



J N P G R O U P
CONSULTING ENGINEERS

Phase II Geotechnical and Geoenvironmental Report

Project: Manor Farm,
Great Houghton,
South Yorkshire,
S72 0AZ

Client: Harron Homes

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EXECUTIVE SUMMARY

Site location	Manor Farm, Great Houghton, South Yorkshire, S72 0AZ	
Development scheme	Construction of 86 residential properties with associated infrastructure and public open space.	
NGR	SE 42935 07028	
Current use	On-site: Agricultural fields and farmyard.	Off-site: agricultural, residential, and road infrastructure.
Geology (from GI)	Made Ground: Mixed lithology gravels and sands, containing fragments of brick, concrete, etc. Encountered from ground level to depths between 0.20m – 0.80m bgl across farmyard area in south-west corner of site. Topsoil: At the southern end of the site, loamy and silty sand topsoils, grading northward into sandy clay topsoils, gravelly and loamy clay topsoils, and finally into loamy clay topsoils at the northern end of the site. Encountered from ground level to depths of between 0.30m – 0.60m bgl across the fields; also encountered beneath Made Ground in DS05 from 0.40m bgl to 0.80m bgl. Newstead Rock Member: Extending across the southern portion of the site. Yellow and brown granular soils and heavily weathered sandstone. The top of the unit was 0.20m – 0.80m bgl; the depth to the base of the unit was not proven. Pennine Upper Coal Measures Formation: Extending across most of the site north of the Newstead Rock Member. Cohesive soils, weathered mudstones, and thin shallow coal seams. The top of the unit was 0.30m – 0.60m bgl; the depth to the base was not proven. Likely excavation instability in Newstead Rock Member and in shallow coal seams, prudent to allow for excavation support.	
Groundwater	Confined groundwater within weathered and fractured shallow coal seams. Groundwater levels will rise above the level of the coal seams if/when they are pierced. In the vicinity of the proposed drainage attenuation basins in the north-east of the site, coal seams were encountered in excess of 1.55 m to 1.60 m bgl, with the depth of the water table 0.6 m to 0.95 m bgl. Prudent to allow for groundwater control measures during construction particularly during wet periods.	

Foundation design	South of inferred fault, shallow strip foundations within granular soils of the Newstead Rock Member at a minimum depth of 0.60m bgl, with an allowable bearing pressure of 125kN/m² at 0.60m bgl. North of inferred fault, shallow strip foundations are feasible within cohesive soils of the Pennine Upper Coal Measures Formation at a minimum depth of 0.9m bgl, based on soils of medium volume change potential. Allowable bearing pressure of 100kN/m² at 0.9m bgl. Influence of vegetation may control foundation depths. In addition, it is recommended that 0.50m of natural strata is present between the base of foundations and the top of the shallow coal seams; if not possible given required founding depths, foundations will have to be deepened through coal seams to 0.15m below the base of the coal. Design sulphate class DS-1 and ACEC class AC-1 is required for buried concrete within the Made Ground and granular soils of the Newstead Rock Member. Design sulphate class DS-3 and ACEC class AC-4 is required for buried concrete within the Pennine Upper Coal Measures Formation north of the inferred fault (excluding where coal is present). Design sulphate class DS-4 and ACEC class AC-5 is required for buried concrete within the Pennine Upper Coal Measures Formation north of the inferred fault where concrete will be facing coal.
Road construction	A CBR of 3% is anticipated north of the inferred fault in the cohesive soils, and a CBR of 20% is anticipated south of the inferred fault, in the granular soils, subject to outstanding test results. This should be checked upon receipt of an addendum report and on site with plate bearing tests.
Contamination	There is a risk to human health from elevated concentrations of beryllium and PAHs, as well as the presence of asbestos, within the Made Ground deposits across the farmyard area in the south-western corner of the site. Watching brief recommended during site clearance works for unanticipated areas of contamination. Suitable clean capping system, anticipated to be 600mm, required within garden areas where the Made Ground is present within the former farmyard area. Low / no risk to controlled waters or ecology. Risk to plastic water pipeline from the shallow Made Ground deposits encountered in the farmyard area. Mitigation required.

Ground gas	Based on the calculated Gas Screening Value in accordance with BS 8485:2015 and CIRIA C665 a CS2 classification should be assigned, but a Green classification is determined based on NHBC 2007. Based on maximum concentrations then a CS1 or Green classification is applicable. Therefore, gas protection measures may or may not be required at the site to ensure risks are acceptable to the end users, this is pending the results of an ongoing full gas monitoring and assessment programme. Risk to construction workers during below ground works due to depleted O₂ levels. No radon protection measures required.
Recommendations	An implementation plan will be required for the required remediation for the contaminated farmyard area in the south-west corner of the site. A Materials Management Plan or equivalent exemption will be required for any re-use of material on this or any other site. A tree survey to be able to assess their impact upon foundation types and depths. A ground gas monitoring and risk assessment programme be completed, to include periods of low and falling atmospheric pressures, to fully characterise the site's ground gas regime. An asbestos demolition and refurbishment survey should be undertaken of the building(s) present at the site.

1 INTRODUCTION

1.1 General

1.1.1 JNP Group was instructed by the client to undertake a ground investigation of:

Manor Farm,
Great Houghton,
South Yorkshire,
S72 0AZ,

hereinafter referred to as 'the site'. This report is subject to the limitations presented in Appendix A.

1.1.2 It is understood that the existing farmyard buildings at the southern end of the site are to be demolished, and the site redeveloped with 86 new two-storey residential properties, with roads and areas of hardstanding for access servicing and parking, and with private gardens. Attenuation basins for the surface water drainage are proposed in the north east of the site. The proposed redevelopment layout is shown on external Drawing Reference RED115 910 produced by Residential Engineering Design Ltd., issued October 2020.

1.1.3 All comments given are based on the understanding that the proposed redevelopment will be as detailed above.

1.2 Objectives

1.2.1 The purpose of the investigation was to determine the geotechnical and geoenvironmental ground conditions at the site and assess the implications of such relative to the proposed residential redevelopment. The scope of work comprised an intrusive investigation, laboratory testing, and gas and groundwater level monitoring. This report contains details of the site, the work and laboratory testing undertaken, strata encountered, geotechnical and chemical laboratory test results, monitoring results, and provides an interpretative assessment of the ground conditions regarding geotechnical and contaminated land issues.

1.3 Methodology

1.3.1 This report has been compiled in accordance with the on-line Land contamination: risk management (LCRM) guidance produced by the Environment Agency (June 2019). This can be found on the UK government website: <https://www.gov.uk/guidance/land-contamination-how-to-manage-the-risks>.

1.3.2 With regard to geotechnical aspects, reference is also made to the requirements of BS EN 1997, Eurocode 7, Geotechnical Design, and associated standards.

1.3.3 This report has been prepared following review of a previous Phase I Desk Study undertaken by Ecus Ltd. 'Manor Farm, Great Houghton, Phase I Geo-environmental Desk Study' (Ref: 14358) dated January 2020.

2 SITE DESCRIPTION

- 2.1.1 The site is located off High Street, in Great Houghton, South Yorkshire, approximately 8.5km east of Barnsley town centre (see Figure 1 Key Plan). The centre of the site is located at National Grid Reference SE 42935 07028. The site covers an area of approximately 3.1 hectares.
- 2.1.2 The boundaries of the site were hedgerows to the north, east, and west, and an unmarked boundary through the existing farmyard to the south. Another hedge row ran south-west to north-east between the two fields that make up most of the site.
- 2.1.3 Adjacent land uses were agricultural, residential, and road infrastructure.
- 2.1.4 The site sloped gently from south-west to north-east; surface water flows north-east across the site towards the ditch along the northern boundary.
- 2.1.5 Most of the site was covered in grass over softstanding ground, with limited areas of hardstanding and granular Made Ground in the farmyard at the southern end of the site.
- 2.1.6 There were several barns/large sheds and silos in the farmyard at the southern end of the site, as well as a small shed in the south-eastern corner of the western field. Asbestos roof sheets were observed on several of the building in the farmyard, and on the small shed in the field. The buildings and silos were in a relatively poor condition, having clearly been in place for several decades.
- 2.1.7 The two fields were lined with hedgerows on all sides except from at the south-western ends of the fields, where they meet the farmyard. There were several mature trees in the south-western corner of the site, along the western margin of the farmyard.
- 2.1.8 There were some items of old, likely disused, agricultural equipment throughout the barns/large sheds in the farmyard, and there were old glass fragments strewn across much of the western margin of the western field (likely a result of refuse being thrown from vehicles driving past the site along High Street); other than this, the site was generally in a good condition.
- 2.1.9 Photos of the site taken during the site works are given in the Photo Document in Appendix C.
- 2.1.10 No invasive species were noted during the site work. However, JNP Group recommend that an arboreal specialist be consulted to confirm this.

3 UK CONTAMINATED LAND LEGISLATIVE FRAMEWORK

3.1 General

- 3.1.1 Given that the site is being assessed with the potential for future development, the most applicable appraisal relates to the requirements of the Planning Regime as described in the National Planning Policy Framework.
- 3.1.2 In order to proceed with an assessment of contamination issues it is essential that there is compliance with UK guidance as detailed in the on-line Land contamination: risk management (LCRM) guidance produced by the Environment Agency (June 2019). This can be found on the UK government website: <https://www.gov.uk/guidance/land-contamination-how-to-manage-the-risks>.
- 3.1.3 Part IIA of the Environmental Protection Act, 1990, which was enacted by Section 57 of the Environment Act 1995, and the associated Contaminated Land (England) Regulations 2000 (SI 2000/227), was introduced on 1 April 2000. It created a new statutory regime for the identification and remediation of land where contamination poses an unacceptable risk to human health and the environment. The guidance was subject to a review by DEFRA in 2012, and a revision was published.
- 3.1.4 Part IIA provides a statutory definition of contaminated land:
“any land which appears to the Local Authority in whose area it is situated to be in such a condition by reason of substances in, on or under the land, that significant harm is being caused, or that there is a significant possibility of significant harm being caused, or that pollution of controlled waters is being or is likely to be caused”.
- 3.1.5 Controlled waters are considered to be all groundwaters, inland surface waters, and estuarine and coastal waters.
- 3.1.6 To determine whether land falls under the Part IIA definition of contaminated land, the site should be evaluated in the context of a risk-based framework. The assessment of contaminated land is typically a two-phase process, which is initially based on a qualitative assessment of the likelihood of complete pollution linkages, with a quantitative element that seeks to determine the degree and the significance of the harm. Land is only defined as ‘Contaminated Land’ if a “significant pollutant linkage” is present.
- 3.1.7 A pollutant linkage must comprise the following:
Source - a contaminant at a concentration capable of causing adverse health or environmental effects.
Receptor - there must be a receptor (e.g. human, controlled waters, ecological, or property) present, which may be at risk of harm or impact from the source.
Pathway - there must be an exposure pathway through which the receptor comes into contact with the contamination source.
- 3.1.8 Each of these elements can exist independently, but they create risk only when they are linked together, so that a particular contaminant affects a particular receptor, through a particular pathway.
- 3.1.9 The responsible authority then needs to consider whether the identified pollution linkage:
- is resulting in significant harm being caused to the receptor in the pollutant linkage.

- presents a significant possibility of significant harm being caused to that receptor.
 - is resulting in the pollution of controlled waters, which constitute the receptor; or is likely to result in such pollution.
- 3.1.10 If a pollutant linkage is demonstrated, then the Part IIA legislation provides powers for remedial action to be enforced by the Local Authority in whose area the contaminated land is situated.
- 3.1.11 In addition, JNP Group has undertaken a preliminary risk assessment based on the probability of receptor exposure to the identified source and the consequences of such exposure.
- 3.1.12 Risk management, which can include site surfacing, formal management systems, legal requirements; is then considered to provide an overall residual risk. The categories of environmental risk used by JNP Group are given in the table that follows.

Table 3-1: Risk Matrix

Environmental Risks		
HIGH		Issues within this category likely to provide a significant cost or liability. Further detailed investigation may be required to clarify the risk.
MEDIUM		It is possible that issues within this category may provide a cost or liability. Further investigation may be required to clarify the risk.
LOW		It is unlikely that issues within this category will provide a significant cost or liability. Basic investigation may be required to clarify the risk.
NONE		No source – pathway – receptor linkage present.

4 CONCEPTUAL SITE MODEL AND PRELIMINARY RISK ASSESSMENT

4.1 General

4.1.1 This section uses information from field observations and the Phase I Desk Study produced by Ecus Ltd. to provide a conceptual model and qualitative assessment of the potential risks posed to human health and environmental receptors from potential on-site and off-site sources of contamination. The assessment is presented as a 'source-pathway-receptor' model in accordance with Part IIA of the Environmental Protection Act 1990.

4.1.2 The conceptual site model has been developed assuming that the site will be redeveloped for residential housing with private gardens.

4.2 Potential Sources of Contamination

4.2.1 Potential On-Site Sources of Contamination

- The site was undeveloped agricultural fields on the earliest historic map from 1854. A pond was shown at the northern end of the site from 1892 to 1993, after which the pond was no longer present. The fields which comprise most of the site have remained undeveloped since.
- It is unclear from the historic maps when the farmyard buildings were constructed at the southern end of the site, as they are not shown until 2001, but are clearly much older. Heavy metals, hydrocarbons, asbestos and soil gas associated with limited Made Ground materials may be present across the farmyard area due to the agricultural development.
- In accordance with C733 guidance, any structure built, refurbished, or modified during the Twentieth Century has the potential to contain asbestos containing materials (ACM). In addition, any demolition material either stockpiled or used as backfill on site also has the potential to contain asbestos containing materials (intact or broken up).
- Drainage runs including gullies are a potential source of contaminated material such as hydrocarbons and heavy metals.
- The pond at the northern end of the site was shown on maps from 1892 to 1993; it is possible that it was backfilled, or that a land drain was put in to drain the pond. If the area was backfilled or partially backfilled with material, JNP Group consider that material used would have most likely to have been inert, with a low organic content, such as recycled soils or rubble, rather than domestic waste, chemical waste or industrial waste.
- Based upon guidance given in CL:AIRE research bulletin RB17 (CL:AIRE 2012), as the depth of the infilled ground is unlikely to be greater than 5.00 m, and the soil atmosphere is likely to be aerobic and of small area, the former pond is unlikely to generate significant volumes of ground gas. RB17 indicates that even where ground gas is present from Made Ground and recycled soils, it generally does not pose a risk. In addition, RB17 indicates that based upon available case studies, sites where fill is > 30 years old, the gassing regime results in a characteristic situation 1 classification, where gas protection measures are not required. The last date of a recorded pond was 1993, so if the pond was backfilled or partially backfilled, it was around 28 years ago.

4.2.2 Potential Off-Site Sources of Contamination

- No potential off-site sources of contamination have been identified that could impact on ground conditions at the site. The site is surrounded by residential properties and agricultural fields.

4.3 Receptors

4.3.1 The site is to be redeveloped for residential housing with private gardens. In addition, the site overlies a Secondary-A Aquifer (Pennine Upper Coal Measures Formation). The primary receptors, considered to be potentially at risk from any identified contamination are as follows:

Human Health

- Construction workers during the redevelopment phase.
- Residential end users.

Controlled Waters

- The Pennine Upper Coal Measures Formation beneath the site is classified as a Secondary-A Aquifer. JNP Group considers groundwater to be a sensitive receptor, although there are no recorded licensed groundwater abstractions or Source Protection Zones within 1km of the site.
- The nearest surface watercourse is an unnamed inland river 178m south-east of the site. A ditch bordering the north of the site discharges into this watercourse. The ditch is considered a sensitive receptor due to its proximity to the site.

Ecological

- The site is not located within an environmentally designated sensitive area.
- Given the site setting, sensitive species are considered unlikely to be present at the site (subject to any ecological survey undertaken).

Property / Infrastructure

- Concrete vulnerability to aggressive ground conditions.
- Build-up of gases with potential for explosion.
- Water supply pipework.

4.4 Pathways

4.4.1 Potential contaminant migration pathways considered relevant to the site are:

Human Health

- Ingestion of contaminated soils and dust particles.
- Direct physical contact with near surface soils and contaminated dust particles.
- Inhalation of wind-blown contaminated dust.
- Inhalation of vapours and gases, migrating vertically into the atmosphere.
- Inhalation of vapours and gases, migrating vertically into buildings and confined spaces.

- Consumption of vegetables cultivated in contaminated soils.
- Consumption of soil attached to vegetables cultivated in contaminated soils.
- Consumption of contaminated potable water.

Controlled Waters

- Leaching of contaminants in Made Ground / natural ground into groundwater.
- Lateral migration of contaminated groundwater into the unnamed river to the south-east.
- Vertical migration of contaminated shallow groundwater impacting deeper groundwater in the aquifer sequence.
- Run-off of site-derived contamination into the ditch / unnamed river to the south-east during construction.

Ecological

- Migration of contamination through groundwater and subsequent uptake by plant roots.
- Direct contact between ecological receptors and contaminated surface water.
- Direct contact between ecological receptors and contaminated soils.
- Ingestion of contaminated soils/surface waters by ecological receptors.
- Inhalation of vapours or wind-blown dust by ecological receptors.

4.5 Pollutant Linkages

- 4.5.1 A 'pollutant linkage' describes the relationship between a contaminant, a pathway and a receptor, a 'pollutant' being the contaminant in a pollutant linkage. A contaminant, pathway and receptor must all be present for a pollutant linkage to exist, which forms the basis for determination that a piece of land is Contaminated Land. Potential sources, pathways and receptors have been assessed. The following Tables summarise the significant pollutant linkages potentially active at the site.

Table 4-1: Potential Source-Pathway-Receptor Linkages for Human Health Risk Assessment

Source	Pathway	Receptor
Contaminated soils	Ingestion of soil	On-site female child: 0 - 6 yrs old
		On-site construction worker
	Ingestion of household dust	On-site female child: 0 - 6 yrs old
	Ingestion of contaminated vegetables	On-site female child: 0 - 6 yrs old
	Ingestion of soil attached to vegetables	On-site female child: 0 - 6 yrs old
		On-site female child: 0 - 6 yrs old
	Dermal contact	On-site female child: 0 - 6 yrs old
		On-site construction worker
	Dermal contact with household dust	On-site female child: 0 - 6 yrs old
	Inhalation of fugitive soil dust	On-site construction worker
		On-site female child: 0 - 6 yrs old
	Inhalation of fugitive household dust	On-site female child: 0 - 6 yrs old
	Inhalation of vapours in outdoor air	On-site female child: 0 - 6 yrs old
		On-site construction worker
	Inhalation of vapours in indoor air	On-site female child: 0 - 6 yrs old
	Consumption of contaminated potable water	On-site female child: 0 - 6 yrs old
Ground gas	Vertical and lateral migration	End users

Table 4-2: Source Pathway Receptor Linkages for Controlled Waters Risk Assessment

Source	Pathway	Receptor
Contaminated soils	Leaching mechanisms	Groundwater stored in the Pennine Upper Coal Measures Formation
	Runoff during construction works	Ditch to the north of the site discharging into unnamed river to the south-east of the site
Contaminated groundwater	Vertical migration	Groundwater stored in the deeper Pennine Upper Coal Measures Formation
	Lateral and vertical migration (baseflow)	Ditch to the north of the site discharging into unnamed river to the south-east of the site

Table 4-3: Potential Source-Pathway-Receptor Linkages for Property Risk Assessment

Source	Pathway	Receptor
Contaminated soils	Contact with contaminated soils	Concrete
		Water supply pipe materials
Ground gas	Vertical and lateral migration and accumulation in voids	Residential housing / commercial properties

4.6 Preliminary Risk Assessment

- 4.6.1 From the information obtained from the desk study JNP Group has undertaken a preliminary risk assessment.

Table 4-5: Preliminary Risk Assessment

Risk Receptor	Risk		Justification
HUMAN HEALTH	MEDIUM		Low across the agricultural fields that make up most of the site. Medium across farmyard at the southern end of the site due to potential sources of contamination from previous phases of development, i.e., Made Ground and potential hydrocarbon and asbestos contamination.
GROUNDWATER	MEDIUM		The site is located on productive strata (Secondary A Aquifer) but is not within a SPZ.
SURFACE WATER	LOW		Ditch located adjacent to the site discharging into the nearest recognised surface water course located more than 150m away from the site.
PROPERTY & INFRASTRUCTURE	MEDIUM		Historic land use of southern end of the site as a farmyard suggest potential sources of contamination at southern end of site.
ECOLOGY	NONE		Based on the assumption that there are no sensitive/ protected species on site (subject to any ecological survey undertaken).

- 4.6.2 In line with BS ISO 18400-202:2018 based on the conceptual site model as above most of the site is probably uncontaminated, but the farmyard area at the southern end of the site is probably contaminated.

5 SITE WORK AND MONITORING

5.1 Introduction

- 5.1.1 The intrusive site work was undertaken by JNP Group on 16th, 17th, 18th and 22nd March 2021, and comprised ten dynamic sampling boreholes and sixteen mechanically excavated trial pits. So far, two of the three return gas and groundwater level monitoring visits have been undertaken, on the 30th March and 8th April 2021, with the third and final visit to take place on 21st April 2021.
- 5.1.2 All site work was completed under the instruction and supervision of JNP Group with the ground investigation procedures and sample descriptions given in the following publications:
- BS 5930 (2015). Code of Practice for Site Investigations;
 - BS 10175 (2001+A1:2013+A2:2017). Investigation of potentially contaminated sites - code of practice;
 - BS EN ISO 14688-1. "Soil - Identification and Description;
 - BS EN ISO 14688-2. Soil - Classification principles and quantification of descriptive characteristics;
 - BS EN ISO 14689. Rock - Identification and description;
 - BS 18400-104:2018. Soil Quality – Sampling. Part 104: Strategies;
 - BS 18400-202:2018. Soil Quality – Sampling. Part 202: Preliminary Investigations;
 - BS 18400-203: 2018. Soil Quality – Sampling. Part 203: Investigation of potentially contaminated sites;
 - BS 18400-205: 2018. Soil Quality – Sampling. Part 205: Guidance on the procedure for investigation of natural, near natural and cultivated sites.
- 5.1.3 For sites affected by asbestos impacted soils, the guidance given in the following publications has been followed:
- Industry Guidance on Interpretation for Managing & Working with Asbestos in Soil and Construction and Demolition Materials (CL:AIRE 2016);
 - Asbestos in Soil and Made Ground: a guide to understanding and managing risks (CIRIA C733 2014).
- 5.1.4 The design and installation of groundwater quality monitoring points has been undertaken following the guidance given in the Environment Agency science report:
- SC020093. Guidance on the design and installation of groundwater quality monitoring points. 2006.
- 5.1.5 The locations of the exploratory holes are shown on JNP Group Drawing No. S11400-JNP-XX-XX-DR-G-1001 Rev.A. The exploratory hole records including strata and groundwater encountered, in-situ testing and samples taken are presented in Appendix B. The full details of the site work undertaken are summarised in the following sections.
- 5.1.6 The site investigation strategy comprised judgemental (i.e. targeted) locations of the barns/sheds and the rest of the farmyard area at the southern end of the site, the former

pond at the northern end of the site, the proposed attenuation pond locations, and the geological fault anticipated to cross the site, with the remainder of the positions providing a systematic distribution across the site to suit the proposed redevelopment and address relevant spatial locations considered most likely to be sensitive. Table 5-1 shows the rationale for the location of each exploratory hole.

Table 5-1: Exploratory Hole Location Rationale

Exploratory Hole Reference	Rationale
DS01	To target the former pond at the northern end of the site.
DS02 and DS03	To target the barns/sheds in the farmyard.
DS05 and TP04	To target the ground around the silos in the farmyard.
DS04, DS06 and TP03	To target the rest of the farmyard.
DS08 and DS09	To target the proposed attenuation pond locations to determine groundwater level.
TP03, TP06, TP07, TP08 and TP12	To target and locate the geological fault anticipated to cross the site.
DS10, TP01, TP02, TP05, TP09, TP10, TP11, TP13, TP14, TP15 and TP16	To provide a systematic distribution across the rest of the site.

- 5.1.7 The general sampling strategy was to take representative soil samples from the ground to characterise the strata encountered and to provide suitable horizontal distribution, however, where visible contamination was present or suspected, targeted spot samples were taken.

5.2 Dynamic Sampling Boreholes

- 5.2.1 Ten dynamic sampling boreholes, designated DS01 to DS10 (inclusive) were formed on 17th and 22nd March 2021, to depths of between 1.00m and 3.00m below ground level (bgl) at various locations across the site. All the boreholes refused on weathered bedrock.
- 5.2.2 The dynamic sampling technique uses a lightweight tracked rig to advance a borehole by 1 m intervals using 1 m long steel sampler tubes, at diameters of 100 mm, reducing to 70 mm. The soils are then recovered from each sample tube as continuous core samples, which are logged and sub-sampled on site. Environmental soil samples were generally taken from each Made Ground material, together with any materials suspected of containing elevated concentrations of contaminants, based on visual and olfactory evidence. The environmental samples comprised a small volatiles jar, and an amber glass jar. Bulk and small plastic tub samples were also taken from selected materials, for laboratory geotechnical testing. In situ Standard Penetration Tests (SPTs) were undertaken in accordance with BS 5930 (2015) at 1.0 m depth intervals in the boreholes in order to obtain in situ strength or relative density parameters for geotechnical design.
- 5.2.3 Four boreholes (DS01, DS04, DS08 and DS09) were completed with 50 mm gas monitoring standpipe installations, with flush fitting steel covers set in concrete at ground level. The remaining boreholes were backfilled with arisings and the ground surface left in a safe and tidy manner.

5.2.4 Response zones within the installations were installed between varying depths, from 0.5m to 1m bgl to 1.7m to 3m bgl.

5.3 Trial Pits

5.3.1 Sixteen trial pits, designated TP01 to TP16 were excavated on the 16th and 18th March 2021, to depths of between 1.50m and 2.50m bgl. The pits were excavated using a JCB 3CX and a tracked excavator and logged by a ground engineering specialist by examining soil samples brought to the surface.

5.4 Monitoring

5.4.1 Monitoring of the installed standpipes/wells has been undertaken on three occasions (30th March, 8th April, 21st April 2021).

5.4.2 Monitoring involved the measurement of the ground gas composition at each of the installations for methane (CH₄), carbon dioxide (CO₂) and oxygen (O₂) concentrations, together with atmospheric pressure, downhole pressure and flow rates, using a Geotech GA5000 gas meter. After the measurement of gas concentrations, the depth to any groundwater within the standpipe was recorded.

5.4.3 The frequency and duration of gas monitoring was selected based on the guidance given in the following publications:

- CIRIA C665. Assessing risks posed by hazardous gases to buildings. 2007;
- BS 8485. Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings. 2015;
- CL:AIRE RB 17. A Pragmatic Approach to Ground Gas Risk Assessment. 2012.

5.4.4 Groundwater monitoring was also undertaken on the same dates after the completion of the site work. Table 5-2 justifies the response zones selected for each monitoring borehole.

Table 5-2: Response Zone Rationale

Exploratory Hole Reference	Response Zone (m bgl)	Rationale
DS01	1.00 – 2.00	To monitor groundwater levels and gas concentrations within the Pennine Upper Coal Measures Formation (PUCMF) near the infilled pond at the northern end of the site.
DS04	0.70 – 1.70	To monitor groundwater levels and gas concentrations within the PUCMF at the southern end of the site.
DS08	0.50 – 2.50	To monitor groundwater levels within the PUCMF in the proposed attenuation pond locations at the northern end of the site.
DS09	1.00 – 3.00	To monitor groundwater levels within the PUCMF in the proposed attenuation pond locations at the northern end of the site.

5.4.5 It should be noted that long-term groundwater levels may vary from those reported due to seasonal fluctuation or weather events, such as droughts, significant rainfall, or recent

flooding. However, the timing of the monitoring that has occurred usually captures maximum groundwater levels which occur in late winter.

- 5.4.6 The monitoring results are presented in Appendix D.
- 5.4.7 It should be noted that once the groundwater monitoring boreholes are no longer required, they need to be decommissioned following the guidance given in the EA science report SC020093 (EA 2008).

6 LABORATORY TESTING

6.1 Geotechnical

- 6.1.1 A programme of laboratory testing was scheduled by JNP Group to determine the geotechnical properties of selected soil samples obtained from the investigation. The details of the geotechnical testing are summarised below:

Table 6-1: Scheduled Geotechnical Laboratory Tests

Test Description	Number of Tests
Atterberg limits including moisture content	7
Particle size distributions	1
Ground Aggressivity Suite (in accordance with BRE SD1)	8

- 6.1.2 Tests were undertaken in accordance with BS1377 (1990) "Methods of test for Soils for Civil Engineering purposes". The results of the geotechnical testing are presented in Appendix E.

6.2 Environmental

- 6.2.1 A programme of chemical laboratory testing was scheduled by JNP Group on selected soil samples taken from various depths in the Made Ground and natural ground recovered from the exploratory holes. Samples of any soils displaying visual or olfactory evidence of contamination were also collected and submitted for laboratory analyses. The samples were placed into suitable containers for the required chemical analyses.

- 6.2.2 All samples were transported, on the day after collection, to Eurofins Chemtest Ltd. in Newmarket, Cambridge, which is accredited under UKAS and MCerts. The following table summarises the contaminants scheduled:

Table 6-2: Scheduled Soil Chemical Analyses

Determinant	No
Metals and semi-metals (arsenic, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium and zinc)	12
Polycyclic Aromatic Hydrocarbons (PAH) 16 USEPA Speciated	12
TPH Criteria Working Group (TPH CWG)	8
Soil Organic Matter (SOM)	5
Asbestos screening	10
Pesticide Screen	5
Loss on ignition (coal)	2
Calorific value (coal)	2

- 6.2.3 The results of the laboratory chemical testing are interpreted in Section 9 and are presented in full in Appendix F.

7 GROUND AND GROUNDWATER CONDITIONS

7.1 Strata Encountered

- 7.1.1 The ground conditions encountered during the intrusive investigation were generally consistent with the published geological map. In the farmyard at the south-western corner of the site, a variable thickness of Made Ground was found to be underlain by granular sands and weathered sandstone of the Pennine Upper Coal Measures Formation. These weathered sandstones extended across the rest of the southern portion of the site, beneath a loamy silty sand Topsoil. Most of the site (the central and northern portions) were underlain by cohesive soils and weathered mudstones of the Pennine Upper Coal Measures Formation, with thin shallow coal seams, all overlain by a loamy clay Topsoil. A fault was inferred between the two distinct bedrock units on the site, running west-north-west to east-south-east across the site, as shown on JNP Group drawing S11400-JNP-XX-XX-DR-G-1001.
- 7.1.2 A summary of the stratigraphy encountered during the investigation is presented in Table 77-1 and described in the following sections, but for full details and descriptions, reference should be made to the exploratory hole records presented in Appendix B.

Table 77-1: Stratigraphy Encountered

Stratum	Depth to Top (m bgl)	Depth to Base (m bgl)	Thickness (m)
Made Ground DS02, DS03, DS04, DS05, DS06, TP03, TP04	Ground level	0.20 – 0.80	0.20 – 0.80
Topsoil DS01, DS05, DS07, DS08, DS09, DS10, TP01, TP02, TP05, TP06, TP07, TP08, TP09, TP10, TP11, TP12, TP13, TP14, TP15, TP16	Ground level – 0.40	0.30 – 0.80	0.30 – 0.60
Newstead Rock Member DS02, DS03, DS04, DS05, DS06, DS07, TP03, TP04, TP05, TP07, TP08	0.20 – 0.80	Not proven	Not proven
Pennine Upper Coal Measures Formation DS01, DS08, DS09, DS10, TP01, TP02, TP06, TP09, TP10, TP11, TP12, TP13, TP14, TP15, TP16	0.30 – 0.60	Not proven	Not proven

7.2 Made Ground

- 7.2.1 Made Ground was encountered across the farmyard area in the south-west corner of the site, and consisted of various topsoils, sands and gravels, containing fragments of brick, crushed concrete, glass, sandstone and occasionally ash. The Made Ground extended from ground level to depths of between 0.20m to 0.80m bgl. There were also limited areas of fractured hardstanding concrete at the southern end of the farmyard, although these were not targeted during the site works.

7.3 Topsoil

- 7.3.1 Natural topsoils, reworked by ploughing, seed drilling, etc., were encountered across the entire site, except in the farmyard. Generally, the topsoils at the southern end of the site were loamy and silty sand topsoils, which graded northward into sandy clay topsoils, gravelly and loamy clay topsoils, and finally into loamy clay topsoils at the northern end of the site. The sand/clay content of the Topsoil across the site generally correlated with the underlying subsoil and bedrock types encountered across the site.

7.4 Newstead Rock Member

- 7.4.1 Granular soils and heavily weathered sandstone inferred to be of the Newstead Rock Member of the Pennine Upper Coal Measures Formation, were encountered in DS02, DS03, DS04, DS05, DS06, DS07, TP03, TP04, TP05, TP07 and TP08. The top of the unit was encountered beneath the Made Ground and Topsoil at depths of between 0.20m to 0.80m bgl; the thickness of the unit was not proven. The unit comprised sands in the upper portion, underlain by heavily fractured and fragmented weathered sandstones.

Table 7-2: Newstead Rock Member – Geotechnical Laboratory Test Results Summary

Property	Number of Tests	Range	Mean	Assessment
SPT 'N' Values (granular)	10	30 – 100	64	Dense to very dense
Gravel Content %	1	53	53	Brown very sandy silty gravel.
Sand Content %	1	32	32	
Silt / Clay Content %	1	15	15	

- 7.4.2 The SPT N value / depth profile is presented as Figure 2.

7.5 Pennine Upper Coal Measures Formation

- 7.5.1 Cohesive soils, weathered mudstone and thin shallow coal seams, inferred to be of the Pennine Upper Coal Measures Formation, were encountered across the central and northern portions of the site beneath natural Topsoil. The top of the unit was encountered between 0.30m to 0.60m bgl; the thickness of the unit was not proven. The unit comprised soft to stiff orange and grey mottled clays with occasional ironstone gravel, overlying thin shallow coal seams, overlying stiff clays and weathered mudstones.
- 7.5.2 The depth to the top of the shallow coal seams across the site (between 0.95m to 1.60m bgl where encountered) suggest that they dip shallowly to the north-north-east, roughly following the topography of the site, which slopes shallowly to the north-north-east. In some exploratory holes, only one coal seam was encountered, while in other holes two to three thin seams were encountered. The coal seams ranged in thickness between 0.05m and 0.63m; the coal itself was heavily weathered, mostly to a coarse black vitreous gravel, although in some places it was weathered almost to a clay. The coal seams were occasionally wet, with the only groundwater encountered during the site works being encountered within the fractured and weathered coal seams. There were no indications that the shallow coal seams had been historically worked.

Table 7-3: Pennine Upper Coal Measures Formation – Geotechnical Laboratory Test Results Summary

Property	Number of Tests	Range	Mean	Assessment
Natural Moisture Content	7	21 – 27	24	Low to medium volume change potential. Low to high plasticity clays (CL, CI, CH).
% passing 425 sieve	7	92 – 100	99	
Liquid Limit %	7	34 – 58	51	
Plastic Limit %	7	18 – 26	24	
Plasticity Index %	7	16 – 32	27	
Modified Plasticity Index %	7	16 – 32	27	
$c_u = 4.5 \times \text{SPT 'N' Value (kN/m}^2\text{)}$	10	45 – 450	206	Medium to high strength.
Hand Shear Vane (kN/m ²)	29	50 – 150	106	

7.5.3 The SPT N value / depth profile is presented as Figure 2, the undrained shear strength / depth profile as Figure 3, and a plasticity chart is presented as Figure 4.

7.6 Groundwater

7.6.1 Details of groundwater entries recorded during the site work period, and levels recorded subsequently during the monitoring visits, are summarised in Table 7-4 which follows.

Table 7-4: Summary of groundwater observations

Exploratory Location	Groundwater during site work		Groundwater during monitoring
	Strikes (m bgl)	Comments	Range (m bgl)
DS01	-	-	0.90 – 0.95 (TBC)
DS02	-	-	-
DS03	-	-	-
DS04	-	-	Dry
DS05	-	-	-
DS06	-	-	-
DS07	-	-	-
DS08	2.00	Wet coal sample	0.60 – 0.65 (TBC)
DS09	2.00	Wet coal sample	0.90 – 0.95 (TBC)
DS10	-	-	-
TP01	-	-	-
TP02	-	-	-
TP03	-	-	-
TP04	-	-	-
TP05	-	-	-
TP06	-	-	-
TP07	-	-	-
TP08	-	-	-

Exploratory Location	Groundwater during site work		Groundwater during monitoring
	Strikes (m bgl)	Comments	Range (m bgl)
TP09	-	-	-
TP10	-	-	-
TP11	-	-	-
TP12	-	-	-
TP13	-	-	-
TP14	-	-	-
TP15	1.50 rising to 1.10	Seepage from coal seam	-
TP16	2.00 rising to 1.50	Seepage from coal seam	-

7.6.2 Where groundwater was encountered during the site works, it was within the shallow coal seams, which are overlain and underlain by low permeability cohesive soils and weathered mudstones of the Pennine Upper Coal Measures Formation.

7.6.3 Following the monitoring visits undertaken to date, groundwater levels within DS01, DS08 and DS09 have been recorded at depths of between 0.60m and 0.95m bgl, above the levels of the coal seams in each borehole. This confirms that groundwater in the coal seams is confined by the overlying strata, and that the groundwater within the coal is under pressure and will rise to above the depth of coal seam when the coal is penetrated/exposed.

7.6.4 In the vicinity of the proposed drainage attenuation basins in the north-east of the site, the coal seams were encountered in excess of 1.55 m to 1.60 m bgl with the rest water table 0.6 m to 0.95 m bgl.

7.7 Ground Contamination and Deleterious Material

7.7.1 Visual and olfactory evidence of contamination was observed in parts of the farmyard in the south-western corner of the site. Visual evidence of TPH contamination (an oil or fuel spill) was observed across the surface of the centre of the farmyard on the 16th March 2021; however, the visual evidence of this spill was no longer present across the farmyard by the 17th March.

7.7.2 There were several asbestos roofing sheets, and smaller fragments of sheets, observed on the ground around the barns on the eastern side of the farmyard.

7.7.3 There were fragments of glass throughout some of the Made Ground deposits encountered in the farmyard. There was also a significant amount of glass fragments strewn across the Topsoil along the western margin of the site, adjacent to the High Street.

7.8 Ground Gas Conditions

7.8.1 During the monitoring visits undertaken to date, the maximum methane concentration encountered was 0.2%, and there was a maximum carbon dioxide concentration of 3.3% recorded, with a maximum flow rate of 4.9l/hr. Full details of the gas concentrations and flow rates recorded during the monitoring period are presented in Appendix D.

7.9 Trees and Tree Roots

- 7.9.1 Several mature trees were present along the western margin of the farmyard in the south-western corner of the site. There were mature hedgerows along all the margins of the two fields that make up the majority of the site. No major roots were observed in any of the exploratory holes.

7.10 Desiccation

- 7.10.1 Following laboratory testing of cohesive soils, two commonly accepted methods for determining the degree of desiccation (as stated in BRE 412 'Desiccation in Clay Soils') are as follows:
1. Desiccation has occurred when the moisture content is less than the Plastic Limit;
 2. Significant desiccation has occurred when the moisture content is less than $0.4 \times$ the Liquid Limit (this is known as the Driscoll Limit).
- 7.10.2 When the results of laboratory testing are compared with Method 1, samples at TP10 at 0.80m bgl, TP13 at 1.00m bgl, TP14 at 2.00m bgl, and TP16 at 1.00m bgl are indicated to be desiccated.
- 7.10.3 When the results of laboratory testing are compared with Method 2, one sample from TP16 at 1.00m bgl is indicated to be significantly desiccated.
- 7.10.4 A plot comparing moisture contents with the Liquid Limits and the Driscoll Limits is included as Figure 5.

7.11 Obstructions

- 7.11.1 No obstructions were encountered within the ground during the site works.

8 HUMAN HEALTH DETAILED QUANTITATIVE RISK ASSESSMENT

8.1 Introduction

8.1.1 Qualitative assessment of risks may be sufficient in many cases to eliminate the possibility of significant pollutant linkages. However, quantitative risk assessment is formally required to determine whether there is a 'significant possibility of significant harm being caused'. Part IIA of the Environmental Protection Act 1990 recommends that 'authoritative and scientifically based guideline values for concentrations of the potential pollutants in or under the land' be used to quantify the risk posed by contamination.

8.1.2 Under the Planning Regime, a quantitative risk assessment can be used to decide whether the site is suitable for the proposed use. In addition, the National Planning Policy Framework (March 2012) also indicates that after remediation, as a minimum land should not be capable of being determined as contaminated land under Part IIA.

8.2 Current UK Screening Values

8.2.1 The UK technical guidance for assessing risks to human health is issued from various UK bodies, including the Environment Agency (EA), DEFRA, Contaminated Land: Applications in Real Environment (CL:AIRE), Chartered Institute of Environmental Health (CIEH), and Land Quality Management (LQM) Ltd (part of the University of Nottingham).

8.2.2 New and updated screening values in the form of provisional Category 4 Screening Levels (C4SL) (published in 2014), and Suitable for Use Levels (S4UL), (published 2015), have been produced by DEFRA and CIEH / LQM respectively using modified versions of the EA's Contaminated Land Exposure Assessment (CLEA) software.

8.2.3 C4SL

8.2.4 Provisional C4SL have been derived by CL:AIRE (project team for DEFRA's SP1010 project) following revised statutory guidance, and as a tool to assist in applying the Part IIA Category 1- 4 classifications to a site. The purpose of the C4SL is to provide a simple test for deciding that land is suitable for use, and definitely not contaminated land under Part IIA. They describe a level of risk that is above minimal, but is still low.

8.2.5 In calculating provisional C4SL some of the exposure modelling scenarios and exposure parameters used in the CLEA software have been modified. These modifications are not discussed further, but reference should be made to the original CL:AIRE / DEFRA publications should further information or clarification be required. A list of the new publications is included in the references section at the end of this report.

8.2.6 To date, six contaminants have been assigned provisional C4SL: arsenic; benzene; benzo[a]pyrene; cadmium; chromium VI, and lead, for the standard land uses (residential with, and without plant uptake, allotments, commercial, and public open space (parks and residential)).

8.2.7 The C4SL are also considered suitable to be used under the planning regime, and DEFRA have confirmed this to all local authorities.

8.2.8 S4UL

8.2.9 The LQM / CIEH S4UL represent generic assessment criteria based on minimal or tolerable risk that are intended to be protective of human health. They have been derived in

accordance with current UK legislation using a modified version of the CLEA software, and are still based on many conservative assumptions. They represent values above which further assessment of the risks or remedial actions may be needed.

- 8.2.10 S4UL have been derived for a comprehensive list of metals, non-metals, petroleum hydrocarbons, polycyclic aromatic hydrocarbons, chlorinated hydrocarbons, phenolic compounds, explosives, and pesticides, for the standard land uses (residential with, and without plant uptake, allotments, commercial, and public open space (residential and park)).
- 8.2.11 For details of the exposure parameters and scenarios used to derive the S4UL the reader is reference to the original LQM / CIEH document "The LQM/CIEH S4UL for Human Health Risk Assessment" (2015).
- 8.2.12 Both sets of screening values can be used to undertake a generic risk assessment by comparing the data directly to the screening value which is considered a conservative approach or statistically to the screening value. Alternatively and if a sufficient dataset is available, a statistical assessment can be undertaken following the guidance given in the joint Chartered Institute of Environmental Health (CIEH) and the Contaminated Land: Applications in Real Environment (CL:AIRE) organisation publication "Guidance On Comparing Soil Contamination Data with a Critical Concentration" (CIEH / CL:AIRE May 2008).

8.3 Atkins ATRISK Soil Values

- 8.3.1 Further to the above screening values, Atkins Ltd, have derived their own screening values in March 2011 for a wide range of contaminants, including PAH species, chlorinated hydrocarbons, metals and inorganics. These have been derived for either a 1% Soil Organic matter (SOM) sand soil type, or 6% SOM sandy loam soil type, using the CLEA software V1.04-1.06, and are available for standard (residential with plant uptake, residential without plant uptake, commercial, and allotments) and non-standard land uses (parks, playing fields, and open spaces). Where S4UL are not available, JNP Group have adopted the ATRISK soil values.

8.4 Petroleum Hydrocarbons

- 8.4.1 JNP Group have followed the guidance given in the Environment Agency publication 'The UK Approach for Evaluating Human Health Risks from Petroleum Hydrocarbons in Soils' (Environment Agency, 2005). LQM S4UL values have been published based on carbon banded hydrocarbons with aliphatic and aromatic split, corresponding to the TPH CWG bands.
- 8.4.2 The Society of Brownfield Risk Assessment (SoBRA) have produced some Generic Assessment Criteria for assessing chronic risks from the inhalation of vapours arising from groundwater ($GAC_{gw vap}$) for a short list of 66 organic contaminants (SoBRA February 2017). These are designed to a defensible screening criteria to assist in evaluating this exposure pathway. They represent concentrations below which the chronic risks from vapour migration and inhalation can be considered low / tolerable. $GAC_{gw vap}$ have been developed in line with current UK risk assessment guidance, and CLEA v1.07 software was used for residential and commercial land use scenarios.
- 8.4.3 Further details of the input parameters selected for use to generate the $GAC_{gw vap}$ can be found in the SoBRA report, and have not been reproduced here. However, it should be noted that they have been derived using some conservative assumptions:
 - Impacted ground / perched water is beneath the buildings;

- An infinite source term is present;
- There is no biodegradation;
- Groundwater depth is 0.65m below ground;
- Use of a sand soil type (in line with SR3)

8.5 Water Supply Pipes

- 8.5.1 Where plastic water supply pipes are proposed, the Thames Water Threshold Values have been used to compare the chemical test results with a published set of guideline values for metal, organic and inorganic contaminants found in soil, that may have a detrimental effect upon plastic water supply pipes.

9 SOIL AND GROUNDWATER ASSESSMENT RESULTS

9.1 Soil Results

9.1.1 The results of chemical testing of six samples of Made Ground and 29 samples of natural soils have been compared with the C4SL and the LQM S4UL values for a 'residential with gardens end use'. These comparisons are summarised in the following Table 9-1. In addition, Loss on Ignition and Calorific Value tests have been undertaken on two samples of the shallow coal encountered during the site works; the results of these tests are summarised in Table 9.2 below.

9.1.2 Five SOM tests were undertaken on the four material types identified at the site. These were the Made Ground (within the farmyard), the Topsoil in the fields, the clay of the Pennine Upper Coal Measures Formation, and the sand of the Newstead Rock Member. A SOM of 2.5% is applicable to the Made Ground deposits within the farmyard and the topsoil across the fields, and a SOM of 1% is applicable to the natural soils of the weathered profiles of the Pennine Upper Coal Measures and the Newstead Rock Member.

Table 9-1: Comparison of Soil Chemical Test Results with Residential with plant uptake Guideline Values

Determinant	Maximum Measured Concentration	Background Concentration	LQM/CIEH S4UL: Residential with plant uptake (mg/kg)			Number of tests	Number of exceedances
Arsenic	20	19	37			12	None
Beryllium	1.8	N/A	1.7			12	1 (DS05 @ 0.1m bgl – Made Ground)
Boron	4.8	N/A	290			12	None
Cadmium	0.72	0.32	11			12	None
Chromium (trivalent)	51	59	910			12	None
Chromium (hexavalent)	<dl*	N/A	6			12	None
Copper	140	27	2400			12	None
Lead	85	72	200**			12	None
Mercury (elemental)	0.28	N/A	1.2			12	None
Nickel	35	22	180			12	None
Selenium	0.49	0.63	250			12	None
Vanadium	35	66	410			12	None
Zinc	110	89	3700			12	None
			1%	2.5%	6%		
Naphthalene	0.88	N/A	2.3	5.6	13	12	None
Acenaphthylene	0.53	N/A	170	420	920	12	None
Acenaphthene	0.93	N/A	210	510	1100	12	None
Fluorene	1.1	N/A	170	400	860	12	None
Phenanthrene	19	N/A	95	220	440	12	None
Anthracene	5.1	N/A	2400	5400	11000	12	None
Fluoranthene	31	N/A	280	560	890	12	None
Pyrene	31	N/A	620	1200	2000	12	None
Benzo(a)anthracene	13	N/A	7.2	11	13	12	1 (TP04 @ 0.1m bgl – Made Ground)

Determinant	Maximum Measured Concentration	Background Concentration	LQM/CIEH S4UL: Residential with plant uptake (mg/kg)			Number of tests	Number of exceedances
Chrysene	14	N/A	15	22	27	12	None
Benzo(b)fluoranthene	20	N/A	2.6	3.3	3.7	12	1 (TP04 @ 0.1m bgl – Made Ground)
Benzo(k)fluoranthene	7.9	N/A	77	93	100	12	None
Benzo(a)pyrene	14	N/A	2.2	2.7	3.0	12	1 (TP04 @ 0.1m bgl – Made Ground)
Indeno(1,2,3-c,d)pyrene	11	N/A	27	36	41	12	None
Dibenzo(a,h)anthracene	2.8	N/A	0.24	0.28	0.3	12	2 (TP04 @ 0.1m bgl – Made Ground) (DS06 @ 0.1m bgl – Made Ground)
Benzo(g,h,i)perylene	9.8	N/A	320	340	350	12	None
TPH Aliphatic C ₅ – C ₆	<dl*	N/A	42	78	160	8	None
TPH Aliphatic C ₆ – C ₈	<dl*	N/A	100	230	530	8	None
TPH Aliphatic C ₈ – C ₁₀	<dl*	N/A	27	65	150	8	None
TPH Aliphatic C ₁₀ – C ₁₂	<dl*	N/A	130	330	760	8	None
TPH Aliphatic C ₁₂ – C ₁₆	<dl*	N/A	1100	2400	4300	8	None
TPH Aliphatic C ₁₆ – C ₃₅	<dl*	N/A	65000	92000	110000	8	None
TPH Aliphatic C ₃₅ – C ₄₄	<dl*	N/A	65000	92000	110000	8	None
TPH Aromatic C ₅ – C ₇	<dl*	N/A	70	140	300	8	None
TPH Aromatic C ₇ – C ₈	<dl*	N/A	130	290	660	8	None
TPH Aromatic C ₈ – C ₁₀	<dl*	N/A	34	83	190	8	None
TPH Aromatic C ₁₀ – C ₁₂	<dl*	N/A	74	180	380	8	None
TPH Aromatic C ₁₂ – C ₁₆	<dl*	N/A	140	330	660	8	None
TPH Aromatic C ₁₆ – C ₂₁	16	N/A	260	540	930	8	None
TPH Aromatic C ₂₁ – C ₃₅	200	N/A	1100	1500	1700	8	None
TPH Aromatic C ₃₅ – C ₄₄	<dl*	N/A	1100	1500	1700	8	None
Pesticides	<dl*	N/A	N/A			5	None
Asbestos ID	Detected	N/A	N/A			10	1 (DS02 @ 0.2m bgl – Made Ground)
Asbestos Quantification	<0.001%	N/A	N/A			1 (DS02 @ 0.2m bgl)	1 (DS02 @ 0.2m bgl – Made Ground)

*<dl lower than detection limit

** provisional C4SL

Table 9-2: Results of Loss on Ignition and Calorific Value tests undertaken on coal samples.

Coal sample	Loss on ignition (%)	Calorific value (MJ/kg)
DS09 @ 2m bgl	52	18
TP15 @ 1m bgl	55	10

9.2 Interpretation

9.2.1 The analyses recorded marginally elevated concentrations of one metal, beryllium, and several PAHs (benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene and dibenzo(a,h)anthracene), with asbestos also detected in one sample.

9.2.2 All these elevated concentrations of determinants were detected in samples of the Made Ground present across the farmyard.

9.2.3 The calorific values of the coal samples suggest that the coal beneath the site is weathered lignite and sub-bituminous coal. The loss on ignition values suggest that significant volumes of the coal beneath the site (up to 55%) would be lost if the shallow seams beneath the site were to combust.

Heavy Metals

9.2.4 An elevated concentration of beryllium was found in DS05 at 0.1m bgl, within the Made Ground deposits in the farmyard.

Elevated PAH

9.2.5 Elevated concentrations of benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene and dibenzo(a,h)anthracene were found in TP04 at 0.1m bgl, with elevated concentrations of dibenzo(a,h)anthracene also found in DS06 at 0.1m bgl. Both samples were from the Made Ground encountered across the farmyard.

Asbestos

9.2.6 Ten samples were submitted for an asbestos screen; fibres of chrysotile were identified in DS02 at 0.20m bgl, within the Made Ground beneath the barn at the north-eastern corner of the farmyard. Asbestos quantification testing of this sample indicated that the sample contained <0.001% (lower than the detection limit) asbestos, suggesting that although there should be a consideration of asbestos-containing soils during the demolition and remediation phases in the farmyard, no specific precautions are required (subject to approval by relevant authorities).

9.3 Summary

9.3.1 Based on the chemical testing undertaken, JNP Group considers that a viable risk to human health exists from elevated concentrations of beryllium, PAHs and asbestos in near surface Made Ground deposits across the farmyard area of the site. Hence, remedial actions at the site are considered necessary in the farmyard area for the proposed development.

9.4 Risk to Controlled Waters

9.4.1 Regarding risks to controlled waters, surface run off from the site is not considered a risk to the nearby river due to the contaminated soils being located in the south-west away from the ditch feeding the closest watercourse, the distance between the site and the

watercourse, the effect of sorption and dilution and the control that the proposed drainage strategy will introduce to site run-off.

- 9.4.2 JNP Group does not consider the slightly elevated concentrations of determinants discussed above to pose a significant risk to groundwater, again due the effects of dilution, and because there were no elevated concentrations of these determinants recorded in the underlying natural soils.

9.5 Summary

- 9.5.1 On the basis of the chemical testing undertaken, JNP Group consider that a risk to human health is present from elevated concentrations of beryllium and PAHs in near surface Made Ground deposits across the farmyard in the south-western corner of the site, and from the presence of asbestos in the Made Ground beneath the barn in the north-eastern corner of the farmyard. Hence remedial actions at the site are considered necessary in these areas.

9.6 Soil Results and Water Supply Pipeline Assessment

- 9.6.1 The results of chemical testing of 12 samples of Made Ground and natural soils from depths of between ground level and 1m bgl, (the anticipated depth of the pipeline), have been compared with the Thames Water Threshold Levels (Yorkshire Water threshold levels not available). These are summarised in Table 9-3 that follows.

Table 9-3: Comparison of Chemical Laboratory Test Results with Thames Water Threshold Levels.

Determinant	Maximum Measured Concentration (mg/kg)	Thames Water Threshold Levels (mg/kg)	No. of tests undertaken	No. of exceedances
Naphthalene	0.88	5	12	None
TPH Aliphatic C ₅ – C ₁₂	<dl*	0.5	8	None
TPH Aromatic C ₅ – C ₁₂	<dl*	0.5	8	None
TPH Aliphatic C ₁₂ – C ₂₁	<dl*	10	8	None
TPH Aromatic C ₁₂ – C ₂₁	16	10	8	1 (TP04 @ 0.1m bgl – Made Ground)
TPH Aliphatic C ₂₁ – C ₃₅	<dl*	500	1	None
TPH Aromatic C ₂₁ – C ₃₅	200	500	1	None

<dl* below laboratory detection limits.

- 9.6.2 The results of the chemical testing are presented in Appendix F.
- 9.6.3 Based on the results of the chemical testing there is a risk to plastic water pipeline from the shallow Made Ground deposits encountered in TP04 at 0.1m bgl (in the farmyard area), based on the comparison against Thames Water Threshold Levels, and hence either barrier pipe is required or the provision of a clean service trench or the removal of the contaminated Made Ground deposits. It should be noted that Yorkshire Water threshold levels may differ from those used in this assessment and guidance should be sought to confirm the assessment. Any imported fill used in a clean fill trench should be chemically tested and would be subject to approval by Yorkshire Water.

10 GROUND GAS PROTECTION REQUIREMENTS

10.1 Guidance and Standards

- 10.1.1 A full gas monitoring and assessment programme was not included as part of the agreed scope of works; however, JNP Group has used the guidance given in the following documents to undertake a preliminary ground gas risk assessment in addition to the groundwater monitoring programme which was agreed as part of the scope of works:
- CIRIA C665. Assessing risks posed by hazardous gases to buildings. 2007;
 - BS 8485. Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings. 2015 +A1 2019;
 - CL:AIRE RB 17. A Pragmatic Approach to Ground Gas Risk Assessment. 2012.
 - NHBC. Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present. 2007.
- 10.1.2 It is intended that the proposed development will be low rise housing. In addition, suspended floors are required due to the plasticity of the underlying soils, based on soils of medium volume change potential.
- 10.1.3 The level of gas protection is determined by comparing the following parameters to reference values prescribed within BS 8485 (2015):
- “Typical Maximum Concentrations” for initial screening purposes;
 - Risk based “Gas Screening Values” (GSV) for consideration where the typical maximum concentrations are exceeded.
- 10.1.4 The GSV is calculated using the following equation, and the resulting GSVs are compared to the Site Characteristic GSV given in Table 2 of BS 8485: 2015 +A1 2019.
- $\text{Maximum gas concentration (\%)} \times \text{worst case borehole flow rate (l/h)}.$
- 10.1.5 The NHBC “traffic lights” characterisation system is specific to low-rise housing with a clear ventilated under floor void (minimum 150mm). It is a risk-based system that assigns gas protection for a low-rise housing development by comparing the measured gas emission rates to generic “traffic lights”. The guidance suggests that the calculations should be undertaken for both methane and carbon dioxide and then the worst-case gas regime used to determine appropriate protection measures. The guidance states that the assessment criteria are based on a number of assumptions regarding the proposed structures and designers should ensure that these assumptions are appropriate to the site.
- 10.1.6 For the NHBC “traffic lights” system, a Gas Screening Value (GSV) needs to be determined for both methane and carbon dioxide by using the equation:
- $\text{Maximum gas concentration (\%)} \times \text{worst case borehole flow rate (l/h)}.$
- 10.1.7 In accordance with Section 11.10.3 of the NHBC Guidelines, GSVs have been calculated on the basis of the peak concentration and flow rate for methane and the stable concentration and flow rate for carbon dioxide.

10.2 Definitions

- 10.2.1 In accordance with Table 4 of BS 8485: 2015 +A1 2019, varying levels of protection are required for each category of risk for 'Type A' buildings (private housing), 'Type B' buildings (hotels, managed apartments, small commercial/retail), 'Type C' buildings (commercial, retail, industrial), and 'Type D' buildings (large industrial / commercial / warehouse).
- A 'CS1' determination requires no ground gas protection measures to be installed.
 - A 'CS2' determination requires ground gas protection measures to be installed. The level of ground gas protection required should be equal or greater than 3.5 points for a Type A building, when at least two items from the following three: Table 5 (structural barrier); Table 6 (ventilation), and Table 7 (gas resistant membrane) within BS 8485: 2015 +A1 2019 are selected.
- 10.2.2 In accordance with Table 14.2 in NHBC 2007, varying levels of protection are required for each category of risk (green, amber, and red, on the "traffic lights" system):
- Green: Ground gas protection measures are not required.
 - Amber 1: Low-level ground gas protection measures are required, using a membrane and ventilated sub-floor void that creates a permeability contrast to limit the ingress of gas into buildings. Gas protection measures are to be installed as prescribed in BRE 414. Ventilation of the sub-floor void should be designed to provide a minimum of one complete volume change per 24 hours.
 - Amber 2: High-level ground gas protection measures are required, creating a permeability contrast to prevent ingress of gas into buildings. Gas protection measures are to be installed as prescribed in BRE 414. Membranes used should always be fitted by a specialist contractor and should be fully certified (see Appendix E). As with Amber 1, ventilation of the sub-floor void should be designed to provide a minimum of one complete volume change per 24 hours.
 - Red: Standard residential housing is not normally acceptable without further Ground Gas Risk Assessment and/or possible remedial mitigation measures to reduce/remove the source of the ground gases. In certain circumstances, active protection methods could be applied, but only when there is a legal agreement assuring the management and maintenance of the system for the life of the property.

10.3 Results

- 10.3.1 The maximum CO₂ concentrations, the maximum flow rate, and the screening values for each borehole during the site work periods, are summarised in the following table.
- 10.3.2 The raw and collated results of the ground gas monitoring undertaken are presented in Appendix D. This includes a graph showing the atmospheric pressure trend throughout the monitoring period.

Table 10-1: Calculated Gas Screening Values

Location	Maximum CH ₄ Concentration (% v/v)	Maximum CO ₂ Concentration (% v/v)	Maximum Flow Rate (l/hr)	Gas Screening Value for CH ₄ (l/hr)	Gas Screening Value for CO ₂ (l/hr)
DS01	0.2	2.9	4.9	0.0098	0.1421
DS04	0.2	1.6	<0.1	<0.0002	0.0016
DS08	0.2	3.3	<0.1	<0.0002	0.0033
DS09	0.2	1.9	<0.1	<0.0002	0.0019

10.4 Interpretation

- 10.4.1 As detailed within this report, a full ground gas risk assessment was not agreed as part of the scope of works at this site; however, gas readings were taken from the monitoring boreholes during the groundwater monitoring visits, to allow a preliminary ground gas risk assessment to be undertaken. In addition, the monitoring boreholes are in locations that target both of the potential gas sources on the site – the potential infilled pond, and the shallow coal seam – so it is the opinion of JNP Group that the current monitoring boreholes provide sufficient coverage of the site to accurately characterise the ground gas situation.
- 10.4.2 Based on the gas monitoring results from the three visits undertaken and one elevated flow rate, a “CS2” determination would be derived for the results from DS01 in accordance with BS 8485:2015 and CIRIA C665. Therefore, based on the guidance given in BS 8485:2015 and CIRIA C665, this would suggest that the whole site should be given a CS2 classification, pending further gas monitoring. It is of note that this is not on maximum concentrations but on one elevated flow rate only.
- 10.4.3 Notwithstanding the above, the NHBC ‘traffic lights’ characterisation system, outlined in “NHBC: Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present. 2007”, is specific to low-rise housing with a clear ventilated under floor void (minimum 150mm), and the calculated GSVs come to a “Green” classification, based on Table 14.1, suggesting that no ground gas protection measures are required.
- 10.4.4 Due to the discrepancy between the level of gas protection measures recommended for the calculated GSVs in BS 8485:2015, CIRIA C665, and NHBC 2007, JNP Group recommend that a full gas monitoring and assessment programme be undertaken for the site, based on the guidance given in the documents listed previously, with six monitoring visits undertaken over three months. This further monitoring, and subsequent reassessment, should clarify the ground gas risk across the site, and allow the site to be fully classified, or zoned.
- 10.4.5 If, following the further planned gas monitoring and assessment, it is considered appropriate to classify the whole site, or part of the site, as CS2 (based on BS 8485:2015 and CIRIA C665 guidance), then ground gas protection measures with a score of at least 3.5 points would be required for the areas of the proposed development classified as CS2. Based upon the options available within BS 8485: 2015 +A1 2019, the following ground gas protection measures are recommended:
- Good performance passive sub-floor ventilation (venting can be a clear void or formed using gravel, geocomposites, polystyrene void formers, etc.) - 1.5 points;
 - Traditional beam-and-block floor – 0 points;

- Installation of gas resistant membrane fulfilling all requirements within Table 7 of BS8485 (2015 +A1 2019), with verification in accordance with CIRIA C735 – 2 points.

11 REVISED CONCEPTUAL SITE MODEL AND OVERALL ENVIRONMENTAL RISK

11.1 Summary

11.1.1 Following the ground investigation and subsequent assessment undertaken, the conceptual site model and overall environmental risk assessment have been updated as detailed in Table 11-1 below.

Table 11-1: Updated Conceptual Model and Risk Assessment

Issue	Risk	Justification
HUMAN HEALTH	MEDIUM	Unacceptable concentration of beryllium, some PAHs and asbestos, are present within the Made Ground across the farmyard in the south-western corner of the site. Remediation is required in the farmyard area to reduce the risks to acceptable levels. Elevated concentrations of carbon dioxide have been recorded to a CS2 classification based on BS 8485:2015 and CIRIA C665, but a Green classification based on NHBC 2007; therefore, gas protection measures may or may not be required at the site to ensure risks are acceptable to the end users, pending the results of a full gas monitoring and assessment programme.
GROUNDWATER	LOW	Contamination concentrations, although slightly elevated in places, are close to background levels, and do not pose a significant risk to groundwater, due to sorption and dilution.
SURFACE WATER	LOW	Contaminated soils are located in the south-west away from the ditch feeding the closest watercourse, the nearest recognised watercourse is over 150m from the site and the proposed drainage strategy will control site run-off.
PROPERTY & INFRASTRUCTURE	MEDIUM	Elevated concentrations of carbon dioxide have been recorded to a CS2 classification based on BS 8485:2015 and CIRIA C665, but a Green classification based on NHBC 2007; therefore, gas protection measures may or may not be required at the site to ensure risks are acceptable to the end users, pending the results of a full gas monitoring and assessment programme. Some elevated PAH in farmyard area, mitigation required subject to agreement by the water supply provider.
ECOLOGY	NONE	Based on the assumption that there are no sensitive/ protected species on site (subject to any ecological survey undertaken).

11.2 Outline Remediation Options Appraisal

- 11.2.1 Given the revised conceptual site model, it has been determined that remediation is required in the farmyard area due to the presence of contaminants in the near surface soil. Assuming the levels are to remain similar, the most likely option will be the removal and replacement of the Made Ground in this area with 600mm of chemically clean capping material within garden areas. This may be reduced if the Made Ground is shallower than 600mm and clean natural ground is proven prior to 600mm from finished ground level.
- 11.2.2 The ground gas regime on the site needs further assessment which is ongoing and the required protective measures will be confirmed once complete. The current assessment is outlined within section 10.4. This recommends the following gas protection measures:
- Good performance passive sub-floor ventilation;
 - Traditional beam-and-block floor;
 - Installation of gas resistant membrane fulfilling all requirements within Table 7 of BS8485 (2015 +A1 2019), with verification in accordance with CIRIA C735.
- 11.2.3 The proposed verification and capping system will require formalising within an approved Implementation Plan for the import (or otherwise) and placement of clean cover systems to garden areas.
- 11.2.4 Should natural excavated material be re-used on site this may be required to be undertaken through an approved Materials Management Plan.

12 GEOTECHNICAL ENGINEERING ASSESSMENT

12.1 Proposed Development / Redevelopment

- 12.1.1 It is proposed to redevelop the site with approximately 86 residential properties with private gardens. New access roads are to be constructed, and the scheme also includes two flood detention ponds in the north-eastern corner of the site.

12.2 Summary of Ground and Groundwater Conditions

- 12.2.1 The ground conditions encountered during the intrusive investigations were generally consistent with the published geological records. In the farmyard at the south-western corner of the site, a variable thickness of Made Ground was found to be underlain by granular sands and weathered sandstone of the Pennine Upper Coal Measures Formation. These weathered sandstones extended across the rest of the southern portion of the site, beneath a loamy silty sand Topsoil. Most of the site – the central and northern portions – were underlain by cohesive soils and weathered mudstones of the Pennine Upper Coal Measures Formation, with thin shallow coal seams, all overlain by a loamy clay Topsoil. A fault was inferred between the two distinct bedrock units on the site, running from west-northwest to east-south-east across the site.

12.3 Site Preparation and Earthworks

- 12.3.1 To prepare the site for construction, the buildings across the farmyard will need to be demolished, the areas of hardstanding across the farmyard area will need to be broken out and removed, and the contaminated Made Ground present across the farmyard will likely need to be removed from the site.
- 12.3.2 There will be a requirement to cut material from the north-eastern corner of the site to install the two proposed flood detention ponds.
- 12.3.3 A Materials Management Plan may be required should excavated material be used on this or any other site.

12.4 Shallow Foundations

- 12.4.1 Traditional shallow strip or pad foundations are considered feasible, placed within the cohesive soils of the Pennine Upper Coal Measures Formation north of the inferred fault, and within the Newstead Rock Member south of the inferred fault.
- 12.4.2 North of the inferred fault, foundation excavations should be taken through the topsoil and foundations placed within the cohesive soils of the Pennine Upper Coal Measures Formation at a minimum founding depth of 0.9m bgl, based upon soils of medium volume change potential. An allowable bearing pressure of 100kN/m² would be available at 0.9m bgl, based upon standard 0.60m wide foundations. The allowable bearing capacity includes an overall factor of safety of 3 against bearing capacity failure, whilst ensuring total settlements are maintained at less than 25mm. However, there are several trees, bushes and hedges in and around the site, and the influence of these may be the controlling criteria for determining foundation type and depth. In addition, there needs to be a thickness of 0.50m of cohesive soils or weathered mudstone between the base of the foundations and the top of the shallow coal seams present across the site; therefore, where required founding depths would bring the base of foundations within 0.50m of the top of the shallow coal seams, foundations will have to be taken deeper, as trench fill foundations, through the coal, to a depth of 0.15m