1249 REGENERATION PARTNERSHIP LLP

Barnsley Markets and Adjacent CEAG Sites

Stage 2 (Pre-demolition) Site Investigation Report

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Barnsley Markets and Adjacent CEAG Sites
Stage 2 (Pre-demolition) Site Investigation Report

PREPARED BY:

P Hesketh	Environmental Scientist
J Lymer	Environmental Chemist
G Whitmore	Principal Environmental Geologist
PP R L Seedhouse	Chief Geotechnical Engineer

APPROVED BY:

C D Comberbach	Technical Director
N P Tovey	Regional Director

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WARDELL ARMSTRONG LLP
Unit 4, Newton Business Centre, Newton Chambers Road, Thorncliffe Park, Chapeltown, Sheffield S35 2PH U.K.
Tel: +44 (0)114 245 6244 Fax: +44 (0)114 245 6242 www.wardell-armstrong.com

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1. INTRODUCTION

1.1 Instructions

This report is prepared in accordance with instructions from Mr F McPeake, Tropus and Spicer Ltd, 128 Buckingham Palace Road, London SW1W 9SA on behalf of the 1249 Regeneration Partnership LLP and confirmed in a letter dated 17 March 2008 (ref.FM/TCL) and in accordance with our standard terms and conditions as attached at Appendix I. This follows initial proposals dated 25 January 2008 (ref. CDC/PH/GPW/SH03582/J50) by Wardell Armstrong.

1.2 Site Location

The Site comprises the Metropolitan Shopping Centre, Barnsley Markets, multi-storey car park, the former Council offices, the Zero Ice complex (former Carpet World) and the CEAG premises, either side of an existing railway line (the Site). The Site is located as shown on the site location plan, Drawing No. SH03582/01 (1:50,000 plan) and more detailed site plan, Drawing No. SH03582/28.

Ground levels within the main existing market/car park area fall eastwards from about 97m AOD to levels of about 93-94m AOD, which are retained above the railway. Levels near to the railway and the Markets Basement entrance road are at about 91.5m AOD. The floor of the basement is at about 91m AOD. East of the railway, ground levels on the CEAG area fall southwards from about 92m AOD to about 90m AOD.

The Site is located in the centre of Barnsley, South Yorkshire, is surrounded by mixed commercial and residential areas, and is bounded by Kendray Street and Jumble Lane Crossing to the north, Harborough Hill Road to the east, a private road and the Alhambra Shopping Centre to the south, and Cheapside and May Day Green to the west.

1.3 Purpose and Basis of Report

The Stage 2 Site Investigation follows a Preliminary Stage 1 Site Investigation which was reported in November 2007. The Stage 2 investigation builds on and incorporates all of the results and findings of the Stage 1 investigation to further characterise the contamination and geotechnical conditions beneath the Site and constrain the risk posed by identified soil and groundwater contamination, and potential shallow mine workings. The report includes a waste classification assessment of the main areas of proposed basement excavations and a geotechnical assessment of the Site to allow the preparation of detailed foundation design. The report will also facilitate the separate completion of an outline contamination remediation strategy including a detailed quantitative risk assessment.

1.4 Proposed Site Use

It is proposed that the Site will be redeveloped as mixed retail, markets, leisure and residential uses on the west side of the railway and a new multi-storey and external car park on the east side.

2. SUMMARY OF HISTORICAL INVESTIGATIONS

2.1 Introduction

This section presents a condensed summary of ground conditions and contamination previously documented in Chapter 7 of the Environmental Statement (ES) for the Site. The summary describes the assessment of general ground conditions, the presence of contamination and the possibility of mining instability.

The assessment for the ES was primarily a desk-based review of pre-existing information, which included land use history, mining archive records and some limited intrusive site investigation results. The latter were obtained several years ago, when some of the current methodologies employed to assess contamination risks were not commonplace.

2.2 Sources of Information

The assessment was based upon a site walkover and review of historical data, in consultation with Barnsley Metropolitan Borough Council. Sources of information included:

- Inspection of Coal Authority underground mining abandonment plans.
- Discussions with staff from South Yorkshire Mining Advisory Service (SYMAS).
- Preliminary Report on Environmental Audit – Site at Lambra Road, Barnsley; prepared by Jordan Pritchard Gorman and Owen Williams Geotechnical for Osprey Commercial Properties Ltd (ref. L198/001, December 1994).
- Further Environmental Investigations – Site at Lambra Road, Barnsley; prepared by Jordan Pritchard Gorman and Owen Williams Geotechnical for Osprey Commercial Properties Ltd (ref. L198/002, April 1995).
- Due Diligence Study – The Metropolitan Centre, Barnsley; prepared by Symonds Group for Yorkshire Forward (ref. 4M/59074, dated October 2002).
- Mineral Reports prepared by SYMAS – May Day Green & Kendray Street Sites, Barnsley (ref. FW/SML/M4364, dated October 2002) and Market Redevelopment, Barnsley Centre (ref. MAL/SML/M4364/2, dated October 2003).
- Report on Barnsley Shopping Centre - Investigation of Design Information of Existing Foundations and Basements; prepared by Mott MacDonald for Yorkshire Forward (ref. 213289/01/A/08, dated April 2004).
- Baseline Environmental Information to Support an EIA: Barnsley Markets Project – Vol.1 Report and Vol.2 Appendices; prepared by Enviros Consulting Limited for Yorkshire Forward (ref. YO0010043A, dated December 2004).

- Environmental Statement Scoping Report – Proposed Retail, New Market, Leisure and Residential Development and Car Parking – Land at Barnsley Markets Site and Adjacent CEAG Site, Barnsley; prepared and submitted by RPS (dated 27 January 2005).
- Formal response letter to the Scoping Report; prepared by BMBC Planning and Transportation Service (ref. DC/JH/EIA/01/05, dated 2 March 2005), which included comments from The Environment Agency on pollution prevention and licences, Highways and Engineering Drainage Section on the Sough Dyke, Environmental Health Service on contamination and SYMAS on mining.
- Development Agreement Design Report for the Barnsley Markets Project dated 8th December 2005; prepared by CZWG Architects and Holder Mathias Architects (HMA).
- Coal Authority site specific Mining Report dated 16th January 2006 (ref. 10016602-06).
- British Geological Survey site specific Radon Report dated 16th January 2006 (ref. GR_037057_1).
- Baseline update consultation letter from the Environment Agency dated 30th January 2006.
- Historical plans of the Sough Dyke alignment provided by BMBC.
- Site foundation drawing extracts provided by the architect HMA.
- Published geological maps & memoirs for the locality.

2.3 Summary of Previous Reports

2.3.1 Jordan Pritchard Gorman and Owen Williams Geotechnical - Preliminary Report on Environmental Audit and Report on Further Environmental Investigations at Lambra Road, Barnsley (December 1994 and April 1995)

2.3.1.1 General

The Lambra Road site comprised the south eastern portion of the current Barnsley Markets site, adjacent to the market hall and multi-storey car park. The reports covered two site investigations for contamination purposes that were completed for potential redevelopment of the site to an area of commercial retail and car parking. [*Note: The Enviros baseline report indicated that the site investigations were completed to discharge a condition associated with a planning application for the commercial development. The investigation area is currently occupied by the Zero Ice (Carpet World) building*].

The first report included a review of site history. The area in question had been historically occupied by a gas works at the northern end and an iron and brass foundry (Borough Foundry) at the southern end, which later became a depot and works. The reports concluded that the former gasworks and the former foundry

could be sources of contamination on the site. Historical residential housing was recorded further south but was not subject to the investigation as that land was subsumed by the carriageway of Harborough Hill Road. Further details of the land use history are given in Table I.

Buildings in the area at the time of the site investigations had not been demolished.

Five boreholes up to 6.25m deep and eleven trial pits of unknown depths were completed during the two investigations. Borehole logs were available in the first report but no logs for the trial pits were given in the second.

The borehole logs showed that all five were drilled through concrete hardstanding. Beneath, made ground (comprising clay, bricks and stones) was present across the site (thickness range in boreholes 0.4 to 5.9m), predominantly as thin deposits with the thickest units beneath parts of the former gas works at the northern end of the site. Drilling results confirmed that the made ground was underlain by Middle Coal Measures comprising brown and grey mudstone, with thin shallow coal seams in the central area. Shallow perched groundwater in made ground was identified in the borehole (No. 1) with the thickest made ground at the northern end of the site. The other boreholes were mainly dry with no indication of groundwater in the mudstone.

Chemical testing by Inchcape Testing Services comprised 55 soil samples (23 in the top 1 metre) and 5 groundwater samples. No details were provided regarding methods of sample collection or testing. Results were screened against the now obsolete ICRCL trigger levels to guide a contamination assessment and suggest appropriate remedial works.

Borehole logs taken from the Jordan Pritchard Gorman and Owen Williams Geotechnical Report are included within Appendix II.

2.3.1.2 Observations of Contamination

Oily puddles and thick oily deposits were identified over large areas of hardstanding and wooden flooring (S end) across the site. Two storage pits, one that potentially contained paraffin (N end), were identified. In addition, a storage tank of unknown nature was identified next to a workshop in the central portion of the site.

[*Note: The Enviros baseline report prepared later for the ES included evidence of hydrocarbon odour and staining in the made ground and coal measures. The source of that information was not clear, however*].

2.3.1.3 Chemical Testing

Chemical data for soil were assessed against the existing ICRCL trigger levels in 1994. There were scattered exceedances for phenol, "benzine" compounds, xylene, toluene, toluene extractable matter, sulphides, As, B, Cu, Hg, Pb and Zn. The most impacted samples were from 6m of made ground encountered in BH01 and from TP01 and TP02 at the northern end of the site, near the former gas works. Phenol concentrations were also highest to the north and at the interface between made ground and mudstone.

Two groundwater samples from BH01 were assessed against ICRCL trigger levels. One of the samples from 4.5m below ground level contained an elevated concentration of phenol. Three groundwater samples from TP2 and TP11 were reported to contain relatively low levels of contamination.

Sulphate concentrations in soils and groundwater samples were initially considered not to be at levels so as to cause concern with regard to building materials. Some acidic ground conditions were identified by the second investigation. This resulted in an upgrade to the recommended sulphate class for concrete.

[*Note: The Enviros baseline report stated that a survey was also done of the dismantled electrical substation on the site and that there was no trace of Poly-Chlorinated Bi-Phenyls (PCBs) in any of the samples taken from beneath the site].*

The main conclusion was that the contaminant concentrations were not sufficiently high to preclude development of the site. The report stated that the proposed hard cover and engineered capping for the development would, in the main, provide adequate environmental protection to the then current requirements. Some advice was also given on demolition practices (incl. asbestos removal), the protection of construction workers, the possibility of mine gas emissions and other health and safety matters.

[*Note: Additional discussions by Enviros, during the 2004 baseline study, with representatives of the Council's Urban Regeneration Group indicated that a planning condition relating to the presence of contamination arising from the former gasworks was discharged by the Local Authority in 1994. No evidence of such was made available for the ES assessment*].

2.3.2 Symonds Group Due Diligence Study – The Metropolitan Centre, Barnsley (ref. 4M/59074, dated October 2002)

2.3.2.1 General

The Symonds report constituted a 'development feasibility study' of the Barnsley Metropolitan Centre, in consultation with BMBC and South Yorkshire Archaeological Service (SYAS). The study area (approx. 0.8ha) was smaller than the current proposed development site area and was confined to its western end, as follows:

- Site A (0.7ha) – Council offices plus retail units between Charter Arcade and Cheapside and between May Day Green Arcade and May Day Green, with extensive underground basement.
- Site B (0.1ha) – block of retail/commercial units bounded by May Day Green, Burlington Arcade and Eldon Street.

The report comprised a desk-based study of available information on the following:

- Environmental contamination
- Services
- Geotechnical and coal mining
- Archaeological research

No intrusive investigation was completed. However an internal asbestos assessment was conducted.

Much of the report was in the style of a typical Phase 1 environmental report with Landmark data, similar in many respects to various sections of ES Chapter 7 and the Enviros baseline report.

2.3.2.2 Geology

The Symonds report indicated that superficial deposits were generally absent but some alluvial deposits might be present in the vicinity of a **"**…. culverted stream that follows the route of Queen Street and Cheapside".

It is likely that this was either an inaccurate reference to the Sough Dyke or refers to a local sewerage drain.

2.3.2.3 Hydrogeology

Information obtained by Symonds from BMBC Building Control indicated that groundwater was not encountered during construction of the basement (up to 7mbgl) and no groundwater was actively pumped from it. However, there was reference made to groundwater at shallower depths to the S and W being continuously pumped from other basements (e.g. 150m W – Boots extension).

Symonds concluded that the groundwater table was likely to be lower than the foundations of the buildings, though the basement could be prone to future changes in local groundwater conditions.

2.3.2.4 Hydrology

Further reference to the culverted stream along Queen Street and Cheapside confirmed there was no available Environment Agency information about size, flow or water quality.

2.3.2.5 Site History

A large part of Site A was previously occupied by the former Union Foundry.

The eastern portion of Site B was once a cattle market.

2.3.2.6 Landfill Sites

Although unlikely to be a major source of pollution, a former landfill site on Doncaster Road to the south might warrant a ground gas monitoring programme for redevelopment purposes.

2.3.2.7 Ground Conditions

Building Control had apparently advised that significant variations exist in ground conditions in the town centre, both laterally and vertically, over short distances. No site specific geotechnical information was available for the report.

Building Control had also reportedly advised earlier enquiries by Campbell Reith Hill that the geology in Site A was boulder clay over coal measures; with concrete pad foundations in the boulder clay; and piled foundations to 3m below basement floor levels. No records of site investigations or groundwork for the area were available.

Symonds added that:

- No other records of the presence of boulder clay on site had been found.
- Variability in made ground could have implications for foundation treatment, particularly if significantly contaminated.
- Coal measures strata would be more suitable for founding, but dependent on the weathering profile, shallow mining potential and proposed redevelopment designs.
- Variability in groundwater conditions may require some control measures for redevelopment.
- Further geotechnical investigations would be likely for redevelopment.

Symonds considered that most of any contaminated ground in Site A would have been removed during basement construction, to leave potential for isolated hot spots.

It was considered unlikely that either Area A or Area B would have posed significant risks to human health, groundwater or surface water. However, redevelopment could have implications for site investigation, monitoring and remediation.

With respect to unrecorded shallow mining, Building Control had advised that bell pits had been found in past town centre construction works. They also apparently stated that there was no evidence of coal seams or workings having been encountered during construction of the Metropolitan Centre.

2.3.2.8 Asbestos

Symonds conducted a "Phase 1" asbestos survey of the buildings. This was an inspection (without sampling) to identify the potential presence of asbestos containing materials (ACMs) in four areas comprising the:

- Basement – Low to medium overall risk of significant ACM presence
- Ground Floor – Low to medium overall risk of significant ACM presence
- First Floor – Medium overall risk of significant ACM presence
- Second Floor – Low to medium overall risk of significant ACM presence

They summarised the results as:

a) Site A – Low to medium overall risk of significant ACM presence

b) Site B – Medium overall risk of significant ACM presence

The potential for significant ACM presence was noted in other adjacent buildings (e.g. Lower Market Hall).

2.3.3 SYMAS Reports - May Day Green and Kendray Street, Barnsley 10/10/2002 (ref. FW/SML/M4364) and Market Redevelopment, Barnsley Centre 10/10/2003 (ref. MAL/SML/M4364/2)

2.3.3.1 General

The SYMAS reports outlined the geological and mining setting at the Site and provided the results of investigations on adjacent sites. Conjectured coal seam outcrops from the reports are replicated on Drawing SH03582/07.

The main observations and recommendations are discussed below.

2.3.3.2 Shallow Mineworkings

Although a number of coal seams outcrop through and in the vicinity of the Site, there were no plan records to indicate that the shallow seams had been exploited beneath the Site.

Site investigations were conducted in the past on land adjacent to the south (Alhambra Centre) and north (Bus Station Interchange) of the current Site, in order to prove the position with the Winter and Beamshaw Coal Seams.

a) SI on 10th June 1986

Four boreholes were drilled on the site of the Alhambra Centre. These proved the Winter and Top and Low Beamshaw Seams to be present beneath the area, but to be generally of poor quality with several interstratified dirt bands. The seams were estimated to have a full dip around 1 in 15 in an easterly direction.

(b) SI from 2nd to 4th May 1989

Six boreholes were drilled on the site of the Interchange office block. The Top Beamshaw and Winter Coals were found to be present under the location, dipping at approximately 1 in 8 eastwards.

The reports stated that there was no evidence from these ten boreholes, or other holes previously drilled in the immediate vicinity for highways projects etc., to suggest that any unrecorded mineworkings had taken place in the shallow coal seams beneath the area.

The results indicated that the Beamshaw and Winter Coals in this locality have poor sections and would be incapable of economic working.

However, records indicated that underground workings took place in the Winter Coal Seam approximately 200m to the north-east from Mottram Wood Colliery prior to 1920.

These activities encountered old unrecorded workings some 600m to the north-east of the area in the vicinity of Dryden Road, although no such disturbances were known to affect the sites under consideration.

Borehole logs taken from the SYMAS Reports are included within Appendix II.

2.3.3.3 Deep Mining

Some information was given on deep workings in the Barnsley and Top Fenton seams, similar to that outlined in the Coal Authority report but with an implied last date of working of 1953.

2.3.3.4 Mine Gas

SYMAS had no records of any specific mine gas migration in the vicinity of the Site.

2.3.3.5 Future Development

The reports indicated that:

- It would seem prudent to carry out a limited borehole investigation before any development is undertaken to check the depth and nature of the shallow coal seams.
- Although there were no known problems relating to fugitive mine gases in the area, due to the outcrop and possible shallow workings the above boreholes could be utilised to monitor the situation for 6 months or so prior to any development commencing.
- If any coal is encountered during any future development works it should be blinded off using a lean mix concrete or other suitable inert material to prevent spontaneous combustion from occurring.
- Model specification documents advise that coal and other unsuitable material associated with coal found to exist at formation level is to be excavated for a depth of at least 300mm and replaced with suitable material.
- Considering the coal seam outcrops and potentially fissured sandstone bedrock lying beneath the surface of the Site area, all the usual safety precautions should be employed regarding the possible presence of fugitive gases in any excavations taking place during site investigations and subsequent development works.

2.3.4 Mott MacDonald Report on Barnsley Shopping Centre - Investigation of Design Information of Existing Foundations and Basements (ref. 213289/01/A/08, dated April 2004)

2.3.4.1 General

This report was prepared to compile archive information held by Mott MacDonald on existing foundations and ground conditions that might be of use to the site redevelopment.

The report covered the 'Barnsley Central Area Development', which was designed in 1968-1974 and constructed in the early 1970s. This is effectively equivalent to that part of the current development site west of the railway. It did not include information on the CEAG site to the east.

The archive information available comprised:

- Limited geotechnical information;

- Structural calculations (but no as-built drawings);
- Sough Dyke information; and
- Foundation details.

*2.3.4.2 Geotechnical**

A soil investigation report dated May 1967 gave details of a two-stage site investigation. The first stage comprised five trial pits that were excavated across the site in late 1966, with positions recorded on a plan and simple descriptions tabulated. As far as can be determined, three of the five (nos. 2, 4 and 6) were dug in the northern section of the current basement area, one (no. 7) on Cheapside and one (no.1) to the north near the Council Chambers. This is at best an approximate estimate but will be used for the purposes of description.

Trial holes in the basement area recorded 0.7-1.0m of fill above 0.6-1.7m of soft brown sandy clay, above 2.7-3.5m (unproven thickness) of medium grey clay with lumps of sandstone. Water was observed at about 5m bgl. Probing with a steel rod met solid resistance at about 6-6.5m bgl. The trial hole no.7 on Cheapside encountered fill, brown and grey clay thicknesses of 0.8m, 0.7m and 4.7m respectively, with water at 5.6m bgl and still no solid resistance to the probe at 7.4mbgl. Trial hole no.1 recorded 0.3m, 2.1m and 2.7m respectively then bottomed on the top of a coal seam. Water appeared to be entering the hole from a nearby air raid shelter.

When it was found that the pits had not encountered rock, as had been envisaged, the second stage was employed and comprised eight 16" rotary augered boreholes. These were drilled to refusal in rock strata (maximum depth of drilling 9.7m), five in the same locations as the pits and another three in the central and southern section of the current basement area.

From the simple descriptions, the final recorded thickness of fill ranged from 0.7m-2.6m and the material was deemed unsuitable for structural foundations. Hard strata (grey shale), encountered at depths of 5.8-8.2m, was described as suitable bearing material for deep mass foundations or small diameter piles of "about 50 ton capacity". The report suggested that, based on indicative in situ SPT tests, "..bearing loads of up to 10tons/ft^2 could be carried".

The report described the material overlying the rock and beneath the fill as very variable, including clays, shales and coals. Unconfined compression testing on undisturbed samples of clay gave a wide range of shear strength characteristics and, although some indications were given on separate calculation sheets, no precise bearing load was quoted in the report.

Notable (but thin and apparently intact) coals of 0.3-0.8m thickness were encountered on site at depths of 6.1mbgl (BH2), 4.6mbgl (BH3) and 6.1mbgl

(BH8) and possibly 2.7mbgl in BH5. Off site, BH1 encountered 1.7m of coal with shale at a depth of 4.0mbgl.

Consultation with the National Coal Board indicated that the highest unworked coal seam beneath the site was the Low Beamshaw with a thickness of 2ft (c. 0.6m) at a depth of 29 yds (26.5m). No correlation was made with the shallower coal seams encountered in some of the boreholes.

Groundwater depths encountered varied from 4.9-9.7m bgl.

Surface elevations recorded on the logs for the six boreholes seemingly within the basement area (c. 94.5 – 95m AOD, with one at c 92.5m AOD), if representative, are a little higher than those for the current basement slab (91-92m AOD) shown on a recent cross section in the Mott Macdonald report. This could be evidence of some soil removal during construction. However, the transposed positions are only approximate and data is not sufficiently detailed to guarantee the accuracy required to form a complete judgement on this.

In 1970, the logs of the 1967 boreholes, compression tests and SPT results were reported again but with logs for an additional ten boreholes. No location plan was shown, however. All logs were in a summary table. Records of the extra ten holes showed they were drilled from elevations within the range 93 – 96mAOD. The logs indicated they encountered 0.0-0.5m of tarmac/concrete above 0.9-8.5m of fill above 0.0-2.1m of very soft to firm brown or grey clay above 0.0-3.3m (unbottomed) of shale and occasional sandstone and "coal measures". The latter were recorded in two holes with thicknesses of 0.8-1.1m. Some boreholes were dry, in other seepages were recorded at 1.8-4.9mbgl; four logs indicated standing water levels at 1.2mbgl.

No descriptive text or conclusions were shown behind the front title page cover, except for a short statement on 'permissible bearing pressures' in the upper brown and lower grey clays and the underlying grey shales. These were recommended as 1ton/ft^2, 3tons/ft^2 and 6tons/ft^2 respectively subject to inspection at each foundation.

The next section of the Mott MacDonald report comprised pile test results and pile logs dated February 1971. There were 23 logs but they only provided simple descriptions and very limited site coverage as they were concentrated at the NE i.e. access end of the existing multi-storey car park basement (clustered close to borehole 3 of the 1967 series). In summary, they recorded thicknesses of fill from 0.0m-5.5m and depths to hard strata ('rock shale or mudstone') of 4.9-8.8m, with intervening clays and coals. Coal (0.5 – 1.5m thickness; possibly Top Beamshaw?) was recorded in all holes at depths from 3 – 7m bgl.

Therefore, coal thicknesses recorded in the 1970s series were greater than those in the 1967 series. Nonetheless, the logs contained no evidence of coal

workings. The degree of data reliability is unknown, however, nor is there sufficient detail to determine coal quality.

Borehole logs taken from the Mott MacDonald Report are included within Appendix II.

2.3.4.3 Sough Dyke

The report contained brief details of the Sough Dyke, and provisions made for it in certain column foundations.

It also included Dyke alignment information on a 1979 BMBC theodolite survey plan (1:500) and 1962 edition of the OS base (1:2500).

2.3.4.4 Foundations

Mott MacDonald divided the existing site foundation layout into a series of areas, and produced a detailed drawing for each, together with a site composite plan and full cross section.

Calculations summarised on several of the area sheets stated indicative values for the ground bearing pressures below the basement foundations (overall range 1.6-3.8 tons/ft^2) and high level foundations (overall range 1.4-3.1 tons/ft^2).

* - thicknesses in section 2.3.4 are approximate conversions from imperial.

2.4 Land Use History

The Enviros baseline report commented that there was considerable historical information concerning the market within the former mining (e.g. coal mining in 1284 and later in the 17th and 18th centuries) and manufacturing (e.g. in linen and weaving) town of Barnsley.

The history of the Site and its immediate vicinity has been investigated for this section by consultation with a range of archive sources and statutory bodies. The historical data is based on a Landmark Envirocheck report dated August 2004 and other information within the Enviros Baseline report. Information was also obtained from the Environmental Statement and the reports mentioned therein.

The Site history has been primarily researched to identify previous land uses, including any significant potentially contaminative uses. Where other features that may have an effect on development of the Site have been identified, they are described.

Table I summarises the history of the Site and its immediate vicinity over the period from about 1855 to the present day.

TABLE I - SUMMARY OF LAND USE

Date	Site Land Use	Adjacent Land Use
Pre-1900s	Main site occupied, from west to east, at the N end by a cattle market, Union Foundry & The Orchard and at the S end by unnamed (probably commercial) buildings, Borough Foundry and a gas works. Tramway on Kendray St between cattle market and Union Foundry. Railway (2 spurs) dissects the main site from the land to the E, occupied by residential dwellings and malthouses.	The Site is surrounded by residential to the north, south and west, with a number of industrial premises also to the north and south-west, including timber yards, a saw mill and foundries. Land to east is predominantly open land (agricultural) with a clay pit (40m) and Mount Osborne Colliery (150m) to SE. There are records of a colliery shaft sinking as pre dating 1871.
1900 - 1910	The Orchard replaced by electricity works. Tank labelled towards N boundary on eastern side of railway.	Mount Osborne Colliery replaced by Yorkshire Metal Works. Residential dwellings to the east. Saw mill on N boundary absent.
1930s - 1950s	Building layout changes recorded on main site with much of Union Foundry demolished, partially replaced by water coolers (northern segment). Part of gas works	Borough Colliery (drift) to NE. Increased residential to east.

TABLE I - SUMMARY OF LAND USE		
Date	**Site Land Use**	**Adjacent Land Use**
	replaced by Borough Foundry. Malthouses E of railway fully demolished, replaced by lamp works. WWII air raid shelters recorded towards the NW portion of the site, to the east of Kendray Street (see Chapter 6).	
1960s	Much of the main site has undergone extensive building configuration changes. The Old Union foundry area is labelled New Market, the gas works and Borough Foundry replaced by depot and works. Tramlines removed from Kendray Street. Lamp works appears to have been extended towards S & E site boundaries.	Borough Colliery shown as disused air shaft. Increased residential dwellings to east. Majority of surrounding industrial premises absent.
1970s - 1990s	Main site has been redeveloped to a similar layout as it is today with the majority of the site occupied by the market, Council buildings, retail developments and a multi-storey car park. Depot & works still present towards south. Two electrical substations near S boundary. Partial demolition of the railway network (1 spur). Residential dwellings to east of railway removed. Gas governor adjacent to lamp works.	Dual carriageway (Harborough Hill Road) to the S and E.
2000	Historic works buildings to south demolished, replaced by single unit as seen today (Carpet World).	No major changes to surrounding area.
Present day	The western (main) portion of the site is occupied by Council buildings, retail developments and car parking facilities, market and multi-storey car park, including a basement floor 6m bgl. The eastern portion is occupied by a single industrial type unit (former lamp works; CEAG building).	A mixture of residential and retail properties. Dry cleaners to SW.

None of the available maps show an obvious expression of the Sough Dyke, except for a 1777 map. This shows a meandering watercourse along a similar alignment to that thought to exist at the present day.

A plan of the significant historical land uses against the current site layout is shown as Drawing SH03582/07.

Further historical details of the Site can be found in the Enviros Baseline report and the Environmental Statement.

3. ENVIRONMENTAL SETTING AND CONCEPTUAL SITE MODEL

3.1 General

The environmental setting of the Site and its immediate vicinity has been summarised from Chapter 7 of the ES for the Site. The topographical and environmental data is primarily based on a Landmark Envirocheck report dated August 2004 appended within the Enviros Baseline report and update consultation correspondence from the Environment Agency dated January 2006.

3.2 Waste Management

Information supplied has indicated the presence of the following waste management sites within potential influencing distance of the Site boundary.

TABLE II

Location	Details
Registered Landfill Site: The Old Vicarage, Doncaster Rd, Barnsley **Grid Ref:** 434950, 406050 **Distance from Site:** 200m SE	**Licence Number:** WD20 B 812 **Authority:** Environment Agency – North East Region, Ridings Area **Site Category:** Medium Landfill (25,000 to 75,000tonnes per year). **Authorised Waste:** Excavation waste, soil, subsoil, inert non-Hazardous Building/demolition waste **Licence Status:** lapsed/cancelled/defunct/not applicable/surrendered
Licensed Waste Management Facility: Harborough Hill Rd, Harborough, Barnsley **Grid Ref:** 434800, 406650 **Distance from Site:** 249m N	**Licence Number:** 60598 **Authority:** Environment Agency – North East Region, Ridings Area **Site Category:** Transfer Station **Licence Status:** Surrendered

In addition to the recorded/licensed landfilling activities near to the Site, the possibility of there being unrecorded landfilling activities within influencing distance of the Site cannot be entirely discounted. If at some time in the future, the presence of such an unrecorded landfill is revealed then its potential influence on the Site may need to be investigated and dealt with as necessary.

From the information examined there is one registered waste transfer site in the vicinity of the Site. The licence holder is Yorkshire Electricity and the facility is located approximately 250m north and has a reference WD20 B 879 (MOD 2), dated 1992 (1997), related to the licensed waste management facility discussed above. The input is classed as small (10000-25000t per year).

The Environment Agency baseline update enquiries confirmed the presence of an inert landfill (excavation waste, soil and demolition waste – no asbestos) at grid ref. SE 3450 0700 and licence no. 20 B 446(23). This is more than 250m away from the Site. The licence was cancelled in 1992. The Environment Agency stated that there were no known gas problems associated with this landfill.

3.3 Radon

The Site was shown to lie in an area where consideration should be given to geological data and whether basic protection against radon may be needed should development of residential dwellings or new structures of similar form of construction and compartmentation occur.

The site specific radon report obtained for the Site (see Appendix III) confirms that basic protection would be needed. These measures would normally be required for development of residential dwellings or new structures of similar form of construction and compartmentation. The development proposals include residential development above second floor level, below which will be retail and leisure uses. Owing to the complexity, the precise requirement for the basic radon protection will be defined and incorporated as necessary at detailed design stage.

3.4 Environmental Issues

3.4.1 Pollution Incidents to Controlled Waters

The Environment Agency data via the Landmark report record the following incidents at or in the near vicinity of the Site.

TABLE III

Incident	Details
Operator: Industrial premises, Road Bridge A628, Old Mill Bridge A61 Dearne **Grid Ref:** 435000, 406400 **Distance from Site:** 177m E	**Reference:** 148570 **Pollutant:** Oils - Diesel **Incident Date:** 1st November 1993 **Severity:** Category 3 – Minor incident **Receiving Water:** Freshwater Stream/river

3.4.2 Substantiated Pollution Incidents

The Environment Agency data via the Landmark report and 2006 update record the following incidents at or in the near vicinity of the Site.

TABLE IV	
Incident	**Details**
Authority: Environment Agency – North East Region, Ridings Area **Grid Ref:** 434620, 406200 **Distance from Site:** 32m SW	**Reference:** 45948 **Pollutant:** Fire brigade using pumps to control a fire at Gala Bingo. **Incident Date:** 1st December 2001 **Air Impact:** Category 3 – Minor incident (no impact on land or water).

3.4.3 Discharge Consents

The Environment Agency data via the Landmark report records a total of 54 discharge consents within influencing distance of the Site, four of which are located within the Site boundary. All consents are registered to Yorkshire Water Services Ltd for discharge of storm sewage overflow.

3.4.4 Integrated Pollution Control

The Environment Agency data via the Landmark report records the following current or past IPC permissions at or near the Site.

TABLE V	
Operator	**Details**
Operator: Monckton Coke and Chemical Co Ltd **Grid Ref:** 434390, 406250 **Distance from Site:** 198m W	**Permit Reference:** Bk3441 **Status:** Superseded April 2003

The 2006 baseline update from the Environment Agency stated that there were no Integrated Pollution Control or Integrated Pollution Prevention and Control Authorisations or Radioactive Substances Registrations/Authorisations at or within 500m of the Site.

3.5 Asbestos

Asbestos was identified during the Symonds diligence study. A full asbestos survey should be carried out at the Site prior to demolition. Guidance on the need for asbestos surveys and the method of carrying them out are given in HSE Publication MDHS100.

3.6 Ecology

Japanese knotweed is classed as an invasive weed and it is an offence under the Wildlife and Countryside Act 1981 (as amended) to plant or otherwise encourage the growth of this species. There have been several observations of knotweed growth off site, in areas alongside the railway. There has also been evidence of treatment of the knotweed by spraying. It is recommended that the details should be obtained from Network Rail as part of the development and construction programme to ensure that the knotweed will not affect the Site.

3.7 Geology

A typical conjectured section of strata is provided in Table VI below along with other geological data.

TABLE VI

Strata	Description
Made ground.	Reworked natural material with brick, ash and concrete.
Natural superficials.	None identified.
Solid strata.	Middle Coal Measures. Undifferentiated mudstone, siltstone and sandstone, underlain by sandstone of the Kent's Rock. Information obtained through SYMAS indicates the Top and Low Beamshaw, and the Winter (Abdy) Coal seams crop at the surface on the Site, with the Two Foot Seam outcropping to the east.
Dip and dip direction.	Low angle dip (1 in 8 to 1 in 15) towards the east.
Evidence of faulting.	No faulting is evident in the Site area.
Evidence of other geological structures.	None identified.
Natural cavities.	None identified.
Other – landslides, brine, subsidence etc.	British Geological Information Services via the Envirocheck data indicate the potential for landslides, gulls and cambering subsidence hazard to be low.

3.8 Hydrogeology

The Site was identified as being underlain by Middle Coal Measures which are classified as a minor aquifer. Typically, the principal aquifers within coal measures are the sandstone units, such as the Kent's Rock.

Two active groundwater abstraction licences were identified within a 2km radius of the Site. Both were approximately 0.9km west (NGR: 433700, 406060) and

operated by Sheldale Developments Limited which is licensed to abstract groundwater for drinking water bottling purposes. The Environment Agency baseline update implied that one of the two abstraction licences might have been revoked. A further three groundwater abstraction licences were listed within 2km of the Site but to have been revoked.

The Site does not lie within a groundwater source protection zone.

3.9 Soil Vulnerability Classification – Leaching Potential

The soil on Site has a High Leaching potential (HU) due the sites urban location and hence variability.

3.10 Hydrology

The nearest graded surface watercourse is the River Dearne, which is approximately 900m north-east of the Site. The Environment Agency has given the River Dearne a General Quality Assessment (Chemistry) rating of C (fairly good) for this stretch.

The main surface water feature in the vicinity is the Sough Dyke, which is culverted beneath the Site. Until recently, it was classified as a Critical Ordinary Watercourse (COW), and therefore the responsibility of BMBC. More recently the Sough Dyke has been classified as a Main River and falls under the remit of the Environment Agency. The Sough Dyke drains the western area of Barnsley through the town centre and outfalls to the River Dearne in the east.

Consultation with the Environment Agency confirmed that they did not hold water quality data on the Sough Dyke in Barnsley.

There were records of two active surface water abstraction licences within 2km of the Site. The closest was approximately 1km north-east (NGR 435710, 406850) and operated by Barnsley Metropolitan Borough Council, which was licensed to abstract 7,800m^3 of surface water per year for “crown and government: make-up or top up water” purposes. A further five surface water abstraction licences were listed within 2km of the Site but noted to have been either revoked, lapsed or withdrawn.

The Environment Agency indicative flood risks map indicated that the Site was not on an identified flood plain. This means that the chance of flooding each year from rivers or the sea is 0.1% (1 in 1000) or less.

3.11 Mining

3.11.1 Surface Workings (Quarrying and Opencast)

Research of topographical, geological and other archive mining records did not indicate any significant evidence of surface extraction within the Site boundary.

However, surface extractions were shown on the historical OS maps to the east of the Site, including a possible clay pit 40m south east.

3.11.2 Shallow Underground Workings

From the enquiries made and examination of the geological information there was no significant evidence of recorded and unrecorded shallow underground mining activity directly beneath the Site. However, from inspection of the geological plans, discussions with SYMAS and results of their nearby site investigations it was evident that 3 coal horizons outcrop and/or lie at shallow depth beneath the Site.

These are: Winter or Abdy Coal Seam
Top Beamshaw Seam
Low Beamshaw Seam

Whilst the Beamshaw Coals have been worked at some locations in the area they are recorded in the geological memoir (No. 87, Barnsley) as:

"Around Barnsley the Beamshaw Coals are usually two but sometimes three in number, and are thin seams much mixed with shale and of little value; they are sometimes exposed in the streets of Barnsley near the railway stations".

Thin and apparently intact coals of 0.3-0.8 thickness were encountered in 1967 site investigation boreholes in the basement areas of the site at depths of 6.1mbgl (BH2), 4.6mbgl (BH3) and 6.1mbgl (BH8) and possibly 2.7mbgl in BH5. Their approximate positions, close to conjectured outcrops, indicate that the first two could represent the Low Beamshaw coal and the second pair the Top Beamshaw coal. Off site, BH1 encountered 1.7m of coal with shale at a depth of 4.0mbgl along the strike of the Top Beamshaw. Coal (0.5 – 1.5m thickness; possibly Top Beamshaw?) was also recorded at depths from 3 – 7m bgl in a series of 1971 piling logs that relate to the NE corner of the basement.

The Winter Coal is recorded as worked to the east of the Site.

The Barnsley geological memoir states:

"Abdy or Winter Coal – North of Barnsley this seam is known as the Winter Coal, but south of this place it takes its name from the farm called Abdy between Wath and Rawmarsh. Though in the north it averages a yard in thickness, to the south it is usually rather thinner. At least one thin dirt parting is generally present within the seam, but in some areas there are several such bands up to 10 in. in thickness. The top portion of the seam, with from 27 to 33 in. of coal, appears to be present everywhere in the northern part of the area, where the coal is of good quality and has been considerably mined. The roof of shaly and concretionary mudstone is difficult to manage and it is stated to be the principal reason why the coal has not been more intensively wrought". D.A.W.

'The coal has been worked at a number of small collieries around Barnsley, chiefly on the left bank of the Dearne and between Barnsley and Worsborough Hall. It is an exceedingly pure coal'. *C.E.N.B.*

In addition the higher Two Foot Coal Seam is indicated to outcrop to the immediate east of the CEAG area and dipping away from the Site.

Adits into the Woodmoor Coal (above the Two Foot and Winter Coals) at Borough Colliery are also shown on the geological plan to the east of the Site.

The Mount Osbourne Colliery, located to the south east of the Site, is indicated to have been worked prior to 1871, with a shaft log reporting the presence of the aforementioned seams at shallow depths beneath a datum level of 275 ft (c. 84m) AOD.

3.11.3 Deep Mining

Deep underground mining activity was identified in two seams of coal at 150m to 360m depth. The SYMAS reports indicated that these were the Barnsley and Top Fenton Seams respectively. The last date of working is recorded in the Coal Authority report (Appendix IV) as being 1939 but 1953 in the SYMAS report.

3.11.4 Mine Entries

No recorded mine entries (shafts and adits) were identified on or within influencing distance of the Site.

3.11.5 Mine Gas

The information obtained and discussion with BMBC engineers has confirmed that there is a history of mine gas problems in the general locality.

3.12 Assessment of Contamination on the Carpet World Site Using Current Screening Criteria

The 1994/95 test data for the Lambra Road site was used to give an indication of the significance of contamination by using then current screening criteria for commercial end use.

3.12.1 Soils

Twelve soil samples exceed screening levels for one or more contaminants including sulphide, boron, copper, lead and zinc. Five of the samples were of shallow soil less than 1m below ground level. The upper 95th percentile was not exceeded for any of the contaminants tested (metals, phenol, total cyanide and sulphide). Therefore, the impacted soil samples were interpreted to represent localised hotspots rather than laterally or vertically persistent contamination.

Copper and zinc are phytotoxic metals and not normally hazardous to human health unless present in extremely high concentrations. Such concentrations were not detected in any of the soil samples analysed.

Construction workers are more likely to be at risk from a high single exposure, i.e. an acute dose, which can result in contaminant poisoning. Suggested values for acute lethal doses of arsenic, cadmium, chromium, inorganic mercury, nickel and selenium are outlined in the Environment Agency R&D SGV reports.

None of the samples contained concentrations of cadmium, chromium, inorganic mercury, nickel or selenium that were elevated with respects to an acute lethal dose.

No acute lethal dose value is given for lead. Concentrations of up to 2000mg/kg recorded in TP2 may be significant in terms of an acute lethal dose to construction workers, and as such Appropriate Personal Protective Equipment see 7.3 (PPE) to minimise soil ingestion should have been employed when working in this area.

The effect on flora was not considered, as the site was and will be covered in hardstanding.

By current standards and with the history of oily contamination and demolition of old buildings, further tests for a suite of speciated petroleum hydrocarbons and polycyclic aromatic hydrocarbons, together with further SVOC/VOC and asbestos analysis, would normally have been applied to this site. Moreover, as the remediation history is not known some further analysis would be justified.

3.12.2 Groundwater

Limited groundwater testing indicated that meaningful analysis of the results was unlikely. However, one of the two samples of perched groundwater from BH01 contained 15.4mg/l of phenol, significantly greater than the UK drinking water standard (0.5µg/l) and environmental quality standard for fresh water (300µg/l).

One of the two samples of perched groundwater from TP2 contained 2.02mg/l of cyanide, significantly greater than the current UK drinking water standard (50µg/l).

Although there is a record of a sensitive groundwater use within 1km of the Site, it was not considered likely that the Site constituted a significant risk to the aquifer, or River Dearne (900m distant) and Sough Dyke (onsite nearby, but culverted and in good condition).

3.12.3 Surface Water

No data was available.

3.12.4 Building materials

Soluble sulphate levels of generally <1.2mg/l indicated an Aggressive Chemical for Concrete (ACEC) class of AC-1 to AC-3z (depending on pH) for site concrete.

No results were available for determinands such as TPH and PAH that can affect various pipework and coating materials with implications for the exact positioning of buried services at detailed design stage.

3.13 Preliminary Conceptual Site Model

3.13.1 Potential Environmental Issues

The land use history identified a number of past potentially contaminative uses, both on Site and adjacent to the Site.

Potentially Significant Contaminative Uses On Site:

- Foundries
- Gas Works
- Electrical Works
- Malthouses
- Lamp Works/ Lighting manufacturers
- Railway land
- Above ground storage tank (associated with railway land)
- Made ground associated with historic demolition activities
- Cattle Market

Potentially Significant Contaminative Uses Off Site:

- Foundries
- Timber yards
- Saw Mill
- Dry cleaners

In terms of the proposed development, the land use history and review of the historical site investigation data would indicate that the Site may have had the sources of contamination shown in Table VII.

Table VII also details the potential sources, pathways and receptors and the inter-relationship of these factors as a simplified conceptual model for the Site. It was acknowledged that although there are residential units proposed for the development, they will be above ground level with no gardens. Therefore, the model was geared towards a commercial end use. Proposed phases, where indicated, related to those shown on the Phasing Diagram in Section 6.0 of the December 2005 Design Report.

TABLE VII				
SOURCE	CONTAMINANT	PATHWAY	RECEPTOR (PRESENT)	RECEPTOR (FUTURE)
1. Above ground storage tanks, pipe-work and storage barrels (ASTs and IBCs).	Hydrocarbons[1,2],	1. Inhalation. 2. Dermal contact. 3. Ingestion. 4. Surface runoff. 5. Groundwater migration. 6. Direct contact (aggressive attack).	1. Current occupiers. *4. Groundwater.* 5. Surface water. 6. Plastic service pipes [volatile].	2. Future occupiers. 3. Construction workers. 4. Groundwater. 5. Surface water. 6. Plastic service pipes [volatile].
2. Historic gas works, (on site – mainly proposed Phases 2 and 3).	Hydrocarbons[1,2]. PAH. VOCs. Phenols. Metals. Cyanide. Asbestos. Acids/alkalis. Ammonia. Coal tars.	1. Inhalation. 2. Dermal contact. 3. Ingestion. 4. Surface runoff. 5. Groundwater migration. 6. Direct contact (aggressive attack).	1. Current occupiers. *4. Groundwater.* 5. Surface water. 6. Subsurface building materials [sulphate] and plastic service pipes [phenol].	2. Future occupiers. 3. Construction workers. 4. Groundwater. 5. Surface water. 6. Subsurface building materials [sulphate] and plastic service pipes [phenol].
3. Historic electrical works, (on site - proposed Phases 3 and 4).	Hydrocarbons[1,2]. Phenols. Solvents. PCBs. Metals. Coal. Asbestos.	1. Inhalation. 2. Dermal contact. 3. Ingestion. 4. Surface runoff. 5. Groundwater migration. 6. Direct contact (aggressive attack).	1. Current occupiers. *4. Groundwater.* 5. Surface water. 6. Subsurface building materials [sulphate] and plastic service pipes [phenol].	2. Future occupiers. 3. Construction workers. 4. Groundwater. 5. Surface water. 6. Subsurface building materials [sulphate] and plastic service pipes [phenol].
4. Historic foundries, (on/off site - proposed Phases1, 2, 3 and 4).	Hydrocarbons[1,2]. PAH. VOCs. Phenols. Metals. Inorganic/organic chemicals. Asbestos.	1. Inhalation. 2. Dermal contact. 3. Ingestion. 4. Surface runoff. 5. Groundwater migration. 6. Direct contact (aggressive attack).	1. Current occupiers. *4. Groundwater.* 5. Surface water. 6. Subsurface building materials [sulphate] and plastic service pipes [phenol].	2. Future occupiers. 3. Construction workers. 4. Groundwater. 5. Surface water. 6. Subsurface building materials [sulphate] and plastic service pipes [phenol].

TABLE VII

SOURCE	CONTAMINANT	PATHWAY	RECEPTOR (PRESENT)	RECEPTOR (FUTURE)
5. Historic Lamp works/ lighting manu-facturing (on site - proposed Phase 1A)	Hydrocarbons[1,2]. Solvents. Metals. Halogen Gases. Asbestos.	1. Inhalation. 2. Dermal contact. 3. Ingestion. 4. Surface runoff. 5. Groundwater migration. 6. Direct contact (aggressive attack).	1. Current occupiers. *4. Groundwater.* 5. Surface water. 6. Subsurface building materials [sulphate] and plastic service pipes [phenol].	2. Future occupiers. 3. Construction workers. 4. Groundwater. 5. Surface water. 6. Subsurface building materials [sulphate] and plastic service pipes [phenol].
6. Historic Malthouses (on site - proposed Phase 1A)	Fugitive gases (CH4, CO2) Hydrocarbons[1,2]. Metals. Sulphates.	1. Inhalation. 2. Dermal contact. 3. Ingestion. 4. Surface runoff. 5. Groundwater migration. 6. Direct contact (aggressive attack) 7. Gas migration.	1. Current occupiers. *4. Groundwater.* 5. Surface water. 6. Subsurface building materials [sulphate] and plastic service pipes [phenol].	2. Future occupiers. 3. Construction workers. 4. Groundwater. 5. Surface water. 6. Subsurface building materials [sulphate] and plastic service pipes [phenol].
7. Historic Railway (on/off site – mainly proposed Phases 1A and 3)	Hydrocarbons. Metals. Pesticides.	1. Inhalation. 2. Dermal contact. 3. Ingestion. 4. Surface runoff. 5. Groundwater migration. 6. Direct contact (aggressive attack).	1. Current occupiers. *4. Groundwater.* 5. Surface water. 6. Subsurface building materials [sulphate] and plastic service pipes [phenol].	2. Future occupiers. 3. Construction workers. 4. Groundwater. 5. Surface water. 6. Subsurface building materials [sulphate] and plastic service pipes [phenol].
8. Made ground present across the site (all proposed phases).	Heavy and phytotoxic metals. PAH. Asbestos. Hydrocarbons. PCBs. Phenols. Inorganic/organic chemicals.	1. (Disturbance and) Inhalation. 2. Dermal contact. 3. Ingestion. 4. Surface runoff. 5. Groundwater migration. 6. Direct contact (aggressive attack). 8. Volatilisation.	1. Current occupiers. *4. Groundwater.* 5. Surface water. 6. Subsurface building materials and service pipes.	2. Future occupiers. 3. Construction workers. 4. Groundwater. 5. Surface water. 6. Subsurface building materials and service pipes. 7. Flora and Fauna.

TABLE VII

SOURCE	CONTAMINANT	PATHWAY	RECEPTOR (PRESENT)	RECEPTOR (FUTURE)
9. Former Cattle Market (on site-proposed Phase 1)	Pathogens. Fugitive gases (CH_4, CO_2). Detergents	1. Inhalation 2. Dermal contact. 3. Ingestion. 4. Surface runoff. 5. Groundwater migration. 7. Gas migration.	1. Current occupiers. *4. Groundwater.* 5. Surface water.	2. Future occupiers. *3. Construction workers.* *4. Groundwater.* 5. Surface water.
10. Surrounding historical industry (agriculture, mills, garage). Dry cleaners.	Hydrocarbons. Solvents. Metals. Phenols. Coal tar. Creosote. Pesticides.	1. Inhalation. 2. Dermal contact. 3. Ingestion. 4. Surface runoff. 5. Groundwater migration. 6. Direct contact (aggressive attack).	1. Current occupiers. *4. Groundwater.* 5. Surface water. 6. Subsurface building materials [sulphate] and plastic service pipes [phenol].	2. Future occupiers. 3. Construction workers. 4. Groundwater. 5. Surface water. 6. Subsurface building materials [sulphate] and plastic service pipes [phenol].
11. Historic mining & landfill, local geology. (potentially all proposed phases)	Ground gases (e.g. CH_4, CO_2, radon)	1. Inhalation. 5. Groundwater migration. 7. Gas migration.	1. Current occupiers. *4. Groundwater.* 7. Flora and Fauna.	2. Future occupiers. 3. Construction workers. 4. Groundwater. 7. Flora and Fauna.

1 - Hydrocarbons associated with the industry identified on site typically include oil/fuel hydrocarbons, aromatic hydrocarbons, PAH, chlorinated aliphatic hydrocarbons.

2 - Hydrocarbons associated with diesel range organics typically include alkane carbon ranges from C8 through C21, with low concentrations of PAH and very low concentrations of BTEX compounds.

Whilst the main sources of contamination were likely to have been largely concealed, removed (e.g. by the construction of the underground basement) or redistributed within the Site, contamination could still remain, with possible implications for remediation. This was particularly so for the SE end of the Site (now the Zero Ice) and the CEAG site, where there was less evidence of basement excavations. However, in effect, the whole Site area is covered in buildings, concrete and other hardstanding with no obvious direct pollution linkage between potentially contaminated soils and human receptors. Apart from during construction stages, these types of cover will be maintained when the new development is completed.

3.14 Summary of Ground Conditions and Contamination Impacts

A summary of the potential environmental, geological and other risks identified for the Site prior to the 2007 and 2008 investigations is presented in Table VIII. Where indicated, these risks may need to be considered for the future development of the land.

Table VIII

Issue	Summary	Risk Category	
		Human	Property/ Environment
Contamination Potential:			
Present site use.	Shopping market, Carpet World (Zero Ice), car parking facilities, offices, CEAG.	Low	Low
Past site use.	Gas works, foundries, electrical works, malthouses, lamp works, cattle market, railway land.	Low to Mod.	Low to Mod.
Impact to site from past and present adjacent land uses.	Foundries, timber yards, saw mill.	Low to Mod.	Low to Mod.
Mining history.	Recorded historic deep underground mining; shallow mining & mine gas cannot be discounted. No recorded mine entries within the immediate vicinity.	Low	Low to Mod.
Emissions, pollution incidents, discharges etc.	One pollution incident, one substantiated pollution incident, fifty-four discharge consents and one IPC permission.	Low	Low
Radon gas.	Basic protection required for residential – subject to detailed design checks.	Low to Mod.	Low
Asbestos	Potential identified by Symonds. Full survey required pre demolition.	Mod.	Low to Mod.
Waste	One registered landfill site in the vicinity, but is listed as accepting inert and demolition waste only. In addition there is one waste transfer station.	Low	Low
Environmental Sensitivity:			
Geology.	Made ground overlying Middle Coal Measures	Low	Low

Table VIII

Issue	Summary	Risk Category	
		Human	Property/ Environment
Groundwater vulnerability.	This site is situated on a minor aquifer. The closest active groundwater abstraction licence is 900m west for a sensitive user.	Low to Mod.	Low.
Surface water vulnerability.	Sough Dyke beneath part of site. The nearest graded surface watercourse is the River Dearne 900m north east. The closest surface water abstraction licence is 1km north east.	Low	Low to Mod.
Geological constraints:			
Made ground	Variable thicknesses of made ground and buried structures, if proven, may have implications on foundation design for future development.	Low	Mod.
Superficials / solid geology	No superficials identified. Solid is Middle Coal Measures.	Low	Low
Mining setting	Shallow mine workings cannot be discounted and may have implications on building stability.	Low	Mod.
Risks relating to other constraints (miscellaneous):			
Services	The Sough Dyke is located within the site boundary and may have implications on future developments.	Low	Mod. To High
Liability Issues:			
Risk of liability with current use of site.	Shopping market, Carpet World (Zero Ice), car parking facilities, offices, CEAG.	Low	Low
Risk of liability for proposed use of site.	Redevelopment with continuation of commercial use (mixed retail, leisure and market buildings) plus above ground residential on the existing markets site and car park on the CEAG site.	Low	Low to Mod.
Overall Risk for Site	**Low to moderate**		

4. SITE INVESTIGATION SCOPE

4.1 Introduction

The Stage 2 investigation was designed to further characterise the contamination (in general accordance with BS10175:2001) and geotechnical conditions of the Site determined during Stage 1. Results are used to constrain the risk posed by the identified soil and groundwater contamination and potential shallow mine workings. The report includes a waste classification assessment of the main areas of proposed basement excavations and a geotechnical assessment of the Site to allow the preparation of detailed foundation design. The report will also facilitate the separate completion of an outline contamination remediation strategy including a detailed quantitative risk assessment.

The Stage 2 sampling strategy was designed considering the results and conclusions of the Stage 1 investigation and the preliminary conceptual site model thus allowing a targeted sampling approach to be undertaken.

4.2 Summary of Stage 1 (Pre-demolition) Site Investigation Scope

The Stage 1 site investigation included intrusive site works between 30 July and 24 August 2007 and incorporated fourteen cable percussion boreholes, two rotary open-hole, eight rotary core and eleven window sample boreholes. In total fifteen gas and groundwater monitoring standpipes were installed within boreholes across the Site.

Laboratory geotechnical and chemical testing of soil and rock samples were undertaken. Two rounds of groundwater monitoring samples and one round of upstream and downstream water samples from the Sough Dyke were analysed for chemicals of concern.

Six gas and water level monitoring rounds were completed over a period of approximately three months.

The Stage 1 Site Investigation scope can be found in further detail within the Wardell Armstrong Preliminary Stage 1 (Pre-demolition) Site Investigation Report (ref. SD07-0120) dated November 2007.

4.3 Stage 2 Site Investigation Scope

4.3.1 General

The investigation was designed as a series of tasks that are summarised below in Table IX.

TABLE IX – Summary of Tasks		
Task	**Summary**	**Date(s)**
Preparatory Work	Setting up site investigation contract, services enquiries, contractor health & safety documents and site meetings with the contractor, client and BMBC. Landowner / tenant liaison and management of site occupation.	21 January – 22 February 2008.
Intrusive site investigation	Cable percussion, rotary open-hole and rotary core boreholes (BH series) to nominal depths of 20 to 40m with in-situ pressuremeter and SPT testing where appropriate, window sample boreholes (WS series) to a nominal depth of 6m with in-situ SPT testing where appropriate and trial pit excavations (TP series). Installation of monitoring wells for groundwater and gas.	22 February – 11 April 2008.
Topographic surveying	Positions and levels of completed boreholes.	14 and 15 April 2008
Geochemical laboratory analysis	Chemical testing of soil and water samples in accredited laboratory.	29 February – 02 May 2008
Geotechnical laboratory testing	Geotechnical testing of soil and rock samples in accredited laboratory.	13 March – 22 April 2008
Monitoring	Gas and water level monitoring (ongoing).	26 February – 29 April 2008

The general scope of the investigation was approved in advance by Barnsley MBC and SYMAS and in consultation with the Client's Engineer.

The Stage 2 Site Investigation follows the Stage 1 investigation and is proposed to meet, in part, the Developers obligations under the terms of part 6 of the Development Agreement.

The following minor changes were made to the proposed scope of works during the site investigation:

- The locations and drilling techniques utilised for boreholes BH215, BH217, BH218 and BH220 were amended during the investigation to target the specific requirements for investigation of shallow mine workings.

4.3.2 Pre Site Works

The Site Investigation Contract was awarded to Soil Mechanics who sub-contracted part of the drilling works to Infosoil, Global Probing and Sampling and Wearside Drilling.

Soil Mechanics prepared a site specific Project Plan which included all relevant health and safety documentation. Barnsley MBC Health and Safety Unit duly approved the Project Plan and confirmed that Soil Mechanics and their appointed sub-contractors could operate on Barnsley MBC property. Site Investigation locations on Barnsley MBC owned and managed property were subject to prior approval by Barnsley MBC Estates Department and other various consulted departments. A licence was granted by Barnsley MBC Estates Department prior to works commencing.

Other contractors used as part of the investigation included ALcontrol Laboratories (geochemical analysis), William Gosney Limited (JCB and driver hire for trial pit excavations), Site Vision Surveys and Barrett Environmental (repair of surface water drain and disposal of developed groundwater).

4.3.3 Site Works

The investigation was completed in accordance with Construction (Design and Management) (CDM) Regulations 2007 and a site specific Health & Safety plan which included provisions for gas monitoring during drilling.

Full-time professional supervision and logging of soil samples was provided by Soil Mechanics for the duration of the site works. A Wardell Armstrong engineer was also present during site works.

Investigation locations were positioned as shown on Drawing No. SH03582/28. The positions and numbers of site investigation locations were restricted by existing buildings and services.

4.3.4 Utilities Survey

No adequate underground utilities drawings were available for the Markets Basements area prior to commencement of site works. Due to significant evidence of underground utilities across this area Site Vision Surveys were employed to survey the vicinity of each borehole position within the Markets Basement area and mark out services prior to commencement of drilling. The survey included lifting manhole covers to mark drainage routes and the use of electro magnetic and ground penetrating radar detection techniques to establish the position of the majority of buried services within the vicinity of borehole locations. The surveyors also marked out the Sough Dyke route on the CEAG area.

It was not possible to mark drainage routes in the south-east Markets basement in the vicinity of borehole BH207 as manholes within this area were flooded.

4.3.5 Inspection Pits and Concrete Coring

Hand dug inspection pits were completed at all borehole locations located outside of the Markets Basement prior to drilling commencement. Boreholes located within the Markets Basement were commenced using a concrete corer.

Inspection pits were excavated to a depth of 1.2m below ground level (bgl) where ground conditions allowed. Concrete coring was completed to the base of the concrete stratum where possible. Concrete cores were labelled and bagged for safe storage by the contractor pending any instructions from the client.

Inspection pits and concrete coring were abandoned and repositioned where excessive thicknesses of concrete or brick were encountered. The following inspection pits and concrete coring locations did not extend to 1.2m bgl or the full concrete thickness:

- WS249 – Concrete coring abandoned at 0.5m bgl due to excessive thickness of concrete. WS249 repositioned to WS250.

4.3.6 Cable Percussion Boreholes

Cable percussion drilling was conducted by Global Probing and Sampling. Pilcon 1 tonne and Dando cut down type rigs were utilised for all cable percussion drilling. Twelve cable percussion boreholes of 150mm diameter and one of 200mm diameter were drilled from the base of an inspection pit or concrete core. All cable percussion boreholes were advanced to rockhead with the exception of positions:

- BH212 – drilling terminated at 7.45m bgl due to encountering saturated gravels. It was deemed that arisings would have caused excessive nuisance in a sensitive location. Rotary open-hole drilling commenced from 7.45m bgl; and
- BH213B – drilling terminated at 2.01m bgl due to encountering a sandstone boulder.

The maximum depth achieved by cable percussion drilling was 7.62m bgl at borehole BH219. Logging, sampling and in situ testing was carried out in all boreholes and recorded on the logs. Detailed cable percussion borehole logs are included within the Soil Mechanics Factual Report attached at Appendix V.

4.3.7 Rotary Open-hole Boreholes

Rotary open-hole drilling was conducted by Soil Mechanics, Wearside Drilling and Infosoil. The drilling rigs used were either truck or track mounted. The rotary open-hole drilling rigs used PWF size (121mm outer diameter) drill bits with water

flush. Three rotary open-hole boreholes were drilled from the base of cable percussion boreholes or window sampling location (BH208, BH214, and BH216). Two rotary open-hole boreholes were drilled from the base of an inspection pit or concrete core (BH213 and BH213A).

Rotary open-hole drilling was also utilised at other borehole locations to advance the borehole to the required coring depth and to over drill pressuremeter test pockets. The maximum depth achieved by rotary open-hole drilling was 37.50m bgl at borehole BH216.

Open-hole logging was carried out by the contractor. Detailed rotary open-hole borehole logs are included within the Soil Mechanics Factual Report attached at Appendix V.

4.3.8 Rotary Core Boreholes

Rotary core drilling was conducted by Soil Mechanics, Wearside Drilling and Infosoil. The drilling rigs used were either truck or track mounted. The rotary core drilling rigs used a triple barrel system with SWF and PWF sized core bits (outer diameter of 146mm and 121mm respectively) using water flush with polymer additive to improve core recovery. This produced rock cores with nominal diameters of 112.5mm and 92mm respectively held in plastic inner linings.

Eight rotary core boreholes were drilled from the base of cable percussion, window sample or rotary open-hole boreholes (BH201, BH203, BH206, BH207, BH210, BH212, BH219 and BH220) and three were drilled from the base of concrete cores (BH202, BH205 and BH211).

Rotary core drilling was also utilised at three borehole locations BH215A, BH217 and BH218) to produce rock cores from specific strata of interest. Rotary open-hole drilling was utilised above and below the particular strata of interest. The maximum depth achieved by rotary core drilling was 39.75m bgl at borehole BH201.

Rock cores were boxed, labelled, photographed (after removing the linings) and logged on site. Detailed core logging was carried out by Soil Mechanics. Detailed rotary core borehole logs are included within the Soil Mechanics Factual Report attached at Appendix V.

4.3.9 Window Sample Boreholes

Fifty-nine window sample boreholes were drilled by Soil Mechanics and Global Probing and Sampling using Terrier 2002 and Competitor tracked drilling rigs, to a maximum depth of 6.0m bgl (WS239A). The window sample boreholes were logged and sampled on site for contamination testing off site. Detailed window

sample borehole logs are included within the Soil Mechanics Factual Report attached at Appendix V.

4.3.10 Ground Gas and Groundwater Monitoring Standpipes

Eight boreholes were installed with gas and groundwater monitoring standpipes by the Contractors.

A summary of the monitoring standpipes is included in Table X. Further details are given in the borehole logs included within the Soil Mechanics Factual Report attached at Appendix V.

Table X – Summary of Monitoring Standpipes

Target	Borehole	Response Zone
Groundwater and gas within the made ground.	BH207s, BH208s, BH213As and BH214s	0.5m bgl to a max. of 5.0m bgl.
Groundwater and gas within the made ground and shallow Coal Measures	BH211 and BH212	1m bgl to 5-6.5m bgl.
Deep groundwater within the Coal Measures.	BH202, BH207d, BH208d, BH210, BH213d and BH214d.	Ranging from 10-15m bgl to 15-20m bgl

Note: An additional monitoring standpipe was installed within borehole BH213. However the standpipe was decommissioned due to a potential minor hydraulic oil spillage from a drilling rig.

The standpipes were completed with 50mm or 19mm internal diameter well screen and casing with bottom end caps. The screen sections were constructed with slotted HDPE pipe wrapped with a plastic filter mesh (<120 microns). A filter pack of 4-6 mm washed gravel was placed in each well annulus to just above the screened section. Thereafter the annulus was sealed to the surface with bentonite. Boreholes BH207, BH208, BH213A and BH214 were installed with both shallow and deep monitoring standpipes. The shallow and deep standpipes were hydraulically sealed with bentonite to prevent direct hydraulic conductivity between shallow and deep groundwater within the borehole. Shallow and deep monitoring standpipes are identified with the suffix s or d respectively. Installations were completed with concreted headworks to protect the inner casing and gas valves. All installations were supervised by a Wardell Armstrong engineer on a part-time basis.

After installation, all water-monitoring wells were developed until the pH, temperature and electrical conductivity of the purged water had stabilised (i.e. until any two successive reading were within 10% of each other), the water in the wells was visibly clean or until five well volumes of water had been removed.

Newly installed monitoring boreholes were left for a minimum of 5 days to allow gas levels to equilibrate. Data for methane, carbon dioxide, oxygen and flow rate were collected using a portable infrared gas analyser. Atmospheric pressure and water levels were also recorded at the time of monitoring. Soil gases were analysed and assessed following guidance from CIRIA C659, *Assessing Risks Posed by Hazardous Ground Gases to Buildings*, 2007.

4.3.11 Trial Pit Excavations

Trial pit excavations were conducted by William Gosney Limited and supervised on a full time basis by a Wardell Armstrong Engineer. The trial pit excavations were logged on site and sampled for contamination and geotechnical testing off site. Detailed trial pit excavation logs are attached at Appendix VI.

4.3.12 Sampling and Testing

4.3.12.1 In-situ Standard Penetration Testing

In-situ SPT testing was conducted in all cable percussion and some window sample boreholes in accordance with BS1377-9:1990. SPT testing within window sample boreholes was targeted to areas where cable percussion drilling was not carried out.

4.3.12.2 In-situ Pressuremeter Testing

In-situ pressuremeter testing using a high pressure dilatometer was carried out in seven of the rotary core boreholes. Pressuremeter testing was conducted to determine modulus values and hence the feasibility of pad foundations within areas of the site following the results of Stage 1.

Test pockets were drilled using a double barrel system with TNW sized core bit. This produced rock cores with a nominal diameter of 65mm which was removed directly from the core bit.

Further details and results of the pressuremeter testing are included within the Stage 2 Soil Mechanics Factual Report attached at Appendix V.

4.3.12.3 In-situ Permeability Testing

Rising and falling head tests were conducted in boreholes beneath the markets basement (BH207s, BH207d, BH208s and BH208d) and southern CEAG areas (BH213As, BH213Ad, BH214s and BH214d) to aid subsequent detailed risk assessment of contamination in these areas. Tests were conducted in

accordance with BS5930:1999 and BSI ISO14686:2006 using data logging equipment for groundwater level measurements.

Variable head test results are included within Appendix VII.

4.3.12.4 Sampling and Chemical Analysis of Soil

Two hundred and three disturbed samples of material from beneath the Site were collected for geochemical laboratory analysis. Samples were taken at regular depths, changes in strata and any discrete horizons with a high potential to retain contaminants and logged in general accordance with BS14688:2002. Samples were obtained using a fresh pair of nitrile gloves.

Samples scheduled for analysis of organic contaminants were placed in amber bottles with a minimum of headspace. The bottles were immediately sealed with polytetrafluoroethylene (PTFE) lined caps and labelled. The remaining small disturbed samples were placed in polypropylene tubs with a minimum of headspace, sealed with airtight polypropylene 'snap-on' lids and labelled. The labels detailed individual sample number, location, depth and sampler identity.

Collected samples were stored away from sunlight in temperature controlled conditions and transported by courier to ALcontrol Laboratories. Chain of custody forms were completed for all samples sent to the laboratory. The forms detailed individual bottle identification number and sample location. The forms were signed on release by the Wardell Armstrong field engineer and upon receipt by the laboratory.

The laboratory analyses scheduled were selected to establish the type, level and distribution of the possible harmful contaminants that may be present on the Site given its past and current uses. In order to provide cost effective analysis, solid samples were analysed for a number of determinands depending on depth, matrix and a visual assessment of ground conditions. Samples collected from potential zones of future excavation and remediation were also scheduled for the purposes of waste classification.

The analysis scheduled is presented in Table XI.

TABLE XI – Summary of Sample Geochemical Analysis		
Substance	**No. Soil Samples**	**No. Groundwater Samples**
A standard suite of industrial pollutants including common metals (arsenic, water-soluble boron, cadmium, chromium, chromium^{VI}, copper, lead, mercury, nickel, selenium, and zinc), pH, speciated Polycyclic Aromatic Hydrocarbons (PAH), sulphate, sulphide, sulphur, thiocyanate, total cyanide and phenols.	57	12
A waste classification suite including metals, petroleum hydrocarbons, BTEX, MTBE, PAH, Sulphate and TOC.	38	-
Petroleum hydrocarbons (C_5 – C_{40} with aliphatic/aromatic class separation and carbon banding), BTEX and MTBE.	51	13
Volatile Organic Compounds (VOCs).	23	8
Semi-Volatile Organic Compounds (SVOCs).	27	8
Poly-chlorinated Biphenyls (PCBs).	11	-
Total Organic Carbon (TOC).	30	-
Asbestos.	21	-
Soluble Sulphate.	16	-
Waste Acceptance Criteria – hazardous suite.	19	-
Waste Acceptance Criteria – Inert Suite.	15	-

The results of the chemical analyses are attached at Appendices VIII and IX which also include those from Stage 1.

4.3.12.5 Sampling and Chemical Analysis of Groundwater

Fourteen groundwater samples were collected for laboratory analysis from groundwater monitoring installations using procedures that ensured the collection and preservation of anaerobic sample quality.

Prior to sampling, each well was purged until three well volumes of water had been removed.

All water samples were taken using disposable bailers, to avoid cross-contamination, with a bottom pour tap, to minimise the loss of more volatile components. Samples were placed in laboratory prepared amber bottles and vials with a minimum of headspace. The bottles were immediately sealed with polytetrafluoroethylene (PTFE) lined caps and labelled. The labels detailed individual sample number, location, depth and sampler identity. The analysis scheduled is presented in Table XI.

The results of the chemical analyses are attached at Appendix IX, which also include those from Stage 1.

4.3.12.6 Sampling and Chemical Analysis of Sough Dyke

Water samples were collected during the Stage 2 investigations from upstream and downstream locations (relative to the Site) of the Sough Dyke. Two samples were collected for laboratory analysis and precautions were taken to ensure the collection and preservation of anaerobic sample quality from within the culvert.

The upstream sampling location was situated on the northern extent of May Day Green, at the junction with Kendray Street. The Sough Dyke was accessed from a manhole (manhole referenced as MHS31 in JBA, Critical Ordinary Watercourses – Culvert Inspections, November 2005) situated approximately 3.6m above the Dyke.

The downstream sampling location was situated approximately 280m south east of the Site adjacent to Langdale Road. The Sough Dyke was accessed from a manhole (manhole referenced as MHS16 in JBA, Critical Ordinary Watercourses – Culvert Inspections, November 2005) situated approximately 7.8m above the Dyke.

The intention was to have a third sampling point within the site boundary but ready access was not available.

The results of the chemical analyses are attached at Appendix X, which also include those from Stage 1.

4.3.12.7 Sampling and Geotechnical Analysis of Soil and Rock

Forty-three bulk, ninety small disturbed and six U100 samples of made ground and natural soil strata were collected for geotechnical laboratory testing. Two hundred and seventy-one rock samples were sub-sampled from the recovered rock cores for geotechnical laboratory testing.

Laboratory geotechnical testing was carried out by Soil Mechanics. The laboratory analyses scheduled were selected to establish the character and structure of each stratum present on Site. The geotechnical tests scheduled are summarised below in Table XII.

TABLE XII – Summary of Sample Geotechnical Testing		
Test	**No. Soil Samples**	**No. Rock Samples**
Particle Size Distribution (PSD).	13	
Index Testing (including moisture content, liquid limit, density, plastic limit & plasticity index).	16	2
California Bearing Ratio.	2	
Undrained (Total Stress) Triaxial.	4	
Uniaxial Compressive Strength.		41
Point Load Index.		230

Results of the geotechnical laboratory testing are included within the Stage 2 Soil Mechanics Factual Report attached at Appendix V.

4.3.13 Quality Assurance and Quality Control

The soil and groundwater samples for geochemical analysis were collected, transferred to the laboratory under chain of custody and analysed to ensure traceability and reliability of analytical results. Based on the laboratory QA data and duplicate samples (2 No. collected from soil samples at depths 0.5 to 1.5m and 2.0 to 3.0m in WS259 and WS264 respectively, both referenced as 10m depth), the analytical results are considered acceptable for interpretative use.

4.4 Limitations of Site Investigation

It should be noted that the interpretation of the results of the physical site investigation is based on a limited number of investigation points. The locations and numbers of the investigation locations were governed by the physical state of the Site and the location of known services at the time of the investigation. Although reasonable inferences have been made during the interpretation, it is possible that variances in the thickness, distribution and physical/chemical characteristics of the strata present will exist.

5. SITE INVESTIGATION RESULTS

5.1 Ground Conditions

The sequence of strata encountered beneath the Site generally comprised:

- Hardstanding;
- Made Ground;
- Glacial Till Deposits;
- Weathered strata of the Middle Coal Measures;
- Middle Coal Measures of interbedded mudstone, siltstone with some sandstones associated with the Winter (Abdy), Top Beamshaw and Low Beamshaw coal seams; and
- Kent's Rock (thick sandstone) and Kent's Thin coal seam.

Indicative cross sections through the Site are shown on Drawing SH03582/22D. Section lines and borehole locations (including historic boreholes) are shown on Drawing SH03582/23C. Observations and results from the Stage 1 (Pre-demolition) Site Investigation have been included within this section of the report.

5.1.1 Made Ground

Concrete, tarmacadam and block paving covered the majority of the Site. Concrete extended to significant thicknesses in the Markets Basement area where it ranged in thickness from 0.23m at WS255 to 2.2m (BH211). Concrete was cored to a depth of 0.5m at WS249 and WS105 before these locations were abandoned. The total thickness of concrete at these window sample locations was unproven as the concrete corer was unable to extend beyond this depth.

Beneath the hard standing made ground generally comprising gravel, sand and clay with brick, mudstone, sandstone, concrete and some coal, ash and clinker was observed in the majority of boreholes across the Site. Made ground was generally recorded in boreholes across the Site to between 2m and 3m depth. However, made ground was not recorded in several boreholes in the western section of the Markets Basement. The maximum recorded thickness of made ground was 6m at location BH239A. However, the thickness of made ground at this and a few other locations was unproven.

Made ground observed beneath the Markets Basement and in the vicinity of BH207 was particularly heterogeneous and comprised constituents varying from units of gravel to clay. Of note was a viscous tar encountered from 3.6m bgl to the base of WS105A at 4.3m bgl. The tar material was also recorded within clay in borehole BH207.

Made ground encountered within trial pits in the southern CEAG area generally comprised a thin unit of sandy gravel of ash, concrete, sandstone and clinker

underlain by sandy gravelly clay with sandstone cobbles and boulders. The underlying sandy gravelly clay appeared to be reworked natural material.

Underground structures or obstructions were encountered at various locations across the Site during the Stage 1 and 2 Site Investigations. Of particular note were the concrete, brick and slag structures or obstructions encountered in the Zero Ice, May Day Green retail, Cheapside retail, Open Market and Markets Basement (centred around BH207) areas. Several cable percussion and window sample boreholes refused within the made ground at varying depths across these areas.

Inspection pits completed to approximately 1.2m bgl in the May Day Green, Open Market and Zero Ice areas required the use of a concrete breaker to advance them.

Inferred made ground thickness is shown on Drawing SH03582/33.

5.1.2 Natural Strata

Concrete hardstanding in the western section of the Markets Basement and northern end of the CEAG building basement was immediately underlain by natural strata. Natural material was present beneath made ground in boreholes across the rest of the Site.

Near surface natural materials recovered by cable percussion drilling and window sample boreholes comprised relatively minor clay deposits and widespread, variably weathered Coal Measures.

Although not identified on geological maps material considered to be characteristic of glacial till deposits was present within areas of the Site and was particularly prevalent in the north of the Site. The deposits generally comprised firm to stiff sandy gravelly clay and units of sandy gravels, both with some coal fragments. The gravel fraction typically consisted of mudstone and sandstone.

Occasional plant remains were recorded within clay strata situated at borehole BH118.

Weathered Coal Measures strata were identified above rockhead and generally comprised stiff gravelly clay, with the gravel fraction comprising of mudstone, and weak thinly laminated mudstone. Variably weathered coal bearing strata were also recovered.

Cable percussion and window sample boreholes were advanced to bedrock where possible, which was recorded at between 0.3m (BH203) and 8.6m (BH118) bgl. Bedrock generally consisted of weak to moderately strong, grey mudstone interbedded with siltstone and sandstone. The Kent's Rock sandstone was encountered at locations BH108, BH112, BH202, BH203, BH205, BH206, BH207, BH210, BH211, BH212, BH216 and BH219 at depths of between 15.75m bgl

(BH205) and 35.5m bgl (BH216). The apparent thickness of Kent's Rock was proven at locations BH112, BH203, BH205, BH110 and BH112 and ranged from 6.11m (BH205) to 12.85m (BH203).

Three coal seams interpreted as the Winter/Abdy, Top Beamshaw and Low Beamshaw Coals were penetrated in strata above the Kent's Rock during the investigation. The coals ranged in thickness from 0.25m (Top Beamshaw, BH219) to 1.23m split over two leaves of coal (Top Beamshaw, BH201). Thin, unnamed coal bearing strata were also encountered above the Kent's Rock, however, these are not considered to be of significance. The Kent's Thin Coal was encountered, beneath the sandstone at all borehole locations where Kent's Rock was fully penetrated.

Further details regarding coal seams can be found in section 10.2.

Inferred rockhead level contours (mAOD) are shown on Drawing SH03582/34.

5.2 Groundwater

Groundwater was encountered in the majority of boreholes during the intrusive investigation. Details of groundwater strikes and behaviour are included within the borehole logs (Appendix V).

Groundwater sampling of the Stage 1 boreholes was conducted on 03 September 2007. An additional round of groundwater sampling was conducted on 06 November 2007 to target Stage 1 boreholes that had displayed potentially significant contamination or boreholes where insufficient sample was obtained during the first monitoring round. Stage 2 boreholes and Stage 1 boreholes that previously displayed elevated contaminant concentrations were sampled between 03 April and 09 April 2008.

During development and purging of the monitoring installations, the water was initially cloudy but became increasingly clear with the increasing volume removed. Due to the limited volume of groundwater within borehole WS105A only 50ml of liquid was collected.

Boreholes WS105A and WS119 were not purged before sampling due to the limited volume of groundwater within the wells and slow recharge rates.

A significant hydrocarbon odour was noted on groundwater recovered from WS105A and BH207s (Markets Basement). An oily sheen was also observed on groundwater recovered from borehole BH214d (CEAG site).

Water levels were measured on 29 August, 14 September, 21 September, 29 October, 13 November and 19 November 2007 and on 26 February, 10 April, 17 April and 29 April 2008 using a product/water interface probe. No free phase product was detected in any of the boreholes. Recent groundwater elevations measured relative to ordnance datum are shown in Table XIII. Inferred

groundwater contours are shown on Drawing SH03582/29. It should be noted, however, that the contours are simplified and cannot display the likely irregular changes in local hydraulic gradient induced by buried structures, though the arc expression on the drawing could be indicative of a basement barrier effect.

Table XIII – Groundwater Levels (m AOD)

Borehole ref.	Cover level (m AOD)	26/02/08	10/04/08	17/04/08	29/04/08
BH101	94.17	91.03	91.03		
BH102A	94.99	88.62	89.00		
BH104	95.29	89.83	89.43	89.53	89.47
WS105A	91.20	88.83	88.44		
BH106A	96.15	89.74	89.59		
WS107	91.89	90.01	89.94		
BH108	91.14	88.24	87.38	87.24	87.24
WS110	91.21	87.82	87.96	87.88	87.85
BH112	96.19	90.23		92.49	91.35
BH115	89.63	87.45	87.42	87.34	
BH116	89.78	86.64	86.69		
BH117	91.81	87.51	87.42		
BH118	92.11	86.68	86.73	86.69	86.72
WS119	90.52	88.82	88.83		
WS124	91.34	90.48	90.74		90.79
BH202	91.89		84.50	84.50	84.39
BH207s	91.19		87.40	87.54	87.90
BH207d	91.19		83.55	83.35	83.37
BH208s	91.2		88.23	88.20	88.21
BH208d	91.2		87.69	87.61	87.58
BH210	91.22		87.01	87.15	87.07
BH211	91.36		89.66	89.66	89.65
BH212	94.62		89.45	89.45	89.44

Table XIII – Groundwater Level (m AOD)					
Borehole ref.	**Cover level (m AOD)**	**26/02/08**	**10/02/08**	**17/04/08**	**29/04/08**
BH213s	90.47		87.89	88.35	88.40
BH213d	90.47		87.30	87.25	87.22
BH214s	90.13		88.39	88.29	88.33
BH214d	90.13		88.39	88.29	88.33

Full groundwater monitoring results are included within Appendix XI.

Stage 2 boreholes BH207, BH208, BH213 and BH214 were installed with both shallow(s) and deep(d) monitoring standpipes. Borehole BH210 was installed with a deep monitoring standpipe and was located adjacent to WS110 which was installed with a shallow monitoring standpipe. These boreholes provide direct measurements of shallow and deeper groundwater within the made ground and underlying coal measures.

Notable differences in groundwater levels were recorded between shallow and deep installations within boreholes to the west of the railway. It is considered that the groundwater within the made ground and Coal Measures are more likely to represent separate aquifers across this area.

Groundwater levels in boreholes east of the railway suggest that groundwater within made ground and Coal Measures are in hydraulic continuity and are likely to represent a single aquifer.

Selected results from the groundwater monitoring of the deeper installations suggests an inferred groundwater flow towards the north-east with an approximate hydraulic gradient of 1 in 42.

Rising and falling head tests indicate that shallow made ground beneath the Markets Basement and southern CEAG site has a hydraulic conductivity of approximately 0.0092 and 0.0010m/day respectively. Deeper mudstone strata beneath the Markets Basement and southern CEAG site have a hydraulic conductivity of approximately 0.0102 and 0.0060m/day respectively.

Rising and falling head test results are included in Appendix VII.

5.3 Ground Gas

There are several regulatory authorities that require the assessment of ground gas on potentially contaminated sites. The main stakeholders are Building Control, Local Authority Planning and Environmental Health (Contaminated Land Officers). CIRIA have published guidance (C659, 2006) on risk assessment for new buildings and existing structures on ground with potentially hazardous gassing regimes. This guidance indicates that a semi-quantitative risk assessment for ground gas can be completed using Gas Screening Values (GSV) and consideration of the conceptual site model. The GSV and conceptual site model can be used to attribute the site a Characteristic Situation, which in turn indicates the appropriate gas protection requirements to be employed.

Ten gas monitoring rounds were completed during Stages 1 and 2 over approximately an eight month period. All sets of readings were recorded at relatively low atmospheric pressures.

Gas monitoring results are attached at Appendix XI.

5.4 Observations of Contamination

Frequent observations of minor contamination including ash and clinker were recorded within made ground across the Site. More significant observations were recorded in four main areas and can be summarised as follows:

- May Day Green – hydrocarbon odour noted within made ground strata bearing ash, clinker and tar;
- Zero Ice – widespread recordings of slag present within made ground;
- Markets Basement – hydrocarbon odour, sewage odour, tar, clinker and slag recorded within made ground strata. Tar residue and hydrocarbon odour recorded within fissures of some natural mudstone strata; and
- Southern CEAG site – ash and clinker recorded within made ground strata in numerous boreholes and trial pits.

Detailed observations of soil contamination noted during the site investigation are presented on the borehole logs (Appendix V).

5.5 General Site Observations

The following observations were made during site works:

- Poor environmental management practices within the Network Rail compound located on the southern area of the CEAG site. Containers with oily residue were left in a pile within the compound. Ground beneath and around the containers displayed hydrocarbon staining;
- Anecdotal evidence of an infilled “shaft” beneath the Zero Ice car park (comment by member of public to contractor); and
- Isolated cases of services positions not as shown on the supplied drawings.

6. GUIDANCE ON CONTAMINATION RISK ASSESSMENT

The following section aims to assess the potential risk to human health, surface water, groundwater, ecosystems and buildings from contaminated soil and groundwater. The assessment provides information that is fit for purpose given the regulatory context and completed in accordance with UK best practice. A summary of the risk assessment process is presented below. More detailed information on risk assessments is contained in various reports published by the Environment Agency and DEFRA including:

- Contaminated Land Reports 7 to 10 (CLR 7 to 10), and
- Model Procedures for the Management of Land Contamination (CLR 11).

6.1 General Soil Contamination Guidance

The Environment Agency (EA) has duties and powers to ensure the protection of groundwater and the remediation of contaminated land and groundwater. In order to achieve this, the EA employs the principle of risk assessment - the risk of a contaminant source causing harm or pollution via a given pathway to an identified receptor. If one of the source-pathway-receptor linkages is not considered to be present then there is no risk. However, if a contaminant source is present and there is a pathway for that contaminant to reach a receptor then there is a risk of harm to the receptor. Therefore, if the source-pathway-receptor linkages are complete, there is a requirement to undertake a risk assessment related to the receptor of concern, be it human health, surface water, groundwater, buildings or other property or ecological issues.

The first stage in the assessment of a site is development of a conceptual model. This is a consideration of all possible sources of contamination on the site, the potential receptors and whether there is a plausible pathway between the two. This allows evaluation of whether further risk assessment for an identified receptor is necessary. The preliminary conceptual model developed for this site has already been discussed in Section 3.

Once plausible receptors have been identified a number of risk assessment models are available including:

Contaminated Land Exposure Assessment (CLEA) - Human Health;

Remedial Targets Methodology - Hydrolological Risk Assessment for Land Contamination;

- ASTM Risk Based Corrective Action (RBCA) - Human Health, Surface Water, Groundwater.

In March 2002 the Environment Agency and the Department of Environment, Food and Rural Affairs (DEFRA) released a package of guidance to assess the health risks posed by contaminated land as part of the statutory framework for

contaminated land. The Contaminated Land Exposure Assessment (CLEA) model is a framework for estimating the likely exposure to contaminants in soil as part of the wider approach of the UK's assessment of risk and suitability for use. The methodology adopted for CLEA builds upon the source-pathway-receptor model for the assessment of risk. Following the CLEA model, generic Soil Guideline Values (SGVs) have been developed to act as triggers for intervention in a number of end-use scenarios. The Environment Agency has commenced a programme looking at 55 contaminants, but so far SGVs have only been derived for seven inorganic and three organic contaminants.

The CLEA SGVs are derived using specific parameters, which may not be relevant to each site. The CLEA software allows parameters to be changed and site specific SGVs can be developed. The CLEA methodology also uses a statistical evaluation of all the data collected in order to give an overall impression of the site rather then using individual contaminant values, which may vary dramatically across the site. The statistical tests calculate a normalised upper bound value for the site as a whole and also give an idea of whether a particular value is a statistical outlier (hotspot) or whether it is part of the whole population of samples.

The Soil Guideline Values derived from the CLEA model are intended for use in assessing the risk to long term human users of the site. There is also a requirement to consider the potential for harm from short-term exposure to contaminants at the site, e.g. to construction workers who may be exposed to risk via inhalation of dust or dermal contact with the contaminated material.

Where CLEA guidelines do not encompass contaminants of concern many practitioners rely upon published international screening values such as: the Generic Assessment Criteria (GAC) published by the Chartered Institute for Environmental Health and Land Quality Management; the corrected Dutch Intervention Values (cDIV); United States Environment Protection Agency Preliminary Remediation Goals (USEPA PRG); and the Ecological Soil Screening Levels (Eco-SSL) published by the USEPA. These values have no legal standing in the UK but, in the absence of more appropriate guidelines, they may give an indication of significance.

6.2 General Water Contamination Guidance

Concentrations of contaminants detected in groundwater and leaching tests have been compared to the UK Drinking Water Standards (UKDWS) encompassing the Water Supply (Water Quality) Regulations 1989 and Water Supply (Water Quality) Regulations 2000 where drinking water is the receptor. Where surface water is the receptor the Environment Agency Environmental Quality Standards (EQS) have also been used.

Where the UKDWS and EQS do not encompass contaminants of concern to human health, reference is made to other appropriate guidance. This includes the European Union Council Directives 98/83/EC and 75/440/EEC on the quality of water intended for human consumption and the quality required of surface water intended for the abstraction of drinking water respectively. Additional screening values are derived from the World Health Organisation (WHO) Guidelines for Drinking-water Quality (1984) and the Dutch Target and Intervention Values for Soil Remediation.

7. GENERIC QUANTITATIVE RISK ASSESSMENT

7.1 Soil Contamination Results

Soil samples taken from the site have been tested for potential chemicals of concern appropriate to the former land uses. As the proposed redevelopment is for mixed commercial land use with some overlying residential apartments on the west side of the railway and a new multi-storey car park on the east side, the most appropriate end use for assessment is that of 'commercial/industrial' or equivalent. Results from the chemical testing have been evaluated with reference to each of the plausible receptors identified in the conceptual model. The results are evaluated differently for each receptor.

This section includes a review of all soil analysis results from both Stage 1 and Stage 2 investigations completed by Wardell Armstrong.

Laboratory analysis of representative samples collected from both made ground and natural strata across the site indicate variable abundances of organic matter. The range of soil organic matter (SOM) in the made ground was typically between 0.3% and 10% with several elevated samples up to 27.6%. The abundance of SOM in the natural ground typically ranged from 0.7% to 16%. Samples with elevated SOM values (>30% SOM) in areas of contamination or coal seams have been discounted and not used to characterise the SOM within made ground or natural strata.

The geometric mean for made ground and natural strata were calculated as 3% and 1.85% respectively. In order to be conservative and to simplify this GQRA, it is considered appropriate to use SGVs and GACs for a soil organic matter content of 1.0% for both made ground and natural strata.

7.2 Human Health - Occupiers

As the receptor is human health, the most relevant risk assessment model is the CLEA model. The model estimates child and adult exposures to soil contaminants for those potentially living, working and/or playing on contaminated sites over long time periods and has been used to produce SGV for the United Kingdom. Where SGV are not available, screening criteria from EU and the USA have been adopted as described in Section 6.

The principal pathways of concern for human health are dermal contact, ingestion, and inhalation.

7.2.1 Current Site Levels

Generally, in the assessment of risk to site users with the current site layout, only samples taken in the top 1m are considered as contact with deeper samples is unlikely.

7.2.2 Proposed Site Levels

In several areas of the Site, notably excavation areas A, B and C (Drawing SH03582/24A), it is proposed that the existing ground levels are to be reduced by up to 5m. In these areas, contact with deeper material is considered plausible and samples from below the proposed excavation level have been considered.

7.2.3 Metals, Semi-metals and Non-metals

Statistical analysis for arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc in the shallow made ground was carried out to identify the 95% confidence limits of the measured mean and to compare the upper 95th percentile with the respective adopted screening criteria using the mean value test, as outlined in the Environment Agency's R&D Publication CLR7.

7.2.3.1 Current Site Levels

When considering the results for all samples within the top 1m bgl the upper bound values (US_{95}) for arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc were below their respective screening criteria. Therefore, it may be considered that the concentrations of these substances do not present a significant possibility of significant harm to long-term human health in context of Part IIA of the Environmental Protection Act 1990.

One sample from beneath the Markets Basement (WS238-0.5m) recorded an elevated lead concentration of 990mg/kg compared to the SGV of 750mg/kg. As this sample was collected from beneath 0.5m of concrete and numerous samples in the vicinity contained significantly lower concentrations, it may be considered that the concentration of lead in this area does not present a significant possibility of significant harm to long-term human health.

7.2.3.2 Proposed Site Levels

The maximum concentrations of arsenic, cadmium, chromium, copper, mercury, nickel, selenium and zinc in samples from greater than 1m bgl are all less than their respective SGVs.

The majority of recorded lead concentrations from samples greater than 1m bgl were below the SGV of 750mg/kg. One sample from beneath the Markets Basement (WS243A-4.5m) recorded an elevated lead concentration of 1,100mg/kg. This sample is well below the proposed ground level and samples in the vicinity contained significantly lower concentrations. Therefore, this lead concentration should not present a significant possibility of significant harm to long-term human health.

A duplicate sample from beneath the central CEAG area (WS120-3.5m) was collected for quality assurance purposes. The primary sample recorded a lead concentration of 210mg/kg, well below the SGV. However, the duplicate sample

(WS120-20m) recorded a lead concentration of 900mg/kg in excess of the SGV. This significant variation in concentrations is likely to be due to sub-sampling of the soil matrix. Considering that the samples were collected from 3.5m bgl and that the average concentration in the two samples is below the SGV, lead is not considered to pose a significant risk to human health in this area.

CLR7 statistical analysis of the laboratory results from the top 1m is attached at Appendix XII.

7.2.4 Total Petroleum Hydrocarbons (TPH)

The site investigation identified visual and olfactory evidence for hydrocarbon contamination at several locations. Analytical results also indicated elevated concentrations of TPH, in particular medium to long chain-length hydrocarbons (C12-35), within made ground. However, in most cases the maximum recorded concentrations of petroleum hydrocarbons are all less than relevant GAC. The exceptions to this are samples from the Markets Basement Hotspot which are discussed in greater detail below.

7.2.4.1 Markets Basement Hotspot

A sample from beneath the Markets Basement (WS105A-3.8m) was recovered as a black viscous tar. This sample recorded concentrations of medium to long chain-length aromatic petroleum hydrocarbons (C16-21 and C21-35) of 16,000mg/kg and 29,000mg/kg respectively. These concentrations exceeded the GAC of 9,190mg/kg and 9,250mg/kg respectively. This contamination hotspot was recorded from 3.6m bgl to refusal at the base of the window sample borehole at 4.3m bgl. An additional sample from adjacent borehole BH207-3.7m recorded concentrations of medium to long chain-length aromatic petroleum hydrocarbons (C16-21 and C21-35) of 10,000mg/kg and 18,000mg/kg respectively which are also in excess of GAC. In addition, an oily residue was noted within fissured mudstone to approximately 7m bgl at borehole BH207 and in other boreholes within the vicinity.

It is considered unlikely that TPH poses a significant risk to long term human health via dermal contact and/or ingestion of soil pathways due to the depth contamination being 3.6m bgl or greater and concrete hard standing overlying the made ground. However, more volatile TPH fractions may pose a risk and are considered separately as volatile organic compounds in Section 7.2.6.

A list of the petroleum hydrocarbon concentrations in soil from the Markets Basement Hotspot which exceed the adopted human health screening criteria are listed in Table XIV.

Table XIV – Petroleum Hydrocarbon Soil Exceedances				
Substance	**Location**	**Impacted Strata**	**Recorded Concentration (mg/kg)**	**Adopted Screening Criteria (mg/kg)**
aromatic petroleum hydrocarbons C16-21	WS105A 3.8m	Made Ground	16,000	9,190*
	BH207 3.7m	Made Ground	10,000	9,190*
aromatic petroleum hydrocarbons C21-35	WS105A 3.8m	Made Ground	29,000	9,250*
	BH207 3.7m	Made Ground	18,000	9,250*

* Chartered Institute for Environmental Health Generic Assessment Criteria

7.2.5 Polycyclic Aromatic Hydrocarbons (PAH) and Semi-Volatile Organic Compounds (SVOCs)

Thirty eight samples contained elevated total PAH concentrations above the corrected Dutch Intervention Value (cDIV) of 40mg/kg and these values ranged from 42mg/kg (BH117-0.5m) to 35,000mg/kg (BH207-3.7m). The recorded concentrations of PAH may present a significant possibility of significant harm to long-term human health.

Consideration of speciated PAH and SVOC results allows a more detailed assessment of the risk from these compounds. Results indicate elevated concentrations of benzo(a)pyrene, naphthalene, dibenzo(ah)anthracene and carbazole which exceed the adopted screening criteria. As benzo(a)pyrene is considered to be the most carcinogenic compound it has been used as a proxy to assess the degree of risk posed by PAH on site.

Elevated benzo(a)pyrene concentrations were recorded at various locations at the Site with a maximum concentration of 1,000mg/kg in BH207-3.7m. These concentrations are above the GAC of 29.7mg/kg and may pose a significant risk to human health, particularly in the three hot spots described below.

A list of the PAH and SVOC concentrations in soil exceeding the adopted screening criteria are listed in Table XV.

7.2.5.1 May Day Green Hotspot

Two samples from May Day Green; WS113-0.4m and WS258-0.6m recorded elevated concentrations of benzo(a)pyrene of 45mg/kg and 91mg/kg respectively. Therefore, these concentrations may present a significant possibility of significant harm to long-term human health.

Sample WS113-0.4m recorded ash, coal and tarmacadam within shallow made ground. This material was also prevalent in made ground found at other site investigation locations beneath the May Day Green area and may represent historic road surfacing.

All contaminated made ground within the May Day Green area is designated for disposal off-site as part of proposed basement excavations. Therefore, the recorded benzo(a)pyrene concentrations within the May Day Green area are not considered to present a significant risk to long-term human health.

7.2.5.2 Markets Basement Hotspot

Two significantly elevated benzo(a)pyrene concentrations were recorded in samples WS105A-3.8m and BH207-3.7m at 950mg/kg and 1,000mg/kg respectively. There is currently no identified pathway between this contamination and human receptors. Therefore, this contamination is not considered to present a significant possibility of significant harm to long-term human health.

However, more volatile SVOC such as naphthalene may potentially pose a risk to human health due to inhalation of vapours. Further modelling is required to quantify the potential risk to human health from naphthalene.

7.2.5.3 Southern CEAG Hotspot

Seven samples from the Southern CEAG area recorded ash within shallow made ground, which was restricted to the top 0.2m bgl. This material may relate to historic or recent railway operations in this area. Elevated benzo(a)pyrene concentrations of up to 64mg/kg were recorded within the shallow made ground. This area of contamination may present a significant possibility of significant harm to long-term human health. Further modelling is required to quantify the potential risk to human health.

Table XV – PAH and SVOC Soil Exceedances				
Substance	**Location**	**Impacted Strata**	**Recorded Concentration (mg/kg)**	**Adopted Screening Critiera (mg/kg)**
Benzo(a) pyrene	WS105A 3.8m	Made Ground	950	29.7*
	WS113 0.4m	Made Ground	45	29.7*
	WS119 0.2m	Made Ground	49	29.7*
	BH207 3.7m	Made Ground	1000	29.7*
	WS243A 4.5-5.0m	Made Ground	85	29.7*
	WS252 0.8m	Made Ground	55	29.7*
	WS258 0.6-0.7m	Made Ground	91	29.7*
	TP271 0.2m	Made Ground	42	29.7*
	TP272 0.2m	Made Ground	59	29.7*
	TP273 0.2m	Made Ground	64	29.7*
	TP276 0.1m	Made Ground	64	29.7*
	TP277 1.0m	Made Ground	62	29.7*
	TP280 0.2m	Made Ground	51	29.7*
Naphthalene	WS105A 3.8m	Made Ground	7,100	290*
	BH207 3.7m	Made Ground	9,100	290*
	WS243A 4.5-5.0m	Made Ground	390	290*
Dibenzo(a,h) anthracene	WS105A 3.8m	Made Ground	100	29.7*
	BH207 3.7m	Made Ground	140	29.7*
Carbazole	WS105A 3.8m	Made Ground	330	86.2**
	BH207 3.7m	Made Ground	590	86.2**

* Chartered Institute for Environmental Health Generic Assessment Criteria.

** United States Environment Protection Agency Preliminary Remediation Goals.

7.2.6 Volatile Organic Compounds (VOC)

Relatively low VOC concentrations well below adopted screening criteria were recorded within the majority of the samples tested. However, elevated VOC concentrations including benzene, toluene and styrene identified within WS105A-3.8m and BH207-3.7m (Markets Basement hotspot) are significant due to potential exposure via inhalation. Elevated concentrations of VOCs may

represent a significant risk to human health despite being present at greater than 3.6m bgl. Further modelling is required to quantify the potential risk to human health.

A list of the VOC concentrations in soil exceeding the adopted screening criteria is presented in Table XVI.

Table XVI - VOC Soil Exceedances

Substance	Location	Impacted Strata	Recorded Concentration (mg/kg)	Adopted Screening Criteria (mg/kg)
Benzene	WS105A 3.8m	Made Ground	150	26.9*
	BH207 3.7m	Made Ground	200	26.9*
Toluene	BH207 3.7m	Made Ground	240	150***
Styrene	WS105A 3.8m	Made Ground	82	74**

* Chartered Institute for Environmental Health Generic Assessment Criteria.

** Dutch Serious Risk Concentration.

*** Environment Agency, Soil Guideline Values.

7.2.7 Polychlorinated Biphenyls (PCBs)

Most samples recorded concentrations of PCB below the limit of detection, with the exception of samples WS122-0.5m and TP278-0.2m which recorded total PCB (vs Aroclor 1254) of 52µg/kg and 110µg/kg respectively. Concentrations of PCB have been compared to United States Environment Protection Agency Preliminary Remediation Goals (USEPA PRG). None of the samples tested contained concentrations of PCB's above the USEPA PRG of 744µg/kg. However, the limit of detection for sample WS105A-3.8m was raised to 1,000µg/kg which is above the USEPA PRG. While this may indicate a minor uncertainty, samples from boreholes in the vicinity of WS105A such as BH207-3.7m, WS238-2.9m and WS239A-5.3m recorded PCB concentrations less than the limit of detection of 60µg/kg.

In summary, as the majority of samples tested were below the limit of detection and recorded concentrations were below adopted screening criteria it may be considered that PCBs do not present a significant possibility of significant harm to long term human health.

7.2.8 Other Substances

Statistical analysis for monohydric phenol, total cyanide and sulphide was carried out to identify the 95% confidence limits of the measured mean and to compare the upper 95th percentile with the respective screening criteria using the mean value test.

The maximum value and upper bound values (US_{95}) for phenol and sulphide were below their respective screening values. Therefore, it may be considered that the concentrations of phenol and sulphide in soil on site do not present a significant possibility of significant harm to long-term human health.

In the majority of samples the concentrations of total cyanide were below the corrected Dutch Intervention value of 50mg/kg (pH > 5). The exception to this was elevated concentrations of total cyanide in WS240-2.9m and WS231-3.6m of 110mg/kg and 66mg/kg respectively. These concentrations are not considered to present a significant possibility of significant harm to long-term human health as the concentration of free cyanide in these samples was below the LOD and the samples were collected from greater than 2.9m bgl.

Boron, copper and zinc are phytotoxic metals and are not normally hazardous to human health unless present in extremely high concentrations. Such concentrations were not detected in any of the soil samples analysed.

7.3 Human Health – Construction Workers

The CLEA Soil Guideline Values only apply to the protection of health for long term chronic exposure. Construction workers are more likely to be at risk from a high single exposure, i.e. an acute dose, which can result in contaminant poisoning. Suggested values for acute lethal doses of arsenic, cadmium, chromium, inorganic mercury, nickel and selenium is outlined in the Environment Agency R&D SGV reports.

The levels of arsenic, nickel and phenol could be significant with respect to an acute lethal dose. Appropriate Personal Protective Equipment (PPE) and safe working practices to minimise soil ingestion should be employed when working on the Site.

7.3.1 Asbestos

Twenty one soil samples were screened for asbestos and no fibres were detected. However, asbestos is present within buildings on the Site and due care will need to exercised during the demolition to avoid the spread of asbestos.

7.4 Ecology – Future Landscaped Areas

Ecological Soil Screening Levels (Eco-SSL) have been published by the USEPA for a range of metals. The Eco-SSLs present indicative values for assessing potential risk to plants and other ecological receptors.

7.4.1 Site Wide

As no relevant UK guidance exists for assessing risk to ecology, the recorded metal concentrations from the top 1m of soil have been compared on an individual basis to Eco-SSLs. Exceedances in areas where landscaped areas are not currently proposed have been included below for completeness. Consideration of the proposed landscaped areas is discussed separately below.

One sample, BH102A-1.0m, recorded elevated concentrations of arsenic and nickel of 160mg/kg and 670mg/kg respectively. These concentrations exceed the Eco-SSLs for plants of 56mg/kg and 210mg/kg respectively. These concentrations may pose a risk to sensitive plant growth in future garden or landscaped areas of the posed proposed redevelopment.

Four samples exceeded the chromium Eco-SSLs for plants of 120mg/kg. The maximum recorded concentration (230mg/kg) also occurred in BH102A-1.0m. This concentration and three other concentrations at locations WS103-0.8m, WS119-0.2m and TP271-0.2m may pose a risk to sensitive plant growth in future garden or landscaped areas of the posed proposed redevelopment.

Two samples exceeded the copper Eco-SSLs for plants of 130mg/kg. The maximum recorded concentration (230mg/kg) occurred in WS264-0.7m. This concentration and the slightly elevated copper concentration at BH219-0.7m may pose a risk to sensitive plant growth in future garden or landscaped areas of the posed proposed redevelopment.

One sample WS238-0.5m recorded an elevated concentration of lead at 990mg/kg, which exceeded the lead Eco-SSLs for plants of 490mg/kg. This concentration may pose a risk to sensitive plant growth in future garden or landscaped areas of the posed proposed redevelopment.

7.4.2 Landscaped Areas

Consideration of the proposed landscaped area in Southern CEAG indicates that two samples (WS119-0.2m and TP271-0.2m) exceed the chromium Eco-SSLs for plants. These concentrations may pose a risk to sensitive plant growth.

It is considered that the recorded metal concentrations are unlikely to pose a significant risk to standard tree and hedge planting. Risk to plant growth would be further reduced by the use of tree pits with imported soil as proposed on Camlin Lonsdale drawing, Typical Details: Tree Pit and Anchoring System (Dwg. Ref. 519 LAL (90) 001).

7.5 Groundwater Contamination Results

Groundwater samples taken from the Site have been tested for potential chemicals of concern appropriate to the former land uses. Although there are potentially two groundwater abstraction licences for bottling purposes within 1km of the Site, these are up hydraulic gradient and are not considered significant.

The Sough Dyke is a culverted water course that crosses the Site in the vicinity of the Markets Basement and Southern CEAG Hotspots. It is considered by the Environment Agency that the Sough Dyke presents a sensitive surface water feature. Therefore, the concentrations of contaminants detected in groundwater have been compared to Environmental Quality Standards (EQS) for freshwater. For substances not encompassed by EQS, other appropriate screening values such as UK Drinking Water Standards (UKDWS) have been utilised.

The main pathway by which contaminants are likely to reach the groundwater is through infiltration of rainwater causing vertical movement through the ground. The Site is predominantly covered by hardstanding and it is understood that upon completion of construction works, the majority of the Site will be covered by buildings and hardstanding, which should limit the downward passage of most contaminants. The Sough Dyke is to undergo diversion works in the open-market and east Markets Basement as part of the development. This is likely to improve the structure of the culverted dyke and decrease potential infiltration of groundwater to the dyke.

Groundwater monitoring of Stage 1 borehole installations was conducted in September and November 2007. A subsequent round of groundwater monitoring of all Stage 2 borehole installations and significantly impacted Stage 1 boreholes was conducted in April 2008.

7.5.1 Metals, Semi-metals and Non-metals

The maximum concentrations for boron, cadmium, chromium, lead, mercury and nickel recorded in groundwater samples collected from across the Site were below their respective EQS or limit of detection (LOD). Therefore, the concentrations of these metals do not present a significant risk to human health or the environment.

Boreholes BH104, WS105A, BH207s and BH214s recorded selenium concentrations of 23µg/l, 37µg/l, 54µg/l and 37µg/l which are elevated with respect to the UKDWS value of 10µg/l.

Boreholes BH207s, BH207d, BH115 and WS105A recorded zinc concentrations of 57µg/l, 170µg/l, 54µg/l and 73µg/l which are elevated with respect to the EQS at 50µg/l.

Boreholes WS105A, WS110 and BH104 recorded sulphate concentrations of up to 1400mg/l, 450mg/l and 1700mg/l which are elevated with respect to the UKDWS value of 400mg/l.

The recorded concentrations of cyanide in WS105A and BH207s at 1,200µg/l and 160µg/l respectively, are elevated with respect to the UKDWS of 50µg/l.

The recorded concentration of arsenic in WS105A of 57µg/l is slightly elevated in respect to the EQS of 50µg/l.

As the closest sensitive groundwater abstraction is 900m west (up gradient) of the Site, the elevated arsenic, cyanide, selenium, zinc and sulphate concentrations are not considered to present a significant risk to long term human health. However, these concentrations may pose a risk to environmental receptors and further modelling is required to quantify the potential risks.

A list of the groundwater concentrations exceeding the adopted screening criteria are listed in Table XVII.

Table XVII – Metal, Semi-Metal and Non-Metal Groundwater Screening Criteria Exceedances

Substance	Location	Recorded Concentration (µg/l)	Adopted Screening Critiera (µg/l)
Arsenic	WS105A	57	10*
Selenium	BH104	23	10**
	WS105A	37	
	BH207s	54	
	BH214s	37	
Total Cyanide	WS105A	1,200	50**
	BH207	160	
Sulphate	BH104	1,700,000	400,000**
	WS105A	1,400,000	400,000**
	WS110	450,000	400,000**
Zinc	WS105A	73	50*
	BH115	54	
	BH207s	57	
	BH207d	170	
	BH210	150	

* EQS (Freshwater, annual average where applicable) **UKDWS

7.5.2 Total Petroleum Hydrocarbons (TPH)

Dissolved phase TPH concentrations within groundwater samples collected from boreholes across the majority of the Site were below the limit of detection. However, elevated concentrations were detected in areas of the Site where soil contamination has been identified.

7.5.2.1 Markets Basement Hotspot

Significantly elevated TPH concentrations were recorded in shallow groundwater from BH104, BH207s and WS105A with maximum concentrations of 38,000µg/l in BH207s. Borehole BH104 recorded TPH concentrations of 4,500µg/l, 230µg/l and 31,000µg/l. These elevated TPH concentrations reflect significantly elevated soil concentrations within the Markets Basement Hotspot. The elevated TPH concentrations are not considered to pose a risk to long term human health. However, these concentrations may pose a risk to environmental receptors and further modelling is required to quantify the potential risks.

7.5.2.2 Southern CEAG Hotspot

Elevated TPH concentrations were recorded in BH214d and WS119 at 1,120µg/l and 140µg/l respectively compared to the UKDWS of 10µg/l. The TPH comprised long chain-length (C21-35) aromatic and aliphatic hydrocarbons as identified in soil samples from this area.

The recorded elevated TPH concentrations are not considered to pose a significant risk to long term human health. However, these concentrations may pose a risk to environmental receptors and further modelling is required to quantify the potential risk.

A list of the groundwater concentrations exceeding the adopted screening criteria are listed in Table XVIII.

Table XVIII – Petroleum Hydrocarbon Groundwater Screening Criteria Exceedances

Substance		Location	Recorded Concentration (µg/l)	Adopted Screening Critiera (µg/l)
Aliphatic Hydrocarbons	C5-6	BH207s	11	10*
	C6-8	BH207s	1,100	10*
	C8-10	BH104	150	10*
		WS105A	1,200	10*
		BH207s	1,200	10*
	C10-C12	BH104	360	10*
		WS105A	3,200	10*
		BH207s	4,000	10*

Table XVIII – Petroleum Hydrocarbon Groundwater Screening Criteria Exceedances				
Substance		**Location**	**Recorded Concentration (µg/l)**	**Adopted Screening Critiera (µg/l)**
	C21-35	BH214d	790	10*
Aromatic Hydrocarbons	C6-7	BH104	1,300	10*
		WS105A	6,700	10*
		BH207d	28	10*
		BH207s	13,000	10*
	C7-8	BH104	420	10*
		WS105A	2,100	10*
		BH207s	4,800	10*
	C8-10	BH104	930	10*
		WS105A	2,600	10*
		BH207s	3,300	10*
	C10-12	BH104	550	10*
		WS105A	4,700	10*
		BH207s	6,000	10*
	C12-16	BH104	620	10*
		WS105A	8,800	10*
		BH207s	3,200	10*
	C16-21	BH104	130	10*
		WS105A	1,100	10*
		BH207s	550	10*
	C21-35	WS105A	280	10*
		WS119	140	10*
		BH207s	150	10*
		BH214d	330	10*

*UKDWS

7.5.3 Polycyclic Aromatic Hydrocarbons (PAH) and Semi-Volatile Organic Compounds (SVOC)

PAH and SVOC concentrations within groundwater samples collected from boreholes across the majority of the Site were below the limit of detection. The maximum recorded total PAH concentration was 4.7mg/l in BH207s.

As benzo(a)pyrene is considered to be the most carcinogenic PAH it was used as a surrogate to assess the degree of risk posed by PAH in groundwater. Most samples recorded concentrations of benzo(a)pyrene less than the limit of detection. However, the maximum recorded concentration of benzo(a)pyrene

was 6.4µg/l which is above the EQS value of 0.03µg/l. Further consideration of the elevated PAH and SVOC concentrations is focused on the Markets Basement and Southern CEAG Hotspots.

7.5.3.1 Markets Basement Hotspot

Groundwater from WS105A and BH207s recorded significantly elevated benzo(a)pyrene concentrations of 0.9µg/l and 1.9µg/l respectively. These values exceed the EQS of 0.03µg/l and may reflect the elevated PAH concentrations recorded within soil samples at these locations.

Elevated concentrations of total phenol were detected in BH207s at 470mg/l and in BH207d at 0.73mg/l compared to the EQS of 0.03mg/l. The elevated phenol within the shallow groundwater is considered significant. Speciated phenol analysis of groundwater from the deep aquifer indicates that most of the phenol species are present at concentrations below the limit of detection with a maximum concentration of 2,4-dimethylphenol of 8µg/l. As the speciated phenol analysis is a more sensitive technique than that used for total phenol (monohydric phenol), it is considered likely that the concentrations of phenols within the deeper aquifer (BH207d) do not pose a significant risk to environmental receptors.

Elevated PAH/SVOC concentrations are not considered to pose a significant risk to long term human health. However, PAH/SVOC concentrations within the shallow aquifer may pose a significant risk to environmental receptors and further modelling is required to quantify the potential risks.

7.5.3.2 Southern CEAG Hotspot

Groundwater from WS119 recorded a significantly elevated benzo(a)pyrene concentration of 6.4µg/l. Additionally, BH214d and BH214s recorded slightly elevated benzo(a)pyrene concentrations of 0.06µg/l 0.078µg/l respectively. It is considered that groundwater within the vicinity of WS119 may pose a significant risk to environmental receptors and further modelling is required to quantify the potential risks.

A list of the groundwater concentrations exceeding the adopted screening criteria are listed in Table XIX.

Table XIX – PAH and SVOC Groundwater Screening Criteria Exceedances

Substance	Location	Recorded Concentration (µg/l)	Adopted Screening Critiera (µg/l)
Fluoranthene	BH102A	0.093	0.02*
	WS105A	17	0.02*
	WS110	0.097	0.02*
	BH112	0.041	0.02*
	WS119	9	0.02*
	BH207d	0.57	0.02*
	BH207s	69	0.02*
	BH208s	1.7	0.02*
	BH213As	0.2	0.02*
	BH213Ad	0.027	0.02*
	BH214s	0.034	0.02*
Naphthalene	WS105A	3,900	10*
	BH207d	24	10*
	BH207s	10,000	10*
Anthracene	BH102A	0.26	0.02*
	WS105A	13	0.02*
	WS110	0.031	0.02*
	WS119	0.48	0.02*
	BH207s	51	0.02*
	BH207s	0.59	0.02*
	BH208s	0.42	0.02*
Benzo(a)pyrene	WS105A	0.9	0.03*
	WS110	0.032	0.03*
	BH112	0.022	0.03*
	WS119	6.4	0.03*
	BH213As	0.078	0.03*
Phenol	WS105A	610,000	30*
	BH104	470	30*
	BH207A	470,000	30*
	BH207d	730	30*
	BH208d	40	30*
2-methylphenol	BH104	400	100*
4-methylphenol	BH104	200	100*

*EQS (Freshwater, annual average where applicable)

7.5.4 Volatile Organic Compounds (VOCs)

VOC concentrations within the majority of groundwater samples collected from boreholes across the Site were below the limit of detection. Elevated VOC concentrations above UKDWS and EQS were recorded in shallow groundwater from the Markets Basement Hotspot.

7.5.4.1 Markets Basement Hotspot

Groundwater from BH104 recorded a slightly elevated concentration of xylenes (41µg/l) and a significantly elevated concentration of benzene (71µg/l) during the first round of monitoring. The second round of groundwater monitoring recorded significantly elevated VOC concentrations including benzene (1,300µg/l), toluene (420µg/l) and xylenes (690µg/l). These concentrations are above the EQS for benzene (3µg/l) and above the EQS for toluene (50µg/l) and xylenes (30µg/l).

Groundwater collected from WS105A during the first round of monitoring recorded significantly elevated concentrations of benzene (1,300µg/l), toluene (630µg/l), and xylene (300µg/l) and a slightly elevated concentration of styrene (59µg/l). Results from the second round of monitoring indicate an increased abundance of VOCs including concentrations of benzene (6,600µg/l), toluene (1,800µg/l), xylenes (620µg/l) and styrene (150µg/l).

Groundwater collected from BH207s recorded significantly elevated concentrations of benzene (16,000µg/l), toluene (5,500µg/l), xylenes (1,670µg/l). Groundwater from the deeper aquifer in BH207d indicated that benzene, toluene and xylene concentrations were not significantly elevated with respect to their EQS values.

The recorded VOC concentrations may present a significant risk to long term human health and environmental receptors and further modelling is required to quantify the potential risks.

A list of the groundwater concentrations exceeding the adopted screening criteria are listed in Table XX.

Table XX – VOC Groundwater Screening Criteria Exceedances

Substance	Location	Recorded Concentration (µg/l)	Adopted Screening Criteria (µg/l)
Benzene	BH104	1,300	30*
	WS105A	6,600	30*
	BH207s	16,000	30*
Toluene	BH104	420	50*
	WS105A	1,800	50*
	BH207s	5,500	50*

Table XX – VOC Groundwater Screening Criteria Exceedances			
Substance	**Location**	**Recorded Concentration (µg/l)**	**Adopted Screening Criteria (µg/l)**
Xylene (total)	BH104	690	30*
	WS105A	620	30*
	BH207s	1670	50*
Styrene	WS105A	150	50*
	BH207s	430	50*

*EQS (Freshwater, annual average where applicable)

7.6 Sough Dyke Contamination Results

Two rounds of sampling and geochemical testing has been used to provide a preliminary assessment of water quality in the Sough Dyke both up stream and down stream of the Site. Given the seasonal and most likely daily variation in water quality within the Sough Dyke, this assessment is considered to represent a 'snap shot' of potentially significant issues and is not intended to be comprehensive.

7.6.1 Metals, Semi-metals and Non-metals

The second round of surface water monitoring within the Sough Dyke recorded a slightly elevated concentration of zinc (59µg/l) within the downstream sample. This is zinc concentration is slightly elevated with respect to the EQS at 50µg/l. However, the upstream sample from the same monitoring visit recorded a zinc concentration of 40µg/l which is not significantly different to the down stream concentration. Therefore, the metal concentrations recorded within the Sough Dyke are slightly elevated compared to conservative EQS, are considered to be indicative of background quality and not contamination identified on Site.

7.6.2 Total Petroleum Hydrocarbons (TPH)

Dissolved phase TPH concentrations within water samples collected from the Sough Dyke were below the limit of detection. Therefore, TPH concentrations within the Sough Dyke are not considered to be adversely impacted by contamination identified on Site.

7.6.3 Polycyclic Aromatic Hydrocarbons (PAH) and Semi-Volatile Organic Compounds (SVOC)

Slightly elevated PAH concentrations of 0.3µg/l and 0.54µg/l were detected within water samples collected from the upstream and downstream sampling locations respectively. The maximum recorded upstream concentrations of fluoranthene,

benzo(a)pyrene and anthracene of 0.05µg/l, 0.011µg/l and 0.031µg/l exceed EQS values for these substances. Results for the down stream samples are very similar with maximum concentrations of fluoranthene, benzo(a)pyrene and anthracene at 0.054µg/l, 0.012µg/l and 0.022µg/l.

The recorded concentrations of naphthalene in the upstream and downstream samples are below the EQS value.

The PAH and SVOC concentrations recorded within the Sough Dyke are slightly elevated compared to conservative EQS and are considered to be indicative of background quality and not contamination identified on Site.

7.6.4 Volatile Organic Compounds (VOCs)

The majority of volatile organic compound concentrations within water samples collected from the Sough Dyke were below EQS or the limits of detection. However, an elevated dichloromethane concentration of 0.21mg/l was recorded in one upstream sample which is in excess of the WHO screening value of 0.02mg/l. The elevated dichloromethane concentration recorded within the Sough Dyke is elevated compared to conservative screening values, but is not considered to be linked to contamination identified on Site.

7.6.5 Other Water Quality Indicators

Water samples from the Sough Dyke were tested for a suite of water quality indicators including biochemical oxygen demand (BOD), ammoniacal nitrogen, total coliforms and E.coli. These substances provide an indication of general water quality and may denote sewage pollution.

The maximum recorded BOD within the up stream sample was greater than 131mg/l, while the down stream sample recorded a BOD of 17mg/l. A maximum concentration of ammoniacal nitrogen of 5.7mg/l was recorded in the upstream sample.

These results would indicate a classification of the stream as GQA Grade E (Poor) under the Environment Agency's method of classification of water quality due to elevated ammoniacal nitrogen concentrations.

Total coliform concentrations in the upstream samples were 51,200 and 594,000 total coliforms/100ml during the Stage 1 and 2 investigations respectively and 1,210 and 20,000 total coliforms/100ml in the downstream sample during the Stage 1 and 2 investigations respectively. These samples were above the European Community Quality of Bathing Water Directive guide value of 500 total coliforms/100ml. Both upstream samples and the Stage 2 downstream sample were also above the mandatory microbiological value of 10,000 total coliforms/100ml. E.coli concentrations were also higher in the upstream sample (1,310 and 38,700 No./100ml) than the downstream sample (649 and 4,570

No./100ml). The results for total coliform and E.coli show a marked increase between the Stage 1 and 2 investigations. This is may be attributed to foul sewer overflow discharges during high rainfall events over the winter period.

It should be noted that, the above screening criteria hold no legal standing with respect to the water quality of the Sough Dyke. However, the values do provide a form of baseline prior to development.

7.7 Ground Gas

The presence and concentrations of ground gases were monitored on ten occasions during Stage 1 and 2 over a period of approximately eight months. Seven of the monitoring rounds were recorded at atmospheric pressures of less than 1,000mb.

Elevated methane concentrations were recorded in boreholes BH104 (2.4% and 0.3%), BH108 (3.8% and 0.3%), BH118 (1.2%), BH202 (7.3%, 2% and 1%), BH207s (2.7%, 2% and 2.2%) and BH207d (0.4% and 0.3%).

Slightly elevated carbon dioxide concentrations ranging from 0.1% to 7.1% were recorded across the majority of the Site during the monitoring period. The maximum recorded carbon dioxide concentration of 7.1% was measured at BH108.

Flow rates recorded during the ten monitoring visits were predominantly very low. A maximum flow reading of 1.0l/hr was recorded at BH118 on two occasions.

It is considered that elevated methane concentrations are a result of a combination of natural methane production from underlying coal seams, anaerobic decomposition of organic material and vapours from contaminated soils and shallow groundwater.

Boreholes BH104, BH207s and BH207d are located within the Markets Basement hotspot where soils and groundwater are impacted by hydrocarbon contamination. It is considered that the elevated methane readings taken from these boreholes are likely to comprise vapours from short chain-length hydrocarbons. As contaminated material within this area is to undergo remediation the monitoring data from this area has been discounted for the purposes of the ground gas risk assessment.

The response zones of boreholes BH108 and BH202 both intersect coal seams and it is considered that methane readings are likely to result from natural gas migration from these seams.

Borehole BH202 is screened at depth from 15m to 20m and has recorded elevated methane concentrations. Borehole WS107, located within close proximity to BH202, is installed with a shallow monitoring standpipe and has not recorded any methane concentrations.

The elevated methane concentration recorded within borehole BH118 is likely to be attributed to anaerobic decomposition of plant matter recorded in near surface strata.

The maximum recorded carbon dioxide concentrations were generally recorded at borehole BH108 which intersects a shallow coal seam. This suggests that the coal seam may be the likely source of carbon dioxide in this case.

It is considered appropriate that the Site is divided into two zones based on the conceptual site model. The model identifies different site uses and variance in ground gas results between the eastern and western sides of the railway. East of the railway the Site is to be developed as multi-storey car parking with no basement. Monitoring of ground gas in this area identifies only one slightly elevated methane concentration and generally lower recorded carbon dioxide concentrations than west of the railway. West of the railway the Site is to be developed for commercial land use with basement areas and above ground level residential apartments. Monitoring of ground gas in this area identifies five elevated methane concentrations in two boreholes (excluding previously discounted results) and elevated carbon dioxide concentrations.

East of Railway

A worst case GSV of 0.053l/hr has been calculated for the Site east of the railway based on the maximum recorded carbon dioxide concentration of 5.3% (BH118) and the maximum borehole flow rate of 1.0l/hr (BH118). The conceptual site model and gas monitoring data indicates classification of the Site east of the railway as Characteristic Situation 1 (very low risk) based on a low site sensitivity (commercial) end use, moderate gas hazard and a GSV of less than 0.07l/hr. However, as methane has been recorded above 1% consideration should be given as to whether the Site should be reclassified as Characteristic Situation 2 (low risk).

It is considered that a Characteristic Situation 1 is appropriate to the Site east of the railway based on a proposed low sensitivity end use and slightly elevated methane concentration on only one occasion.

West of Railway

A worst case GSV of 0.06l/hr has been calculated for the Site west of the railway based on the maximum recorded methane concentration of 7.3% (BH202) and the maximum borehole flow rate of 0.8l/hr (BH108). The conceptual site model and gas monitoring data indicates classification of the Site west of the railway as Characteristic Situation 1 (very low risk) based on a low site sensitivity (commercial) end use, moderate gas hazard and a GSV of less than 0.07l/hr. However, as methane has been recorded above 1% consideration should be

given as to whether the Site should be reclassified as Characteristic Situation 2 (low risk).

It is considered that a Characteristic Situation 2 is appropriate to the Site west of the railway due to consistently elevated carbon dioxide concentrations and elevated methane concentrations. The elevated carbon dioxide and methane may potentially originate from three coal seams identified beneath the western portion of the Site.

The general scope of gas protection measures required for a Characteristic Situation 2 is likely to include:

a) Reinforced concrete cast *in situ* floor slab (suspended, non-suspended or raft) with at least 1200 g DPM;
b) Beam and block or pre cast concrete slab and minimum 2000 g DPM/reinforced gas membrane;
c) Possibly under floor venting or pressurisation in combination with a) and b) depending on use; and
d) All joints and penetrations sealed.

Gas monitoring results are provided in Appendix XI.

7.8 Radon Gas

The BRE document "Radon: guidance on protective measures for new dwellings" (1999) provides guidance for reducing the concentration of radon in new dwellings and a two stage procedure using accompanying maps needed to determine the level of protection for a given Site. This document has been consulted and the Site is shown to lie in an area where consideration should be given to geological data and whether basic protection against radon may be needed should development of residential dwellings or new structures of similar form of construction and compartmentation occur.

The site specific radon report (Appendix III) confirms that basic protection would be needed.

The requirements for basic radon protection are likely to be catered for with the installation of gas protection measures described above for a Characteristic Situation 2. Guidance on the installation of protective measures against radon is provided within the *BR211* publication.

7.9 Building Materials

7.9.1 Concrete

Concentrations of total sulphate were measured in order to indicate the potential for concrete attack. Concentrations on site ranged between 0.01% and 1.9% indicating that there is potential for concrete attack on site.

Results from sulphate (2:1 extract) for materials on site ranged between 0.016g/l and 0.55g/l. Sulphate concentrations within groundwater ranged between 50mg/l and 1200mg/l. These results indicate that a design sulphate class of DS-4 and Aggressive Chemical for Concrete (ACEC) class of AC-3 may be appropriate for the Site. Relevant guidelines are given in BRE Special Digest 1: Concrete in Aggressive Ground.

7.9.2 Water Supply Pipes

Permeation and accelerated deterioration of pipe material can occur due to chemical reactions between the pipe and contaminants in the ground in which it is laid. This can lead to premature failures resulting in leakage and loss of water quality.

The Water Supply (Water Fitting) Regulations 1999 in England and Wales, include a requirement to use only suitable materials when laying water pipes and the laying of unprotected water supply pipes through contaminated land is not permitted.

Based upon recommendations of the Foundation for Water Research guidance notes (FR 0448: Laying potable water pipelines in contaminated ground, 1994), a table of threshold values for various contaminants has been produced. Where soil concentrations exceed these threshold values, it is likely that special consideration of material selection will be required.

Due to the presence of the potentially corrosive and organic contaminants it is recommended that wrapped iron or polythene/aluminium/polythene (PE/Al/PE) pipe material be used for water supply pipework to be installed in the ground as part of the redevelopment works.

Further information regarding the selection of materials for water supply pipes is given in the Water Regulations Advisory Scheme Information and Guidance Note No 9-04-03.

8. REVISED CONCEPTUAL SITE MODEL (CSM)

The identified sources of contamination are summarised on Drawing SH03582/17A. Based on this information, the preliminary site model has been revised and developed. The updated CSM is shown in Table XXI and details the potential sources, pathways and receptors and the inter-relationship of these factors.

Schematic models of the Markets Basement and Southern CEAG hotspots are illustrated on drawings SH03582/32 and SH03582/35.

TABLE XXI – Revised Conceptual Site Model

SOURCE	CONTAMINANT	PATHWAY	RECEPTOR (PRESENT)	RECEPTOR (FUTURE)
1. Made ground in the Markets Basement hotspot.	Aromatic hydrocarbons C16-35. PAHs. SVOC. VOCs.	1. Inhalation. 2. Dermal contact. 3. Ingestion. 4. Groundwater migration. 5. Direct contact.	3. Groundwater. 4. Surface water. 5. Subsurface plastic service pipes.	1. Future occupiers. 2. Construction workers. 3. Groundwater. 4. Surface water. 5. Subsurface plastic service pipes.
2. Made Ground in the vicinity of May Day Green and southern CEAG hotspots.	Aromatic and aliphatic hydrocarbons C21-35. Benzo(a)-pyrene.	1. Disturbance and inhalation. 2. Dermal contact. 3. Ingestion. 4. Groundwater migration. 5. Direct contact.	3. Groundwater. 4. Surface water. 5. Subsurface plastic service pipes.	1. Future occupiers. 2. Construction workers. 3. Groundwater. 4. Surface water. 5. Subsurface plastic service pipes.
3. Contaminated groundwater in the Markets Basement Hotspot.	TPH. PAH. SVOC. VOC. Sulphate. Zinc. Cyanide. Selenium. Arsenic.	1. Inhalation. 2. Dermal contact. 3. Ingestion. 4. Groundwater migration. 5. Direct contact.	3. Groundwater. 4. Surface water. 5. Subsurface building material and plastic service pipes.	1. Future occupiers. 2. Construction workers. 3. Groundwater. 4. Surface water. 5. Subsurface building material and plastic service pipes.
4. Contaminated groundwater beneath the south CEAG area.	TPH. PAH. SVOCs. Selenium.	2. Dermal contact. 3. Ingestion. 4. Groundwater migration. 5. Direct contact.	3. Groundwater. 4. Surface water. 5. Subsurface building material and plastic service pipes.	1. Future occupiers. 2. Construction workers. 3. Groundwater. 4. Surface water. 5. Subsurface building material and plastic service pipes.
5. Coal Seams & local geology.	Minor ground gas (CH_4, CO_2 and radon)	1. Inhalation. 6. Gas migration.	6. Current occupiers (minor risk).	1. Future occupiers. 2. Construction workers.

Based on the location and suite of contaminants present within the Markets Basement Hotspot, it is considered likely that the source may relate to former use of the area as a gas works. The material encountered in the Markets Basement, including the significant depth at which tar was encountered and the refusal of window sample WS105A within made ground, may indicate the presence of an old pit or tank. Several boreholes in the vicinity of borehole WS105A also identified evidence for hydrocarbon impact within made ground and natural strata.

The Department of the Environment Industry Profile for Gas Works, Coke Works, and Other Coal Carbonisation Plants, (1994) provides an overview of the type of contaminants and processes used in a gas works and some of the information is of relevance to the Markets Basement hotspot.

Coal tar is a black/brown viscous liquid with distinctive 'organic odour' which was removed from coal gas at various stages and frequently stored in wells and underground tanks. Coal tar was subjected to fractional distillation and chemical processing producing a range of hydrocarbons and other organic compounds. Further processing resulted in the recovery of a mixture of compounds such as BTEX, phenols, naphthalene etc.

Coal tar that was regarded as a waste was often disposed on-site in ponds and lagoons, but in most cases it was kept in underground tanks. The tanks were normally brick lined and surrounded by "puddle" clay.

9. WASTE CLASSIFICATION

9.1 Introduction

This section presents an assessment of the majority of material destined for removal off-site arising as part of the proposed basement excavations. It includes an estimate of the likely excavation volumes of the three main areas of excavation together with the Cheapside Excavation. The approximate proportions of made ground and natural material within these areas, and their likely waste classifications are assessed. The assessment is based on results from the Wardell Armstrong Preliminary Stage 1 (Pre-demolition) Site Investigation Report dated November 2007 and this Stage 2 Site Investigation.

9.1.1 Proposed Excavations

For the purpose of this assessment four main proposed basement excavation areas have been defined and these are identified as:

- Area A – May Day Green,
- Area B – Open Market loading area,
- Area C – Zero Ice and associated car parking area; and
- Cheapside Excavation – area between Cheapside and the existing basement.

The proposed excavation areas and volumes have been estimated from the following available drawings which show the extent and levels of the existing and proposed basements:

- CZWG and HolderMathias, General Arrangement (Plan), Interchange Level, Drawing No. AL (00) 008;
- White Young Green, Site Wide Pile Layout. Drawing No. SPL1 (Rev T2),
- White Young Green, Formation Levels Site Wide General Construction. Drawing No. SL9(11)001 Rev. 2; and
- Charter Oaks, Topographic Survey. Drawing No. 030701-01.

Excavation areas and volumes are based on the extent of the proposed basement minus the existing basement. The extent of the excavation areas have been approximated where the boundary of the proposed basement is not clearly defined in the available drawings. The bases of the proposed basement excavations have been taken as the formation levels provided in White Young Green drawing SL9(11)001 Rev. 2.

The proposed excavation areas for this assessment are defined on the attached Drawing No. SH03582/24A.

9.1.2 Available Data

The assessments of Area A and the Cheapside Excavation are limited by the small numbers and locations of soil samples collected from these areas, as they

were not part of the original scope due to very limited access. Extrapolation of units across these areas of proposed basement excavation should be viewed as broad estimates only. Care should be exercised if applying the results of the assessment to constrain future redevelopment.

9.2 Waste Assessment

This waste assessment has been completed in accordance with Environment Agency guidance documents WM2 V2.1, October 2006 and HWR08 V3.1, June 2007. Within WM2 is a copy of the European Waste Catalogue (EWC) which identifies soil (including excavated soil from contaminated sites) containing dangerous substances as mirror entry hazardous waste (mirror entry 17 05 03*; soil and stones containing dangerous substances). Where the waste does not possess any hazardous properties it is classified as mirror entry non-hazardous waste (mirror entry 17 05 04; soil and stones other than those mentioned in 17 05 03*).

The chemical analysis data from Areas A, B, C and the Cheapside Excavation for made ground and natural ground have been used to compare contaminant concentrations with threshold levels for their appropriate hazardous properties. Laboratory data is attached as Appendix VIII and spreadsheets detailing the assessment are attached as Appendix XIII (Tables A, B, C1, C2, C3, C4, C5 and F). Further information regarding assessment of the chemical analysis data used is included as an explanatory note within the spreadsheets.

Representative samples of made ground and natural material have been scheduled for Waste Acceptance Criteria (WAC) testing. Results have been compared against WAC to further assess whether the material may be accepted as inert, non-hazardous or hazardous for disposal to landfill. In addition to this assessment, further testing of the material is required following excavation to ensure that the classification is representative and to meet landfill acceptance requirements.

9.2.1 Area A

The assessment of Area A is based on twelve samples collected from three boreholes (BH112, WS113 and WS258A) within Area A and four boreholes (BH111, BH114, WS236 and WS256) in the vicinity of Area A.

9.2.1.1 Made Ground

Nine of the samples tested comprised sands, gravels, and clays which are interpreted as made ground. Visual and olfactory evidence of contamination including hydrocarbon odour, tarmac, ash and clinker was recorded within the made ground.

Three samples of made ground (BH112-1.0m, WS113-0.4m and WS258-0.6m) are identified as hazardous as the maximum TPH concentrations and the ratio of carcinogenic PAH compounds compared to oil exceed the thresholds for hazardous property H7 (carcinogenic). For one of these samples (BH112-1.0m), this classification is considered overly conservative as the concentration of DRO and lubricating oil is double counted. When the measured concentration of TPH in the range C16-35 is proportioned to give an approximate C25-35 concentration (appropriate to lubricating oils), the sample is considered to be non-hazardous.

Two samples from Area A (WS113-0.4m and WS258-1.5m) were submitted for Waste Acceptance Criteria (WAC) testing. Results from WAC testing confirm that the samples contained elevated total organic carbon, mineral oil, PAH concentrations and elevated sulphate within the eluate and are likely to be accepted as hazardous .

Seven samples of made ground are below the thresholds for hazardous waste and are classified as non-hazardous.

Samples identified as hazardous generally correspond to the presence of tarmacadam and/or hydrocarbon odour within the shallow strata. Given the spatial distribution of these samples and recorded visual and olfactory evidence of contamination it may be considered that hazardous material is constrained to the shallow made ground (upper 1.2m). This contaminated material may represent historic road surfacing.

9.2.1.2 Natural Material

Three of the samples tested comprised sandy, gravelly clay and mudstone interpreted as material characteristic of glacial till deposits and weathered coal measures respectively (WS236-0.5m, WS236-2.6m and WS256-0.8m). All three samples gave results below the thresholds for hazardous waste and are classified as non-hazardous.

One of the samples (WS236-2.6m) was submitted for Waste Acceptance Criteria (WAC) testing. Results from WAC testing indicate that the sample meets inert WAC and may be accepted as such.

Based on the results of testing from this sample and other testing of natural material in other areas of the Site it is considered likely that natural material in Area A may be accepted as mainly inert.

9.2.2 Area B

The assessment of Area B is based on fourteen samples collected from seven boreholes (BH212, WS247, WS248, WS260, WS261, WS262 and WS263) within Area B and one borehole (WS237) in the vicinity of Area B.

9.2.2.1 Made Ground

Thirteen of the samples tested comprised gravels, sands and clays interpreted as made ground. Minor evidence of contamination including tarmac was recorded within the made ground.

Ten of the samples were tested for total contaminant abundance and all of the samples are classified as non-hazardous.

A further three samples were submitted for Waste Acceptance Criteria (WAC) testing. Results of the WAC testing indicated that two of the three samples (WS248-1.3m and WS260-2.7m) meet inert WAC and may be accepted as such. One of the samples (WS263-1.5m) exceeds inert WAC due to total organic carbon concentration and is likely to be accepted as non-hazardous.

Based on the results of WAC testing from these samples it is considered likely that the majority of made ground in Area B may be accepted as inert. Limited made ground in the area beneath WS263 may be accepted as non-hazardous.

9.2.2.2 Natural Material

One of the samples (WS237-2.5m) comprised sandy, gravelly clay interpreted as material characteristic of glacial till deposits. This sample is classified as non-hazardous based on the absolute abundance of potential contaminants. The sample was also submitted for WAC testing and results indicate classification as inert material.

Based on the results of testing from this sample and other testing of natural material in other areas of the Site it is considered likely that natural material beneath Area B may be accepted as mainly inert.

9.2.3 Area C

The assessment of Area C is based on fifty-one samples collected from twenty-four boreholes within Area C.

9.2.3.1 Made Ground

Thirty-four of the samples tested comprised sands, gravels and clays which were interpreted as made ground. Visual and olfactory evidence of contamination including hydrocarbon odour, ash, slag and clinker was recorded within the made ground.

Four samples of made ground (BH102A-1.0m, WS103A-0.5m, BH201-0.3m and TP277-1.0m) are identified as hazardous. Sample BH102A-1.0m is identified as hazardous waste as the sum of arsenic, chromium, copper, lead, nickel, zinc, PAH and TPH exceed the threshold for hazardous property H14 (ecotoxic). Samples BH201-0.3m and TP277-1.0m are identified as hazardous waste as the

maximum TPH concentrations and the ratio of carcinogenic PAH compounds compared to oil exceed the thresholds for hazardous property H7 (carcinogenic).

Sample WS103A-0.5m is considered to be hazardous waste by H7 using the conservative approach of overestimating the DRO and Lubricating oil. When the measured concentration of TPH in the range C16-35 is proportioned to give an approximate C25-35 concentration (appropriate to lubricating oils), the sample is considered to be non-hazardous.

Five samples were submitted for WAC testing. Results from WAC testing confirm that three samples (WS225-2.4m, WS231-2.3m and WS234-1.6m) meet the inert WAC and are likely to be accepted as such. Two of the samples (WS228-0.4m and TP278-0.5) exceed inert WAC due to mineral oil concentration and elevated antimony within the eluate and are likely to be accepted as non-hazardous waste.

There is no clear correlation between the samples classified as hazardous. It is likely that limited made ground in the areas beneath BH102A, BH201 and TP277 may be classified as hazardous.

Samples of made ground that exceed the inert WAC are generally in the northern portion of the area. It is considered likely that made ground beneath the Zero Ice building may be generally inert and made ground beneath the majority of the car parking may be non-hazardous.

9.2.3.2 Natural

Seventeen of the samples tested comprised weathered coal measures strata.

One sample (BH104-3.2m) is identified as hazardous based on the maximum TPH concentration and the ratio of carcinogenic PAH compounds compared to oil which exceed the thresholds for hazardous property H7 (carcinogenic). The remaining thirteen samples tested for total abundance were below the thresholds for hazardous waste classifying them as non-hazardous.

Four of the samples were submitted for Waste Acceptance Criteria (WAC) testing. Results of the WAC testing indicated that two of the four samples (WS232-3.7m and WS235-3.5m) meet inert WAC and may be accepted as such. Two of the samples (WS221-3.6m and WS229-3.2m) exceed inert WAC due to slightly elevated antimony and fluoride within the eluate and are likely to be accepted as non-hazardous waste.

It is considered likely that natural material in the vicinity of BH104 may be impacted by the Markets Basement hotspot and classified as hazardous. The majority of the remaining natural may be classified as non- hazardous and inert.

9.3 Cheapside Excavation

The assessment of the Cheapside excavation is based on three samples collected from one borehole (WS259) within the area.

9.3.1.1 Made ground

All three of the samples tested comprised gravels and clay interpreted as made ground.

Two samples (WS259-0.5m and WS259-2.0m) were tested for total abundance and were below the thresholds for hazardous waste classifying them as non-hazardous.

One sample was (WS259-3.7m) was submitted for Waste Acceptance Criteria (WAC) testing. The sample exceeds inert WAC due to elevated total organic carbon and is likely to be accepted as non-hazardous waste.

Further WAC testing of made ground within the Cheapside excavation may allow the made ground material to be classified as mainly inert.

9.3.1.2 Natural

No samples of natural material were available for testing within the Cheapside excavation.

Based on the results of WAC testing from natural material in other areas of the Site it is considered likely that natural material in the Cheapside excavation may be accepted as mainly inert.

9.4 Excavation Volumes

9.4.1 Area A

From the available drawings it is calculated that Area A has an excavation area of approximately 2,900m^2. The base of excavation in Area A is taken as 91.425m AOD, this equates to an excavation volume of approximately 14,500m^3. Based on geological information from boreholes within and in the vicinity of Area A the volumes of made ground and natural material arising from Area A have been estimated as approximately 7,200m^3 and 7,300m^3 respectively. Borehole BH114 has not been included within the model as the borehole was located above a sewer and the recorded thickness of made ground is not considered representative of the area.

Based on the limited samples analysed we have broadly estimated the likely volumes of hazardous, non-hazardous and inert waste arising from the proposed excavation Area A. The estimated volumes are detailed in Table XXII.

9.4.2 Area B

From the available drawings it is estimated that Area B has an approximate excavation area of 2,700m^2. The base of excavation in Area B is taken as ranging from 90.425m to 91.475m AOD, this equates to an excavation volume of approximately 10,600m^3. Based on geological information from boreholes within the area and the vicinity, the excavation is likely to comprise made ground only.

Based on the limited samples analysed we have estimated the likely volumes of hazardous, non-hazardous and inert waste arising from the proposed excavation Area B. The estimated volumes are detailed in Table XXII.

9.4.3 Area C

From the available drawings it is estimated that Area C has an approximate excavation area of 6,300m^2. The base of excavation in Area C is taken as ranging from 90.425m to 91.475m AOD. This equates to a total excavation volume of approximately 24,700m^3. Based on geological information from boreholes within and in the vicinity of Area C, the volumes of made ground and natural material arising from Area C, have been estimated as approximately 18,000m^3 and 6,700m^3 respectively.

Based on the samples analysed we have estimated the likely volumes of hazardous, non-hazardous and inert waste arising from the proposed excavation Area C. The estimated volumes are detailed in Table XXII.

9.5 Cheapside Excavation

From the available drawings it is estimated that the Cheapside excavation has an approximate excavation area of 1,500m^2. The excavation is based on a slope from Cheapside level of 96.55m AOD down to the proposed basement formation level of 90.425m AOD as indicated on available drawings. This equates to a total excavation volume of approximately 5,000m^3. Based on geological information from one borehole within the area and boreholes within the vicinity of the area, the volumes of made ground and natural material arising from the Cheapside excavation have been estimated as approximately 3,800m^3 and 1,200m^3 respectively.

Based on the samples analysed we have estimated the likely volumes of hazardous, non-hazardous and inert waste arising from the proposed Cheapside excavation. The estimated volumes are detailed in the Table XXII.

Table XXII
Proposed Basement Excavation Areas

		Volume (m3)	
		Made Ground	Natural
Area A			
	Total	7,200	7,300
Likely Scenario			
Made Ground beneath half of Area A to an approximate thickness of 0.7m to 1.2m identified as hazardous waste. Remaining made ground identified as non-hazardous. All natural material identified as inert.	Inert	-	7,300
	Non-Haz.	5,600	-
	Haz.	1,600	-
Likely Worst Case Scenario			
The majority of made ground beneath Area A identified as hazardous. 75% of natural material identified as inert and the remaining non-hazardous.	Inert	-	5,500
	Non-Haz	2,200	1,800
	Haz.	5,000	-
Area B			
	Total	10,600	-
Likely Scenario			
Likely Scenario. Majority of made ground beneath Area B identified as inert. Limited made ground beneath borehole WS263 identified as non-hazardous.	Inert	9,300	-
	Non-Haz.	1,300	-
	Haz.	-	-
Likely Worst Case Scenario			
Approximately 25% of made ground identified as non-hazardous. Remaining made ground identified as inert.	Inert	8,000	-
	Non-Haz	2,600	-
	Haz.	-	-

Table XXII
Proposed Basement Excavation Areas

		Volume (m3)	
		Made Ground	Natural
Area C			
	Total	18,000	6,700
Likely Scenario			
Made ground beneath an area around BH102A, BH201 and TP277 identified as hazardous. Remaining made ground identified as non-hazardous and inert. Natural material identified as non-hazardous and inert.	Inert	5,700	2,200
	Non-Haz.	11,700	4,500
	Haz.	600	-
Likely Worst Case Scenario			
Approximately 25% of made ground identified as hazardous. Remaining made ground identified as non-hazardous and inert. Approximately 80% of natural material identified as non-hazardous.	Inert	3,400	1,200
	Non-Haz	10,100	5,500
	Haz.	4,500	-
Cheapside Excavation			
	Total	3,800	1,200
Possible Scenario			
Possible Scenario. Approximately 30% of made ground identified as inert and remaining non-hazardous. Natural material identified as inert.	Inert	1,300	1,200
	Non-Haz.	2,500	-
	Haz.	-	-
Subtotal - Likely Volume (m^3)	Inert	**27,000**	
	Non-Haz.	**25,600**	
	Haz.	**2,200**	
TOTAL - Likely Volume (m^3)	**54,800**		

10. GEOTECHNICAL RESULTS

10.1 Ground Conditions

The ground conditions revealed by the investigation comprise the following general material types.

10.1.1 Made Ground

Made ground is present across most of the Site and is typically between 0.5m and 4.0m thick (see Drawing No. SH03582/33). However, made ground extends to greater than 6m thickness in some areas of the Site. It consists of a mix of cohesive and granular materials, but is generally well graded with the coarser particles being angular or sub-angular. The cohesive materials are variously clays classifying as low, intermediate or high plasticity (CL, CI, or CH) on the Casagrande system, but CI materials predominate. The plasticity index is typically around 18. SPT 'N' values are variable, but it is suggested that a characteristic value (defined in accordance with BS EN 1997) of 8 is adopted for design purposes.

10.1.2 Glacial Deposits

Although not identified on geological maps material characteristic of glacial till deposits was present within areas of the Site and was particularly prevalent in the north of the Site. The deposits typically consist of gravelly clay of intermediate plasticity (CI) but contains layers or lenses of well graded sand and gravel. The plasticity index is typically around 16. SPT 'N' values are variable, but it is suggested that a characteristic value (defined in accordance with BS EN 1997) of 14 is adopted for design purposes.

10.1.3 Weathered Coal Measures

The material characteristic of glacial till deposits is in turn underlain by a stiff gravelly clay layer considered to be weathered mudstone. The clay classifies as intermediate plasticity (CI) on the Casagrande system. The plasticity index is typically around 16. SPT 'N' values are variable, but it is suggested that a characteristic value (defined in accordance with BS EN 1997) of 16 is adopted for design purposes.

10.1.4 Coal Measures

Engineering rockhead (i.e. the base of the Weathered Coal Measures) was encountered at levels of between 86 and 91m AOD, with a general easterly falling trend, beneath most of the Site west of the railway. Notable local variances include discernable depressions at about 87m AOD at the southern margin of the proposed new market area, northern end of the proposed new residential area

and in the existing Market Basement hotspot area and a gradual fall in levels towards the south and east in the proposed department store area.

East of the railway (the proposed car park area) rockhead generally falls from 86m AOD to 83m AOD from west to east.

The Coal Measures strata typically consist of mudstones, with subsidiary siltstones, sandstones and coal seams. Although the mudstones below engineering rockhead are generally fresh or slightly weathered, there are frequent thin zones of more highly weathered material, typically described as gravelly clay.

Indicative rockhead level contours are shown on Drawing No. SH03582/34.

10.1.5 Groundwater Effects

Ground water monitoring indicates main ground water levels typically at or around rockhead level over most of the Site. Simplified and inferred main groundwater contours using data from April 2008 indicate a general fall from around 92m AOD at the western boundary to around 86m AOD at the eastern boundary. The general arcuate pattern might be indicative of the existing basement acting as a hydraulic barrier. Most boreholes, however, did not encounter ground water seepages during drilling, indicating that most of the ground is of low permeability. Where seepages were encountered in the boreholes, these were typically associated with granular horizons in the made ground and glacial till deposits.

10.2 Shallow Mining

10.2.1 Introduction

The Coal Authority report in Appendix IV states that 2 seams of coal have been worked at depths between 150m and 360m, and that the Site *"…is in an area where coal is believed to exist at or close to the surface that may have been worked at some time in the past"*.

This and subsequent parts of Section 11 assess the potential for a shallow mining setting at the Site and make recommendations, as appropriate, for necessary remedial works.

10.2.2 Researches

In assessing the potential for a shallow mining instability problem at the Site, consideration has been given to:

- The published British Geological Survey (BGS) 1:10,000 Geological Mapping for the site, (sheet SE30NW, Barnsley), published in 2005;
- The Coal Authority report dated 16 January 2006;
- Stage 1 and 2 site investigation data;
- Geological Survey Memoir; Geology of the country around Barnsley; and
- Discussions with SYMAS about its data and previous site investigations.

10.2.3 Geology

The geological structure of the Site is based upon the conjectured positions of outcrops of coal seams as shown on the geological map which cannot necessarily be regarded as definitive. The outcrop positions are derived by the BGS from the best available information at the time of compilation of the map and have been assumed to provide a fair reflection of the actual geological structure beneath the Site. However, the outcrops have been redefined where the Site investigation data have shown contradictory evidence. The geological structure is also complicated by a variable coal seam sequence in the area.

The published geological mapping identifies that the Site is situated on the Pennine Middle Coal Measures. Three coal seams are reported to outcrop though the Site area; the Abdy or Winter, Top Beamshaw, and Low Beamshaw. The strata are conjectured to dip beneath the Site to the east, at approximately 5 to 8 degrees. The coal seams are indicated to be separated by thin sandstone bands, with the Lower Beamshaw Coal seam underlain by the Kent's Rock Sandstone. The Kent's Thin coal is identified as underlying the Kent's Rock.

Information published in the geological memoir states that around Barnsley the Beamshaw Coals are composed usually of either two or three seams of coal, mixed with shale. This reference to the Beamshaw coals relates to observations in the vicinity of the Barnsley railway station, which is situated in close proximity to the north of the Site. The Beamshaw seams in the vicinity of Barnsley are known to be of variable thickness and often poor quality.

The Winter/Abdy Coal is situated above the Beamshaw coals and it is stated that it averages a thickness of about 0.9m in areas, separated by at least one fine grained parting which from published observations is reported in areas to be up to several bands of dirt which can be about 0.3m in thickness.

10.2.4 Results

The results from the seven rotary open-hole and twenty-two rotary core boreholes were used in order to establish the existence or otherwise of viable coal seams at shallow depths beneath the Site (see Appendix V).

From the investigation the depth to rock head ranges from 0.3m in borehole BH203 to 8.6m in borehole BH118. The positions and datum levels of boreholes are shown on Drawing No. SH03582/28.

The Engineers logs show that four coal seams have been identified at varying depths. Coal was encountered in all open-hole and rotary core boreholes drilled.

It is considered that the Winter/Abdy coal has been encountered at shallow depth in boreholes located to the south and east of the Site, ranging from 2.5m bgl

(WS232) to 10.28m bgl (BH101). The Winter/Abdy coal is recorded as ranging from 0.58m thickness split over three leaves of coal (BH116) to 1.17m (BH101).

Borehole BH213 recorded 'soft brown ground' at a depth between 9.1m to 10m bgl in addition to total loss of drilling flush. This is at the likely horizon of the Winter/Abdy coal and could be attributed to localised old coal workings.

Boreholes BH101, BH102A, BH104 and BH220 record a coal bearing strata beneath the Winter/Abdy coal which is considered relatively insignificant and does not appear to be laterally continuous across the Site.

The Top Beamshaw coal is present in boreholes across the majority of the Site ranging from depths of between 0.3m bgl (BH203) in the west of the Site to 23.95m bgl (BH101) in the south-east of the Site. The Top Beamshaw coal varies widely in thickness and quality across the Site and is often recorded as a shaley coal or a mudstone and coal. The coal is generally subdivided into two leaves separated by a dark grey mudstone, however, it is often recorded as being a single coal and is also recorded as three coals at BH101. The Top Beamshaw ranges in thickness from 0.25m (BH219) to 1.23m split over two leaves of coal (BH201).

The Low Beamshaw coal is present in boreholes beneath the Top Beamshaw coal at depths ranging from 5.16m bgl (BH211) to 31.23m bgl (BH201). The Low Beamshaw is present generally as a single coal ranging widely in recorded thickness across the Site from 0.35m (BH104) to 1.14m including a mudstone parting (BH219).

The Engineers logs presented in Appendix V, highlight zones where no core recovery was attained or there was core loss within a run. It is likely that this relates to weak horizons being washed out with the water flush drilling technique and where the smaller TNW size core barrel was utilised for pressuremeter testing. There are three instances where the core loss is at a depth where coal seams were expected to be encountered. These are located in boreholes BH108 (5.75m to 6.6m bgl), BH117 (20.78m to 21.34m bgl) and BH212 (16.6m to 18.20m bgl).

The core loss within boreholes BH108, BH117 and BH212 are at the likely horizon of the Low Beamshaw coal. Although it is possible that the core loss at locations BH108 and BH212 could be associated with old workings in the Low Beamshaw coal drillers did not report any loss of drilling flush or change in drilling rate. It is likely that the coal may have been washed out with the water flush drilling technique. Additionally the smaller TNW core barrel was utilised at BH212 increasing the likelihood of core loss.

The zone of no recovery in borehole BH117 from 20.78m to 21.34m is situated above a possible material that could represent backfilled or collapsed workings

from 21.34m to 21.59m. This, however, given results from nearby boreholes and the overall position and structure of the Beamshaw coals in this vicinity is considered highly unlikely.

The Kent's Thin Coal is present beneath the Kent's Rock sandstone ranging from 21.86m bgl (BH205) to 35.55m bgl (BH210). The Kent's thin coal ranges in thickness from 0.33m (BH212) to 0.55 (BH210).

11. GEOTECHNICAL ASSESSMENT

11.1 Design Parameters

The following parameters have been assessed from the borehole records and the available test data (see Appendix V for detailed soil and rock testing). These parameters are characteristic values as defined by BS EN 1997, based on the testing carried out; the parameters have been derived as follows:

- Bulk unit weight γ: estimated from BS8002 Table 1;
- Undrained shear strength c_u: from test data and SPT N Values ($c_u = 5.N$);
- Apparent cohesion c': assumed;
- Angle of shearing resistance ϕ': from triaxial test data or estimated from BS8002 Table 2 for cohesive materials, and from BS8002 Table 3 for granular soils;
- Drained modulus E' for granular soils: estimated from SPT N value;
- Drained modulus E' for cohesive soils (assuming soils are compacted or over-consolidated): estimated from undrained shear strength (E'/c_u = 200 for Made Ground, 400 for other strata)

For the soil strata, the following parameters have been assessed:

Table XXI – Design Parameters

Parameter			Granular Made Ground	Cohesive Made Ground	Glacial till Deposits	Weathered Coal Measures
Bulk Unit Weight	γ	kN/m^3	19	19	22	21
SPT 'N' Value			8	8	14	16
Undrained Shear Strength	c_u	kN/m^2	-	51	150	80
Apparent Cohesion (Effective Stress)	c'	kN/m^2	0	0	0	5
Angle of Shearing Resistance (Effective Stress)	ϕ'	deg.	36°	29°	29°	30°
Drained Modulus	E'	MN/m^2	12	8	28	36

In the assessment of parameters for the bedrock, allowance has been made for the presence of clay bands within the mudstone which substantially reduces the rock mass properties of the mudstone horizons. Due to the action of the water flush during drilling, the clay layers were generally recovered in a soft condition, but in situ these materials are likely to have similar properties to the weathered coal measures materials above rockhead. Based on the data obtained from the pressure meter testing, the following rock mass modulus is suggested:

Elastic Modulus (rock mass) E_m 100MN/m^2

The bulk unit weight of the Coal Measures has been calculated from the testing data and found to be 25kN/m^3. The mudstone and siltstone also have an average SPT 'N' value of 25.

11.2 Foundations

It is noted that the majority of the existing development is founded on pad foundations in the material characteristic of glacial till deposits and Coal Measures, with design bearing pressures of the order of 1 to 4 tonnes per square foot (approximately 100 to 400kN/m^2).

Over most of the development west of the railway, engineering rockhead is typically less than 2m below the proposed lowest floor level, but rockhead is locally deeper (around 3m below the main lower slab level) in the vicinity of the proposed residential block, new market and the department store in the southern corner of the Site. For the proposed Car Park to the east of the railway, rockhead level is typically over 5m below the proposed lowest slab level. For the purposes of foundation design, the Site can therefore be divided into the following zones:

- West of Railway (excluding Department Store and Residential Block)
- East of Railway
- Department Store and Residential Block

11.2.1 West of Railway (excluding Department Store and Residential Block)

For this Zone it is considered that, in principle, pad footings at rock head are feasible. In practice, it is likely that excavations will in any case need to be taken down to close to rockhead in order to remove existing structures and foundations.

Based on the rock mass modulus suggested above, the allowable bearing pressures for pad footings at rockhead, based on a limiting maximum settlement of 25mm, are calculated to be as follows:

Table XXIII	
Footings at Rockhead	
Footing Size	**Allowable Bearing Pressure (25mm Maximum Settlement)**
2.5m Square	1300kN/m^2
4.0m Square	800kN/m^2
6.0m Square	500kN/m^2
5m x 8m	500kN/m^2

Consideration should be given to the ability of the superstructure to accommodate differential settlement and different settlement criteria may apply. It may be necessary to increase base sizes to reduce settlement.

Where coal seams are present at or close to foundation level it is suggested that the bedrock is excavated to below the coal seam and replaced with mass concrete.

11.2.2 East of Railway

Piled foundations are to be taken down to bedrock. In areas underlain by the Winter/Abdy coal the piles should be taken below the seam and socketed into intact rock. In areas which are not underlain by the Winter/Abdy coal should be socketed into rockhead.

Given that Borehole BH117 identified some anomalous ground and that pile depths may encroach to within potential influencing zone of the Low Beamshaw coal it is considered that over design of piles may be prudent on a very local basis.

11.2.3 Department Store and Residential Block

In view of the depth to rockhead in these locations and the higher column loads for these buildings, piled foundations are considered to be more appropriate.

For the part of the department store area underlain by the Winter/Abdy coal, it is recommended that any piled foundations are taken below the level of the Winter/Abdy coal. Bored cast-in-place piles are therefore likely to be more appropriate. In all other areas that are unaffected by the Winter/Abdy coal, piles may be founded below rockhead.

11.3 Floor Slabs and Pavements

Ground bearing floor slabs may be adopted on the material characteristic of glacial till deposits, weathered Coal Measures, and Coal Measures strata.

It is recommended that a sub-grade CBR value of 5% is assumed for the design of floor slabs and pavements on the material characteristic of glacial till deposits and weathered Coal Measures.

11.4 Retaining Structures

It is understood that retaining walls will be required on the western and southern sides of the proposed development to support excavations for the proposed basement levels. It is considered that contiguous bored pile walls socketed into the Coal Measures bedrock will be suitable for this purpose.

11.5 Ground Water Control

The results of the investigation indicate that ground water levels are in general below the proposed slab levels, with the exception of the western boundary where ground water levels may be slightly above the proposed slab levels. The investigations also indicate that ground is in general of low permeability.

It is possible that the contiguous bored pile wall along the western boundary of the Site may obstruct ground water flows in the long term causing some increase in ground water level in the adjoining ground along the western boundary. It is therefore recommended that consideration is given to the provision of drainage or water proofing measures to protect the building basement, primarily along the western boundary.

In the temporary case, minor ground water seepages may occur into excavations for the basement and foundations, mainly associated with granular horizons in the made ground and glacial till deposits, but it is expected that pumping from temporary sumps will be sufficient to manage the ground water ingress.

11.6 Shallow Mining

The window sampling, rotary open-hole and rotary core boreholes have identified the presence of four coal seams at depths between 0.30m and 35.55m beneath the Site. It is conjectured that the seams encountered are the Winter/Abdy, Top Beamshaw, Low Beamshaw and the Kent's Thin coals. The thicknesses of the leaves (combined where multiple) range from 0.25m to 1.23m.

Consideration is given to possible workings in two coal seams during the investigation.

The Winter/Abdy coal records possible backfill material at a depth between 9.1m to 10m bgl in addition to total loss of drilling flush at borehole location BH213. No other boreholes recorded potential working within the Winter/Abdy coal.

Research records indicate that underground workings took place in the Winter/Abdy coal approximately 200m to the north-east from Mottram Wood Colliery prior to 1920.

These activities encountered old unrecorded workings some 600m to the north-east of the Site in the vicinity of Dryden Road.

Previous investigations by SYMAS at the Alhambra centre and railway station concluded that the Beamshaw and Winter/Abdy coals in the locality have poor sections and would be incapable of economic working.

The Winter/Abdy coal varies widely in thickness where it occurs across the Site, however, it is present at potentially workable thickness in some boreholes. It is considered that the likelihood of shallow unrecorded abandoned workings being extensive beneath the Site is very low and even if present would likely be of a very limited nature. The subsequent risk of potential surface subsidence is low. However, given the sensitive nature of the development precautionary measures are recommended where the Winter/Abdy coal is present beneath the development area.

From the information gathered as part of the investigation the Winter/Abdy coal is identified as being present beneath the Zero Ice and CEAG site areas. As such precautionary measures may be required beneath the south eastern sections of the proposed department store and multi-storey car park.

In view of the above it would usually be recommended that a combination of excavation, inspection and limited precautionary investigation and stabilisation works would be completed. However, extensive basement excavation in parts of the Site will take place and effectively remove some coal seam areas. During this exercise any evidence of old workings (whilst unlikely) should be recorded and removed by extra over excavation. Remaining areas of coal if visible in the excavations should be blinded with limestone / concrete and clay to prevent spontaneous combustion. The remaining areas will be subject to piling operations beneath the base of the Winter and any significant risk of associated potential surface subsidence is effectively negated by this operation. It is not considered that any grouting is necessary to give lateral support to the piling, however, if any anomalies are recorded during piling they should be reported and considered for whether localised remedial action is necessary.

The Beamshaw Coals are recorded in the geological memoir (No. 87, Barnsley) as:

"Around Barnsley the Beamshaw Coals are usually two but sometimes three in number, and are thin seams much mixed with shale and of little value; they are sometimes exposed in the streets of Barnsley near the railway stations".

The Low Beamshaw coal in borehole BH117 records an anomalous zone at 21.34m to 21.59m bgl. Situated above this a zone of no core recovery is present from 20.78m to 21.34m. No such anomaly or any evidence of workings within the

Low Beamshaw coal was found in any other borehole during the investigations and drilling undertaken as part of the Stage 2 investigation within the vicinity of BH117. Those other boreholes record the Low Beamshaw coal to be intact. As discussed earlier the Beamshaw coals are not known or suspected as having been worked in this vicinity, where they are generally variable, thin and unproductive.

It is considered that though some very limited anomalous areas have been recorded (BH117) these are either not considered to be old workings or that they are possible old workings of such limited extent to not be of significance. Therefore, no further investigation or precautionary measures are required with regard to the Low Beamshaw coal.

However, given that Borehole BH117 did identify some anomalous ground and that pile depths may encroach to within the potential influencing zone of this horizon it is considered that over design of piles may be prudent on a very local basis.

Remaining areas of Beamshaw coals if visible in excavations should be blinded with limestone / concrete and clay to prevent spontaneous combustion.

12. SUMMARY AND CONCLUSIONS

12.1 General

The Barnsley Markets and Adjacent CEAG Sites have undergone numerous phases of development dating back to before the 1900s. Past potentially contaminative land uses include foundries, a gas works, electricity works, lamp works, railway and various other depots and works buildings.

It is proposed that the Site is redeveloped as mixed retail, markets, leisure and residential uses on the west side of the railway and a new multi-storey car park on the east side. This report summarises a preliminary Stage 1 investigation and presents a detailed geo-environmental assessment of combined Stage 1 and Stage 2 investigation data. Results are used to characterise the contamination and geotechnical conditions of the Site and more specifically allow completion of a waste classification assessment of the main areas of proposed basement excavations and completion of a geotechnical assessment of the Site to allow the preparation of detailed foundation design. The report also provides the basis for a separate detailed quantitative risk assessment and preparation of an outline remediation strategy.

12.2 Site Investigation

Observations from a variety of intrusive works have confirmed the presence of made ground comprising gravel, sand and clay with brick, mudstone, sandstone, concrete and some coal, ash and clinker over the majority of the Site. Made ground thicknesses typically varied between 0.5m and 4m. Thicker areas of made ground were recorded within the south east markets basement, Zero Ice and Open Market areas.

Natural strata materials comprised material of similar characteristics to glacial till deposits mainly in the north of the Site and comprising firm to stiff, sandy, gravelly clay and units of sandy gravels and variably weathered Coal Measures.

Weathered Coal Measures strata were identified above rockhead and generally comprised stiff gravelly clay, with the gravel fraction comprising of mudstone, and as weak thinly laminated mudstone. Variably weathered coal bearing strata were also recovered.

Bedrock generally consisted of weak to moderately strong, grey mudstone interbedded with siltstone and sandstone of the Middle Coal Measures underlain by Kent's Rock sandstone. Three coal seams interpreted as the Winter/Abdy, Top Beamshaw and Low Beamshaw coal were penetrated in strata above the

Kent's Rock. The Kent's Thin Coal was encountered beneath the sandstone at all borehole locations where Kent's Rock was fully penetrated.

Soil, groundwater and surface water samples were collected for a suite of geochemical tests comprising volatile and semi-volatile organic compounds; aliphatic, aromatic and polycyclic aromatic hydrocarbons; metals and other inorganic elements.

Bulk, small disturbed and U100 samples of made ground and natural soil strata were collected for geotechnical laboratory testing. Rock samples were selected from the recovered cores for geotechnical laboratory testing.

12.3 Contamination

12.3.1 Human Health

Analytical results were analysed using CLEA methodology to assess the risk to human health in an industrial/commercial scenario. Concentrations of metals, semi-metals and non-metals recorded across the Site were not considered to present a significant possibility of significant harm to long term human health. However, the recorded concentrations of arsenic, nickel and phenols may be significant with respect to construction workers. All future groundwork on Site should be designed and planned to minimise the exposure of workers to contaminated soil.

The site investigation identified visual and olfactory evidence for hydrocarbon contamination at numerous site investigation locations. However, the maximum recorded concentrations of petroleum hydrocarbons, PAH, SVOC and VOC are below the relevant screening criteria for the majority of samples taken from across the Site. The exceptions to this are samples from the May Day Green, Markets Basement and southern CEAG Hotspots.

12.3.1.1 May Day Green Hotspot

Two samples from May Day Green recorded elevated concentrations of benzo(a)pyrene which may present a significant possibility of significant harm to long-term human health. However, all contaminated made ground within the May Day Green area is designated for disposal off-site as part of basement excavations. Therefore, the recorded benzo(a)pyrene concentrations within the May Day Green area are not considered to present a significant risk to long-term human health.

12.3.1.2 Markets Basement Hotspot

Numerous samples in the vicinity of borehole WS105A located in the southeast Markets Basement recorded elevated petroleum hydrocarbons, PAH, SVOC and VOC. It is considered unlikely that this contamination poses a significant risk to

long term human health via dermal contact and/or ingestion of soil pathways due to the depth of contamination being generally greater than 3m bgl and concrete hard standing overlying the made ground. However, it is considered plausible that the more volatile petroleum hydrocarbons, SVOC and VOC may pose a significant risk to human health via the inhalation of vapours. Further modelling is required to quantify the risk posed by volatile contaminants to human health.

Based on the location and type of the contaminated strata it is considered likely that the source may relate to former use of the area as a gas works.

12.3.1.3 Southern CEAG Site

Made ground identified from samples obtained from the southern CEAG site recorded elevated concentrations of benzo(a)pyrene which may present a significant possibility of significant harm to long-term human health. Further modelling is required to assess the potential risk posed by benzo(a)pyrene to human health.

12.3.2 Groundwater

The Site is situated above a minor aquifer. The closest sensitive groundwater abstraction is 900m west of the Site (upgradient) and the culverted Sough Dyke flows from east to west beneath the Site. The nearest graded surface watercourse is the River Dearne, which is approximately 900m north-east of the Site.

The concentrations of most chemicals of concern recorded within groundwater beneath the majority of the Site are below adopted screening criteria. The exceptions to this are samples from the Markets Basement and Southern CEAG Hotspots.

12.3.2.1 Markets Basement Hotspot

Groundwater monitoring in the vicinity of the Markets Basement Hotpsot indicates distinct shallow and deeper groundwater bodies within made ground and Coal Measures strata. Significant contamination is only identified in the shallow groundwater suggesting that the shallow and deeper groundwater bodies are not hydraulically connected in this part of the Site.

Elevated concentrations of arsenic, cyanide, selenium, sulphate, zinc, petroleum hydrocarbons, PAH, SVOC and VOC are recorded in shallow soil and groundwater within the Markets Basement Hotspot. These elevated concentrations are generally not considered to pose a significant risk to long term human health as the nearest sensitive groundwater abstraction is almost 1km up gradient. However, due to the close proximity of the Sough Dyke the elevated concentrations may pose a risk to environmental receptors. Further modelling is required to quantify the potential risk to environmental receptors.

The more volatile petroleum hydrocarbons, SVOC and VOC may pose a risk to human health via the inhalation pathway. Further modelling is required to quantify this risk.

12.3.2.2 Southern CEAG Hotspot

Groundwater levels in boreholes east of the railway suggest that groundwater within made ground and Coal Measures are in hydraulic continuity and are likely to represent a single aquifer.

Elevated concentrations of selenium, TPH and PAH are recorded within soil and groundwater beneath the southern CEAG hotspot. These elevated concentrations are not considered to pose a significant risk to long term human health. However, due to the close proximity of the Sough Dyke the elevated concentrations may pose a risk to environmental receptors. Further modelling is required to quantify the potential risk to environmental receptors.

12.3.3 Surface Water (Sough Dyke)

Two rounds of sampling and geochemical testing has been used to complete a preliminary assessment of water quality in the Sough Dyke. The maximum recorded concentrations for metals, TPH were all below Environmental Quality Standards.

Slightly elevated concentrations of PAH, SVOC and dichloromethane indicate minor impact from these compounds. However, the concentrations are considered to be indicative of background quality and not contamination identified on Site.

In addition, several water quality indicators suggest a classification of Sough Dyke as Grade E or Poor (GQA, Environment Agency).

12.3.4 Ecology

Arsenic, chromium and nickel were recorded at concentrations which may pose a risk to sensitive plant growth.

It is considered that the recorded metal concentrations are unlikely to pose a significant risk to standard tree and hedge planting. Risk to plant growth would be further reduced by the use of tree pits with imported soil as proposed on Camlin Lonsdale drawing, Typical Details: Tree Pit and Anchoring System (Dwg. Ref. 519 LAL (90) 001).

There is a history of recorded knotweed presence alongside the railway, but off Site. Treatment of the knotweed should be investigated as part of the construction programme.

12.3.5 Buildings and Property

Results for sulphate (2:1 extract) concentration indicate that a design sulphate class of DS-4 and Aggressive Chemical for Concrete (ACEC) class of AC-3 may be appropriate for the Site.

Due to the presence of the potentially corrosive and/or organic contaminants it is recommended that wrapped iron or polythene/aluminium/polythene (PE/Al/PE) pipe material be used should water supply pipework be installed as part of the redevelopment works.

12.3.6 Ground Gas

The presence and concentrations of ground gases was monitored on ten occasions, predominantly at atmospheric pressures of less than 1000mb over an eight month period.

Methane concentrations ranging from 0.3% at BH104 to 7.3% at BH202 were recorded in five boreholes across the Site. It is considered that elevated methane concentrations are a result of a combination of natural methane production from underlying coal seams, anaerobic decomposition of organic matter and vapours from impacted hydrocarbon soils and groundwater.

Slightly elevated carbon dioxide concentrations ranging from 0.1% to 7.1% were recorded across the majority of the Site during the monitoring period. The maximum recorded carbon dioxide concentrations were generally recorded at borehole BH108 which as previously indicated intersected a shallow coal seam. This suggests that the coal seam may be the likely source of carbon dioxide in this case.

Flow rates recorded during the ten monitoring visits were predominantly very low with a maximum flow rate of 1l/hr.

Boreholes BH104, BH207s and BH207d are located within the Markets Basement hotspot where soils and groundwater are impacted by hydrocarbon contamination. It is considered that the elevated methane readings taken from these boreholes are likely to comprise vapours from short chain hydrocarbons. As impacted material within this area is to undergo remediation the monitoring results have been discounted for the purposes of the risk assessment.

It is considered appropriate that the Site is divided into two zones based on the conceptual site model. The model identifies different site uses and variance in ground gas results between the eastern and western sides of the railway. East of the railway the Site is to be developed as multi-storey car parking with no basement. Gas monitoring results include only one slightly elevated methane concentration and relatively low carbon dioxide concentrations. West of the railway the Site is to be developed for commercial land use with basement areas

and above ground level residential apartments. Recorded results include five elevated methane concentrations in two boreholes (excluding previously discounted results) and elevated carbon dioxide concentrations.

12.3.6.1 East of Railway

A worst case GSV of 0.053l/hr has been calculated for the Site east of the railway. The conceptual site model and gas monitoring data indicates classification of the site east of the railway as Characteristic Situation 1(very low risk) based on a low sensitivity (commercial) end use, moderate gas hazard and a GSV of less than 0.07l/hr. However, as methane has been recorded above 1% consideration should be given as to whether the Site should be reclassified as Characteristic Situation 2 (low risk).

Overall, it is considered that a Characteristic Situation 1 is appropriate to the Site east of the railway based on a proposed low sensitivity end use and only one recorded elevated methane concentration.

12.3.6.2 West of Railway

A worst case GSV of 0.06l/hr has been calculated for the Site west of the railway. The conceptual site model and gas monitoring data indicates classification of the Site west of the railway as Characteristic Situation 1 (very low risk) based on a low sensitivity (commercial), moderate gas hazard and a GSV of less than 0.07l/hr. However, as methane has been recorded above 1% consideration should be given as to whether the Site should be reclassified as Characteristic Situation 2 (low risk).

It is considered that a Characteristic Situation 2 is appropriate to the Site west of the railway due to consistently elevated carbon dioxide concentrations and elevated methane concentrations.

12.3.7 Waste Classification

A waste classification assessment was conducted on the material from three main areas of proposed basement excavation together with the Cheapside excavation. It includes an estimate of the likely excavation volumes and approximate proportions of made ground and natural material within these areas, and their likely waste classification upon disposal to landfill. In addition to this assessment, further testing of the material is recommended following excavation to ensure that the classification is representative and to meet landfill acceptance requirements.

The total excavation volume of the four excavation areas is likely to be in the order of 54,800m^3. Approximately 27,000m^3 of this is likely to be accepted as inert, 25,600m^3 as non-hazardous and 2,200m^3 as hazardous waste.

A breakdown of volumes and classification of excavation material for each area can be found within Section 9.

12.4 Geotechnical

12.4.1 Foundations

For the purposes of foundation design, the Site has been divided into the following zones, for which the following solutions have been considered:

12.4.1.1 West of Railway (excluding Department Store and Residential Block)

For this Zone it is considered that, in principle, pad footings at rock head are generally viable. In practice, it is likely that excavations will in any case need to be taken down to close to rockhead in order to remove existing structures and foundations.

12.4.1.2 East of Railway

Piled foundations are to be taken down to bedrock. In areas underlain by the Winter/Abdy coal the piles should be taken below the seam and socketed into intact rock. In areas which are not underlain by the Winter/Abdy coal should be socketed into rockhead.

Given that Borehole BH117 did identify some anomalous ground and that pile depths may encroach to potential influencing zone of this horizon it is considered that over design of piles may be prudent on a very local basis.

12.4.1.3 Department Store & Residential Block

In view of the depth to rockhead in these locations and the higher column loads for these buildings, piled foundations are considered to be more appropriate.

For the part of the department store site underlain by the Winter/Abdy coal, it is recommended that any piled foundations are taken below the level of the Winter/Abdy coal. Bored cast-in-place piles are therefore likely to be more appropriate. In all other areas that are unaffected by the Winter/Abdy coal, piles may be founded below rockhead.

Specific design parameters for all the above have been considered and included within Section 11.

12.4.2 Floor Slabs and Pavements

Ground bearing floor slabs may be adopted on the material characteristic of glacial till deposits, weathered Coal Measures, and Coal Measures strata.

Specific design parameters have been considered and included within Section 11.

12.4.3 Retaining Structures

It is understood that retaining walls will be required on the western and southern sides of the proposed development to support excavations for the proposed

basement levels. It is considered that contiguous bored pile walls socketed into the Coal Measures bedrock will be suitable for this purpose.

12.4.4 Groundwater Control

The results of the investigation indicate that ground water levels are in general below the proposed slab levels, with the exception of the western boundary where ground water levels may be slightly above the proposed slab levels. The investigations also indicate that ground is in general of low permeability.

It is possible that the contiguous bored pile wall along the western boundary of the site may obstruct ground water flows in the long term causing some increase in ground water level in the adjoining ground along the western boundary. It is therefore recommended that consideration is given to the provision of drainage or water proofing measures to protect the building basement, primarily along the western boundary.

12.4.5 Shallow Mining

Boreholes identified the presence of four coal seams at depths between 0.30m and 35.55m beneath the Site. It is conjectured that the seams encountered are the Winter/Abdy, Top Beamshaw, Low Beamshaw and the Kent's Thin coals. The thicknesses of the seams range from 0.25m to 1.23m.

Consideration is given to possible workings in the Winter/Abdy and Low Beamshaw coal seams during the investigation.

The Abdy/Winter coal varies widely in thickness across the Site, however, it is present at potentially workable thickness in some boreholes. It is considered that the likelihood of shallow unrecorded abandoned workings beneath the Site is low and even if present would be of a very limited nature. The subsequent risk of potential surface subsidence is low. However, given the sensitive nature of the development precautionary measures are recommended where the Winter/Abdy coal is present beneath the development area.

It is considered that though some very limited anomalous areas have been recorded within the Low Beamshaw coal (BH117) these are either not considered to be old workings or that they are possible old workings of such limited extent to not be of significance. Therefore, no further investigation or precautionary measures are generally required with regard to the Low Beamshaw coal.

13. RECOMMENDATIONS

Based on the conclusions presented above the following items of work or design considerations are recommended.

13.1 Contamination

- Further assessment in the form of a detailed quantitative risk assessment is required to establish the risk posed by identified contamination within the Markets Basement and southern CEAG hotspots to human health and environmental receptors. This should also include generation of remedial targets if required. This additional assessment will be documented in a separate remediation strategy report for the proposed development.
- Gas monitoring has identified slightly elevated concentrations of methane and carbon dioxide beneath the Site. Gas protection measures are recommended on the area of the Site located west of the railway.
- Basic protection against radon is required for residential dwellings or new structures of similar form of construction on the Site.
- Investigation of the apparent treatment history of Japanese knotweed alongside the railway.
- Consideration to the soft landscape planting where proposed in areas of soils with elevated metal concentrations.
- Wrapped iron or polythene/aluminium/polythene (PE/Al/PE) pipe material to be used for water supply pipework to be installed as part of the redevelopment works.
- The use of PPE to minimise exposure of workers when undertaking demolition and construction work.
- Sulphate results indicate that a design sulphate class of DS-4 and Aggressive Chemical for Concrete (ACEC) class of AC-3 may be appropriate for the Site.

13.2 Geotechnical

Broad zoning of piled and pad foundations has been identified for the development from the site investigation. Consideration should be given to the ability of the superstructure to accommodate differential settlement and different settlement criteria may apply. It may be necessary to increase base sizes to reduce settlement.

Provision of drainage or water proofing measures to protect the building basement should be considered, primarily along the western boundary.

Where coal seams are present at or close to foundation level it is suggested that the bedrock is excavated to below the coal seam and replaced with mass concrete. Any evidence of old workings (whilst unlikely) should be recorded and removed by extra over excavation. Any anomalies should be reported and considered for whether localised remedial action is necessary. Remaining areas of coal if visible in the excavations should be blinded with limestone / concrete and clay to prevent spontaneous combustion.

Where the development is underlain by the Winter/Abdy coal (parts of department store and multi-storey car park areas), it is recommended that any piled foundations are taken below the level of the Winter/Abdy coal. For the Low Beamshaw coal it is considered that over design of piles may be prudent on a very local basis around borehole BH117 area on the site east of the railway. It is not considered that any grouting is necessary to give lateral support to the piling, however, if any anomalies are recorded during piling they should be reported and considered for whether localised remedial action is necessary.

