development with the consumption of home grown produce have been adopted as a conservative scenario, based on the proposed end-use. GAC developed for a soil organic matter content of 6% (sandy loam) have been adopted; the organic matter testing gave results of between 0.93% and 26% with an average of 7.05%.

The chemical testing has identified the following exceedances against the adopted screening levels;

At TP11, concentrations of arsenic (47mg/kg at 0.6m at) and lead (570mg/kg at 4.3m) were identified above the screening values of 32mg/kg (arsenic) and 342mg/kg (lead). Reference to the exploratory hole log for TP11 does not indicate any significant sources of anthropogenic inclusions that vary significantly from the remaining samples tested, although a band of weathered coal gravel was identified at 0.5m bgl and pockets of weathered coal were noted in the strata between 2.5m and 4.5m bgl in TP11. It is therefore considered likely that the elevated metals identified in TP11 were derived from the presence of weathered coal deposits within the colliery spoil.

No elevated concentrations of TPH, PAH or BTEX were identified and no visual or olfactory evidence of hydrocarbon contamination was identified during the ground investigation.

Potential asbestos containing material was not recorded during the site works or identified within the 35 soil samples screened for asbestos by the laboratory.

Loss of ignition ranges from 9.24% and 18.5% in the four samples tested. Calorific value ranged between 0.65 MJ/kg and 1.6 MJ/kg in the three samples tested falling below the screening value of 2MJ/kg (Ref. 8).

Controlled Waters

Potential risks to controlled waters were assessed through testing of soil derived leachate samples and by assessing the potential for contaminants in the soil to mobilise and impact on groundwater. The soil leachable contaminant results were assessed against the Drinking Water Standard (DWS) (Ref. 9) and Environmental Quality Standard (EQS) for freshwater (Ref. 10).

18No. leachate samples were tested and the following exceedances of the DWS levels:

Table 5. Leachates - Exceedances of DWS Screening Values

Determinand	Screening Criteria (Source)	Number of Exceedances	Maximum concentration (location)
Cadmium	5µg/l (DWS)	4	7.6µg/l (TP6 @ 0.2m bgl)
Nickel	20µg/l (DWS)	9	200µg/l (TP16 @ 0.8m bgl)
Selenium	10µg/l (DWS)	2	27µg/l (CP6 @ 1.2m bgl)

The leachate analysis identifies exceedances of the DWS for cadmium, nickel and selenium. Concentrations of selenium and cadmium marginally exceed the respective DWS. Elevated concentrations of nickel have been recorded in half of the leachate samples tested.

Samples of groundwater were retrieved from the five gas and groundwater monitoring standpipes and tested for heavy metals and organic (PAHs and TPHCWG) contaminants. The following exceedances were recorded.

Table 6. Groundwater - Exceedances of DWS Screening Values

Determinand	Screening Criteria (Source)	Number of Exceedances	Maximum concentration (location)
Boron	1,000µg/l (DWS)	3 (CP2, CP5, CP6)	1,700µg/l (CP5)
Nickel	20µg/l (DWS)	4 (CP1, CP2, CP4, CP6)	310µg/l (CP2)
Lead	25µg/l (DWS)	1	57µg/l (CP2)

The data reveals elevated levels of nickel, boron and lead within the groundwater.

Boron exceeded the DWS in three of the five groundwater samples tested at concentrations ranging between 1,200µg/l (CP6) and 1,700µg/l (CP5).

Elevated concentrations of nickel were recorded in four of the five groundwater samples tested at concentrations ranging between 51µg/l (CP6 approximate centre of site) and 310µg/l (CP2 up-gradient of CP6). Concentrations of nickel were below the DWS in CP5 which is located in the south-western corner of the site (down-gradient of CP2 and CP6).

The test results reveal a single (CP2) concentration of lead (57µg/l) in excess of the DWS (10µg/l) out of the five groundwater samples tested. CP2 is located in the approximate centre of the site. Concentrations of lead were significantly below the DWS in the leachate samples tested in CP2. In addition, the concentrations of lead are below detection limits in the remaining groundwater samples including those down-gradient of CP2.

Based on the results obtained, the concentrations of the contaminants recorded are not considered to significantly impacting on groundwater. In addition, heavy metals which include nickel, boron and lead are associated with coal measures, which have historically been recorded within the site and adjacent surrounding area (colliery, mineral railway and works). These activities have now ceased.

7.2. Soil Borne Gas Assessment

Gas monitoring standpipes (50mm diameter HDPE with lockable raised headworks) were installed within all five cable percussion boreholes.

Table 7. Gas Data Summary

Borehole	CH_4 (peak) (%vol)		CO_2 (peak) (%vol)		O_2 (%vol)		Flow Rate (l/hr)	
	Range	Average	Range	Average	Range	Average	Range	Average
CP1	0.0-0.0	0.0	7.3-9.9	8.6	5.5-13.2	9.6	0.1-0.4	0.20
CP2	0.0-0.0	0.0	10.1-13.5	11.6	6.9-12.5	10.2	2.9-4.5	3.90
CP4	0.0-0.0	0.0	11.0-13.2	12.1	8.1-11.5	8.8	0.1-0.5	0.30
CP5	0.0-0.0	0.0	4.4-11.2	7.0	5.9-8.9	7.4	-0.1-0.4	0.10
CP6	0.0-0.0	0.0	8.1-18.1	14.0	0.1-8.1	3.1	2.2-3.5	2.90

The results of the gas monitoring were assessed using the classification system contained within CIRIA C665 (Ref 11). The classification system uses gas concentrations and recorded flow rates for methane and carbon dioxide to determine a gas screening value (GSV). The GSV is calculated by multiplying the maximum recorded flow rate (l/hr) against the maximum recorded gas concentration (%) determining a value reflecting the worst case scenario. The GSV is used in turn to determine a characteristic situation for the site.

Based on the data available, the highest gas concentration of 18.1% v/v for carbon dioxide and maximum flow of 4.5l/hr are used giving a GSV of 0.815l/hr for carbon dioxide. This places the site within Characteristic Situation 3 (CS3), or Amber 1 when compared to NHBC guidance. The source of the ground gases is considered to be historical infilling of former mineworkings using colliery spoil (which is likely to weather relatively rapidly and release carbon dioxide in the process) and potentially the disused mine workings.

In accordance with CIRIA C665 (Ref. 11), the typical gas protection measures for residential properties on a CS3 site shall include proprietary gas resistant membrane (minimum 2000 gauge) and either passively ventilated underfloor subspace or positively pressurised underfloor sub-space.

NHBC guidance for an Amber 1 classification requires that a membrane and ventilated sub-floor void are used to create a permeability contrast to limit the ingress of gas into buildings. Gas protection measures should be as prescribed in BRE Report 414 (Ref. 12). Ventilation of the sub-floor void should facilitate a minimum of one complete volume change per 24 hours.

This assessment will be reviewed and revised accordingly upon receipt of the full set of monitoring results.

8. Geotechnical Testing and Assessment

Geotechnical laboratory testing was undertaken in accordance with BS1377:1990 (Ref. 12) as detailed below:

- 17No. Natural moisture content determinations;
- 15No. Atterberg limit determination (1 point method);
- 13No. Particle size distribution determinations by wet sieve; and
- 6No. Dry density / moisture content relationship test using 2.5kg rammer with CBR and hand vane at each compaction point.

The general geotechnical properties for the Made Ground are summarised below:

Table 8. Made Ground – Geotechnical Testing Summary

Parameter	Number of Tests	Values	Average	Assessment
Natural Moisture Content (%)	17	9.2-26	18.07	-
Liquid Limit (%)	15	40-51	45.87	Low to medium plasticity Modified plasticity index of low to medium volume change potential (average: low volume change potential)
Plastic Limit (%)	15	20-24	21.2	
Plasticity Index (%)	15	20-28	24.67	
% passing 425µm sieve	15	54-94	72.47	

Thirteen particle size distribution (PSD) tests were undertaken within the Made Ground deposits. The findings indicate that the Made Ground (colliery spoil) generally comprised slightly sandy to sandy slightly gravelly to gravelly silt/clay with few to frequent cobbles. The stiffness and friability of the colliery spoil meant it was typically recovered as sand and gravel or gravel; One PSD test carried out on a sample from TP12 at 1.7m bgl indicates that the Made Ground at that location was very silty / clayey sand and gravel with some cobbles possibly due to the friability of the material.

Six compaction tests were carried out on the colliery spoil as summarised in the table below.

Table 9. Made Ground – Compaction Testing

Parameter	Results					
	CP4*	**TP1/6/7***	**TP3***	**TP5/CP6***	**TP10/9***	**TP15/14***
	3.0m 1.2m 2.0m	**0.7m 0.9m 2.5m**	**1.0m 2.0m**	**2.0m 1.3m 3.0m 6.0m 7.0m**	**1.0m 2.0m 3.0m 1.0m**	**1.0m 2.0m 3.0m 0.9m 2.0m**
Optimum Moisture Content (%)	14	10	13	13	15	14
Natural Moisture Content (%)	26	13	17	15	19	15
Difference between Optimum and Natural Moisture Content (%)	12	3	4	2	4	1
Maximum Dry Density (Mg/m^3)	1.71	1.85	1.75	1.82	1.68	1.79

* Samples were combined with the same or similar type samples to accumulate the required testing volume

Hand vane tests undertaken at the compaction points indicate that at optimum moisture content and dryer, the strata was too hard to test. At approximately 14% to 17.5% moisture content the average hand vane reading was 126kPa. At approximately 19% to 20% moisture content the average hand vane reading was 88kPa.

The results of the compaction testing indicate that the natural moisture content of the Made Ground is generally only slightly greater than the optimum moisture content, however where the material was recovered wet due to perched water (i.e. CP4 – water strike at 3.0m bgl) the difference is much greater and would likely require measures to reduce the moisture content prior to re-use. All excavated materials should be handled and managed appropriately and protected from adverse weather conditions, the Made Ground of colliery spoil predominantly comprises clay and silt and will therefore be more susceptible to changes in moisture content. The majority of the material is likely to be suitable for re-use in earthworks, if treated and handled appropriately.

California Bearing Ratio (CBR) testing was undertaken on six recompacted samples of Made Ground at each compaction point. The results are summarised below:

Table 10. Made Ground – CBR Testing

Location	Depth (m)	Description of Strata	Mean Moisture Content (%)	CBR Top (%)	CBR Bottom (%)	Wet Density (Mg/m^3)	Dry Density (Mg/m^3)
CP4*	3.0 1.2 2.0	Slightly sandy gravelly clay with rare cobbles	11 13 16 19 20	34 28 10 5.3 2.8	34 26 14 7.4 3.9	1.85 1.92 1.97 1.98 1.97	1.67 1.70 1.70 1.66 1.64
TP5/CP6*	2.0 1.3 3.0 6.0 7.0	Slightly sandy slightly gravelly clay with occasional cobbles	9.45 11.5 13.5 15.5 17.5	19 15 6.1 5.8 3.7	29 19 14 8.2 4.8	1.90 2.02 2.05 2.05 2.01	1.74 1.81 1.80 1.77 1.71
TP1/6/7*	0.7 0.9 2.5	Slightly sandy slightly gravelly clay with occasional cobbles	4.8 6.95 8.9 12 15.5	36 33 26 14 5.3	47 38 28 17 5.5	1.83 1.92 2.00 2.06 2.05	1.74 1.79 1.84 1.84 1.78
TP3*	1.0 2.0	Slightly sandy gravelly clay with rare cobbles	9 10 13 15.5 19	25 34 18 11 2.1	40 33 20 13 2.2	1.86 1.90 1.99 2.00 1.99	1.71 1.72 1.75 1.73 1.67
TP10/9*	1.0m 2.0m 3.0m 1.0m	Slightly sandy slightly gravelly clay	9.5 13 16 17.5 19	28 23 8.7 6.1 1.4	35 26 10 4.5 3.1	1.80 1.89 1.94 1.94 1.94	1.64 1.67 1.67 1.65 1.63
TP15/14*	1.0m 2.0m 3.0m 0.9m 2.0m	Slightly sandy slightly gravelly clay with occasional cobbles	6.85 11 12.5 17 19	29 22 20 5 2.5	37 32 22 6 2.5	1.83 1.96 2.02 2.05 2.00	1.71 1.77 1.79 1.76 1.68

* Samples were combined order to form a sample of the required mass to carry out certain geotechnical tests. Where this was required samples of similar lithology and depths were combined.

BRE Concrete Classification

Soil testing conducted in accordance with BRE Special Digest 1: 2005 (Ref. 14) gave the following results:

Table 11. BRE Concrete Classification

Details	Range	Concrete Class
Number of Tests	14	DS-4 AC-5
Water Soluble Sulphate (mg/l)	340-2500	
Soluble Magnesium (mg/kg)	10-190	
Total Sulphate Extract (%)	0.04-1.36	
pH	4.2-8.4	

Chemical testing of soils for concrete classification, indicates that a concrete classification sulphate class DS-4 and Aggressive Chemical Environment for Concrete (ACEC) class ranging between of AC-3 and AC-5 owing to the variable pH.

9. Updated Conceptual Site Model

9.1. General

The assessment methodology adopted is similar to that derived for the determination of statutory Contaminated Land, as defined in Part 2A of the Environmental Protection Act 1990 (Ref. 6), which is assessed through the identification and assessment of pollutant linkages (Source-Pathway-Receptor relationships). Implicit in the guidance is the application of risk assessment to consider whether potential pollutant linkages may be significant. In accordance with guidance provided in CLR 11 (Ref. 7) human health, buildings and wider environmental Receptors and Pathways have been identified based on the proposed residential (with the consumption of home grown produce) end-use.

The approach adopted involves the development of a Preliminary Conceptual Site Model (PCSM) to summarise potential sources of contamination, potential migration / exposure pathways and potential receptors that may exist at the site that if linked could present significant levels of risk.

Based on the available desk study information, a PCSM has been produced with respect to the proposed redevelopment and future use of the site.

9.2. Sources

Potential on-site sources of contamination have been identified and summarised below:

- Made Ground associated with the historical opencast and clay workings and subsequent restoration works which cover the majority of the site. The source and chemical characteristics of the backfill materials are unknown. Potential contaminants include heavy metals, inorganic compounds, acids, alkalis, asbestos, organic compounds, volatile organic compounds, semi volatile organic compounds, asbestos and soil borne gases (explosive, asphyxiating or toxic).
- Other historical uses recorded within the site include the railway line and branch line within the eastern side, north-eastern and south-eastern corners, air raid shelters (north-east), and drains. Beneath the site mine workings and therefore a potential source of mine gas.

Potential off-site sources of contamination have been identified as:

- Extensive historical quarrying and mining (Church Gresley Colliery) has been recorded adjacent the site. A mineral railway line, shafts, chimneys, a large condenser and spoil mounds/workings have been recorded at the colliery. Infilling is likely and opencast and clay workings have been recorded adjacent to the site. Potential contaminants include heavy metals, hydrocarbons, sulphates, solvents, asbestos, acids, alkalis, soil borne gas (explosive, asphyxiating or toxic), vapours and leachates.
- Historical commercial and industrial sites have been recorded surrounding the boundary of site and are primarily associated with the brick works, factories and depots with railway lines adjacent the eastern and southern boundaries. Near to the site, sewage tanks (180m north-east), reservoir (adjacent southern boundary) and air raid shelters (adjacent northern boundary) have also been recorded.
- Existing commercial and industrial sites have developed on the former colliery to the south-west. An electricity substation is present adjacent to the northern boundary of the site.
- Metal contamination in minewater, metal contamination around the discharge points and mine gas are potential sources.

9.3. Pathways

For the purpose of this PCSM assessment, the potential exposure pathways for human health have been assumed to match the residential end use with the consumption of home grown produce Conceptual Exposure Model (CEM). This CEM is considered to be the closest match to those defined in the Updated Technical Background to the CLEA Model - SR3 (Ref. 8).

The following potential pathways have been identified for the site:

- Leaching/migration of contaminants through soil.
- Direct dermal contact, ingestion of dust from soil or groundwater.
- Migration of contaminants in groundwater.
- Migration through fault.
- Surface water run-off.
- Inhalation of asphyxiating or toxic gases or vapour.
- Direct contact of buildings with contaminants.
- Mine workings.

9.4. Receptors

Potential on-site receptors include:

- Construction workers.
- Site end users.
- Buildings.
- Controlled waters (groundwater and surface waters).

9.5. Contamination

The available information suggests there is a potential risk of contamination at the site predominantly associated with the former uses of the site which have been identified as including opencast and clay workings. Prior to the opencast workings, the site potentially contaminative uses were the railway and potentially impacted Made Ground materials associated with the restoration of the clay pit.

Off-site potential risk of contamination is mainly associated with the industries / works, railway lines, extensive and quarrying/mining infilling within the area surrounding this would require further investigation and monitoring. These may have also impacted upon materials that may have been used in the restoration materials. Testing should be undertaken as part of any future ground investigation to confirm the contamination regime at the site.

9.6. Soil Borne Gas

Made Ground associated with the former uses of the site and infilled/restored land are likely to constitute potential on-site sources of soil borne gases. The potential for colliery spoil, underground workings and faulted ground are potential sources of mine gas.

Potential off-site sources of gas are primarily associated with the Made Ground, infilled pits, historical works and other infilled materials, which may be a source of migration of soil borne gases onto the site. There is a further risk relating to mine gases, which may migrate through former shafts or adits (if present). This would require further assessment through investigation and monitoring of potential soil borne gases / mine gas.

9.7. Groundwater

Based on the historical review, site sources of contamination may impact on the groundwater quality and surface water run-off. However, off-site sources have also been recorded associated with the mining legacy, quarries and extensive industries which may also impact upon groundwater quality.

9.8. Updated CSM Model

The updated Conceptual Site Model (CSM) has been prepared based upon the findings of the preliminary ground investigation, chemical testing and subsequent risk assessments. On the basis of this preliminary assessment, the risk level associated with the proposed development as currently outlined is considered to be low.

In the site's current state there is considered to be no significant risk associated with the isolated exceedances of arsenic and lead identified (both in TP11) due to the depth of the contamination in excess of 500mm below ground level. The marginally elevated metals are considered likely to be associated with the Coal Measures material within the samples of colliery spoil and are likely to be isolated.

The proposed redevelopment is likely to require earthworks (cut and fill). However it is considered that the human health exposure pathways for these potential contaminants can be mitigated by localised removal or the use of materials management and the introduction of pathway breaks such as clean cover within gardens and landscaping, as required by building control / NHBC, hardstanding and building cover.

No significant risks to controlled waters have been identified through the ground investigation.

Risks associated with ground-borne gases and aggressive ground (elevated sulphates) have been identified which require mitigation and management as discussed within this Technical Note.

The updated conceptual site model is summarised in the table below on which also is shown a qualitative assessment of risk. The estimation of risk has been assessed based upon the consideration of magnitude, consequences and probabilities highlighted in Appendix A.

The ground based risks to construction workers include potential exposure to heavy metals and will need to be dealt with by routine precautions (welfare, hygiene, PPE).

Off-site sources are not considered likely to impact upon the site end-users.

Table 12. Updated Conceptual Site Model

Sources	Pathways	Receptors	Mitigation	Residual Risk
Made Ground (heavy metals – lead and arsenic)	Dermal contact, inhalation of soil derived dust, ingestion of soil, consumption of home-grown produce and soil attached to home-grown produce	Human health - construction workers -end-users	Low risk to current site users and future site users due to depth of identified contaminants. Should levels change exposing end users to lead and arsenic (TP11), localised removal or materials management recommended to mitigate risks or placement of clean cover.	Low
Ground-Borne Gases – Associated with colliery spoil (break down of carbonaceous materials)	Accumulation in confined spaces followed by inhalation / asphyxiation	Human health -end users	Based on initial results. The site has been defined as Characteristic Gas Situation 3 / Amber 1. Appropriate gas protection measures required in proposed buildings.	Low
Aggressive ground conditions – Elevated sulphate/ sulfate within Made Ground	Direct contact	Buildings	Use of appropriate concrete (DS-4 AC-3 to AC-5)	Low

10. Development Constraints

The proposals for the site include residential development of up to 306 dwellings, access, parking, public open space, landscaping and associated infrastructure (outline with all matters reserved other than principle means of vehicular access). The final layout and site levels have not yet been established. The properties are assumed to be houses, likely to be 2 to 3 storeys in height, with new roads, gardens and hard / landscaped areas.

The recommendations presented within this report are for indicative purposes only and should be assessed further as part of the detailed design. The following provides a summary of the potential ground abnormals and development constraints identified through the review of historical information and recent ground investigation:

- A large clay pit (later identified as clay, coal and shale opencast quarry) covered the majority of the site prior to being backfilled in the 1970s/80s. The maps show a high wall along the western boundary. Thick Made Ground deposits are present throughout the site with natural ground only identified at one location at a depth of 28.5m bgl (CP1). The base of the Made Ground was not proved in the remaining four boreholes due to obstructions.
- Made Ground (colliery spoil) is present across site, predominantly comprising slightly gravelly slightly sandy clay with few to frequent siltstone cobbles and rare boulders which limited the progression of four of the five boreholes. Rare timber and metal fragments were also identified.
- Whilst coal seams or abandoned workings (voids) were not recorded during the investigation, the site is in the influence of nine coal seams at depths greater than 150m and given the close proximity of the former Church Gresley colliery to the west of the site. However, unrecorded shallower mineworkings may be present between 28.5m bgl (base of the Made Ground proven during the investigation) and 150m where coal seams have been worked.
- There is a significant level difference across the site possibly requiring earthworks, reprofiling or benching to facilitate the redevelopment of the site.
- Marginal heavy metal contamination identified in one location (arsenic at 0.6m bgl, lead at 4.3m bgl), possibly requiring risk mitigation through targeted removal or introduction of a pathway break if site levels are reduced in this location.
- Marginal exceedances of DWS standards for cadmium, nickel and selenium were recorded in a limited number of leachate samples and boron, nickel and lead in groundwater samples. However, based on the results obtained, the concentrations of the contaminants recorded are not considered to significantly impacting on groundwater.
- The groundwater depth across the site is highly variable, with perched water strikes recorded at a range of depths in several boreholes and trial pits. Groundwater monitoring in boreholes has shown the depth of water varies from 1.33m bgl (CP4) to 15.1m bgl (CP1) flowing in south-easterly / easterly direction. Dewatering of excavations for earthworks and foundations is likely to be required where perched groundwater is encountered at shallow depth (east of the site). Testing and on-site observations has shown that the Made Ground is highly susceptible to changes in moisture content, with the integrity and performance of the material being significantly impacted by presence of perched water.
- SPT results within the boreholes indicate that the Made Ground colliery spoil is firm to stiff at traditional foundation depths, becoming stiff from depths of between 3.0m (CP1) and 6.0m bgl (CP2, CP6) and very stiff from depths of between 6.0m (CP1) and 17.0m bgl (CP5).
- The properties of the Made Ground are difficult to predict due to its variability, although the findings of the ground investigation indicate that the colliery spoil is relatively consistent. However, there is a possibility of variation across the site and over short distances, particularly in the area of the indicated high wall in the west, potentially giving rise to high total and differential settlement. Further

settlement can arise from rising groundwater and inundation of groundwater leading to collapse. Settlement will impact upon buildings, highways and services.

- The Made Ground may be suitable for shallow foundations due to the fairly consistent firm-stiff colliery spoil identified, however foundation design would have to mitigate for potentially high settlements and variable firm to stiff strata. Reinforced strip, trench or raft foundations may be suitable within the Made Ground, or alternatively a piled solution founding on the natural bedrock (identified in CP1 at 28.5m bgl) or ground improvement techniques. All options are subject to building control and NHBC requirements.
- Preliminary assessment indicates a concrete classification sulphate class of DS-4 and AC-3 to AC-5 would be suitable within the site.
- The ground-borne gas monitoring and risk assessment has identified elevated levels of carbon dioxide, likely to be generated from the breakdown of carbonaceous material within the backfilled colliery spoil. The data available to date classifies the site a Gas Characteristic Situation 3 / Amber 1, therefore the proposed building will require gas protection measures.
- The final site levels are yet to be established, however earthworks are considered likely to be required. The materials excavated should be reused in accordance with the Highways Agency Specification for Highway Works (Ref. 15). The findings of the compaction testing indicate that the materials can be re-used providing that the moisture content is suitably managed (where perched water is present, moisture contents may need to be reduced).
- The re-use of on-site soils may be undertaken either under the Environmental Permitting Regulations 2007 (EPR) or under the CL:AIRE Voluntary Code of Practice (CoP) which is accepted as an alternative regime to the EPR. Under the CL:AIRE voluntary Code of Practice (CoP) (Ref. 16) materials excavated on-site are not deemed waste if suitable for re-use within the site. Material that may have been classified as hazardous waste under the EPR may be re-used.

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Figures and Appendices

Appendix A. Envirocheck Report

Appendix B. Coal Mining Report

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