LITHOS

Geoenvironmental Appraisal

Land at Westgate, Cleckheaton

For Strata Homes Ltd

Report no: 3043/2C

Date: May 2021

SUMMARY OF GEOENVIRONMENTAL ISSUES

Job No.	3043	**Site area/ha**	6.5
Client:	Strata Homes Ltd	**NGR:**	SE 184 250
Site:	Westgate, Cleckheaton	**Nearest postcode:**	BD19 3NW

The site is located off Westgate, approximately 1km east of Cleckheaton town centre, and currently comprises a roughly square single parcel of former industrial land. The site has been split into 4 areas based on former uses:

- Area A (1.1 ha in north-west) – Former Westgate Chemical works. Ward Fabrication currently occupies the north, with open rough ground to the south.
- Area B (1.7 ha, south) – Former Rolling Iron Mill and Wharfe Textile Mill, with an infilled reservoir in the west corner and Blacup Beck along the southern boundary. Most buildings have been demolished, with a small section of Wharfe Mill still occupied.
- Area C (2.0 ha, east) – Former scrap yard, malthouse, brickworks and quarry. Little evidence of former land use remains. The area is very uneven with a level change of approximately 5m between the south and north.
- Area D (1.6 ha, central and north) – Central industrial units occupied by Garnet Wires, in the central warehouse. Evidence of small units in surrounding area, although all now at slab level. Car park located in the north.

Lithos were commissioned by Strata to provide a geoenvironmental appraisal of the site, which it is understood is to be redeveloped with housing. Lithos' investigation included a review of 3rd party reports, the site's history and environmental setting, and a ground investigation comprising 50 trial pits.

A summary of salient geoenvironmental issues is provided in the table below.

Issue	Remarks
Quarrying	This site has been subject to quarrying for Sandstone and/or Clay, with three areas of quarrying shown on the 1894 OS plan: • Brickworks Quarry (c. 9,000m²) in the east (Area C). • An oval-shaped area (c. 750m²) in the centre-north (Area D). • A roughly square-shaped area (c. 1,500m²) in the north-west (within Area A). The 1894 OS plan shows a rectangular area (c. 100m by 22m) in the south of the brickworks quarry, with cliff faces shown. This suggests high walls here are likely to be very steep, possibly sub-vertical. Trial pitting/trenching can only investigate the dip of high walls within about 4m of ground level, hence there are difficulties where thicker made ground exists. Furthermore, high walls are likely to steepen with depth, as more competent rock is encountered. Rotary drilling with lines of probeholes (at 2m to 3m centres) running across the high walls would provide a better indication of high wall dip.
Mining	Whilst the site lies within a Coal Authority Low Risk area, no significant risks have been identified, and an intrusive mining investigation will not be required.
Made ground	The made ground on site is a heterogeneous mixture of materials, but Ash & Clinker was encountered in the majority of pits, with Cohesive and Granular Made Ground also common. Review of the trial pit logs (and historical maps) suggests made ground thicknesses are: • >2.5m across an area of c. 26,000m² (c. 40% of the total site area). It is likely that made ground across an area of c. 9,000m² (within former Brickworks Quarry) is 10m to 18m deep. • 1.5 to 2.4m across c. 12,500m² (c. 20%) • <1.5m across c. 26,500m² (c. 40%) There is a backfilled reservoir (c. 1,000m²) in the north-west of Area B. Previous investigations suggest a backfill depth of around 4m. Significant below ground obstructions were encountered across the site associated with former foundations, buildings, below ground storage tanks and basements.
Natural ground	Encountered in the majority of pits excavated beyond areas of deep quarry backfill and comprising residual soils (gravelly clays and clayey gravels), with sandstone/mudstone (Coal Measures) bedrock below from around 2.5m. An area of Alluvial deposits (soft grey and brown clay) underlies all but the centre-north and far south of Area B; extent (c. 12,500m²).

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Issue	Remarks
Contamination	Some gross organic contamination has been encountered in Area A and remediation or breakage of pathways will be required. Given historic uses some will likely be encountered during the proposed remediation works and it would be prudent to allow for the off-site disposal of some grossly contaminated soil. Significant inorganic contamination was identified across site along with asbestos fibres and fragments of suspected asbestos cement sheet. Anecdotal evidence suggests an unknown quantity of asbestos was dumped within Area A; exact location unknown. A minimum 1,000mm clean cover system is likely to be required underlain by a 150mm hard dig layer or Lotrak Alarm 18 high visibility contaminated land marker barrier in all garden and landscaped areas. Site-specific risk assessment is required in order to determine remedial target concentrations (health) and potential risks to ground and surface waters. Two further rounds of groundwater sampling are yet to be completed and will be required in order to support the site-specific risk assessment and enable preparation of a Remediation Strategy.
Hazardous gas	The site is in an area where 1% to 3% of homes are estimated to be above the radon action level. There is deep made ground across much of the site and an area of landfill is located just beyond the southern boundary. Gas monitoring is ongoing and on completion a hazardous gas risk assessment will be issued. At this stage it would be prudent to assume that protective measures will be required in all new dwellings.
Preparatory works	Site clearance of all trees/shrubs and all 'fly-tipped' rubbish. Demolition of remaining buildings, along with grubbing up of any in-situ concrete slabs and relict foundations. Turnover of the full thickness of made ground (beyond deep quarry backfill), and the uppermost 3m of made ground within quarry backfill. Re-grade to achieve development levels. Blacup Beck will likely need diverting if it cannot be incorporated into the proposed layout. A Remediation Strategy cannot be finalised prior to completion of the ongoing groundwater sampling programme and subsequent site-specific risk assessment.
Foundations	Foundation solutions here are primarily driven by thicknesses of made ground, and to a lesser extent by the presence of Alluvium in Area B. Shallow strip or deepened trench fill footings will be a suitable foundation solution where made ground is less than about 2m thick (c. 35% of the total site area) and underlying natural soils comprise weathered Coal Measures (not Alluvium). A piled foundation solution is likely to be required across c. 65% of the site. Any plot layout for this site should take account of the known high walls. The anticipated significant earthworks regrade should allow contouring of the base of made ground beyond the deep quarry backfill and this in turn should allow the preparation of a plot-specific foundation schedule.
Groundwater & excavations	Groundwater was encountered within the majority of exploratory holes (particularly in the south; Area B) as seepages and inflows from around 2.0m. Localised perched waters were encountered within backfilled features (basements, reservoir etc). Spalling and overbreak of excavations occurred in the majority of trial pits within the made ground. Particularly where coarse granular deposits were encountered. Excavations through the soft Alluvial deposits also exhibited some instability. However, excavations in firm/stiff clays and clayey gravels (Residual Soils) should remain stable during the construction phase in the short term.
Flooding & drainage	The EA indicate that the majority of site is not located within an indicative floodplain, however the south is located in Flood Zone 2 & 3 due to the presences of Blacup Beck. Due to significant thicknesses of made ground soakaways will not provide a suitable drainage solution. Consequently, it will be necessary to consider alternative sustainable drainage systems (SUDS), and there may be a need for surface water balancing.
Highways	Made ground is present across the majority of the site, typically to depths of around 2m, and consultation with the adopting authority, regarding the specification of the highways, is strongly recommended. Where made ground is present it should be excavated and either replaced with suitable aggregate, or screened, to allow selection of suitable material, before being replaced in engineered layers. Where the made ground is re-engineered it is considered that a CBR value of at least 3% should be achievable. However, this should be verified by field trials.

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Significant developer abnormals relating to geoenvironmental issues at the site are:

- Demolition of existing buildings/foundations and grubbing up of hardstand.
- Turnover of the full thickness of made ground (beyond deep quarry backfill), and the uppermost 3m of made ground within quarry backfill
- Re-grade to achieve final development levels.
- Diversion of Blacup Beck.
- Roughly 60% of plots will require a piled foundation solution; consideration of high walls will be important - piles must be socketed into rock and not allowed to deflect off the high wall.

Gas monitoring and groundwater sampling is in progress; but some further work is required, most notably:

- Post-vacation and post-demolition trial pitting in previously inaccessible areas.

Environmental Permits associated with the former scrap yard will need to be surrendered. Permit surrenders can take a considerable time and consideration should be given to running the surrender process parallel to any planning consultation period.

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Appendix E - Search responses

From	Date	Content
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Appendix F to H - Exploratory records

Appendix F	TPs 402 to 449, 501 to 525 & TTs 401, 411, 428 & 431
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Appendix G - Chemical test results

Appendix H – Geotechnical test results

Appendix I – Gas monitoring results

FOREWORD (geoenvironmental appraisal report)

This report has been prepared for the sole internal use and reliance of the Client named on page 1. This report shall not be relied upon or transferred to any other parties without the express written authorisation of Lithos Consulting Limited (Lithos); such authorisation not to be unreasonably withheld. If any unauthorised third party comes into possession of this report, they rely on it at their peril and the authors owe them no duty of care and skill.

This report has been reviewed by a Competent Person, as defined in the National Planning Policy Framework. We ensure that all projects are managed by individuals with necessary experience, relevant qualifications, and current membership of a relevant professional organisation. Records of engineers, project managers and reviewers involved in this project are maintained by us. Lithos QA/QC procedures for all our work forms an integral part of our ISO9001 accreditation and as such is regularly audited.

The report presents observations and factual data obtained during our site investigation and provides an assessment of geoenvironmental issues with respect to information provided by the Client regarding the proposed development. Further advice should be sought from Lithos prior to significant revision of the development proposals.

The report should be read in its entirety, including all associated drawings and appendices. Lithos cannot be held responsible for any misinterpretations arising from the use of extracts that are taken out of context. However, it should be noted that in order to keep the number of sheets of paper in the hard copy to a minimum, some information (e.g. full copy of the Landmark/Groundsure Report) is not included in the pdf, by request, it can be provided on a CD.

The findings and opinions conveyed in this report (including review of any third-party reports) are based on information obtained from a variety of sources as detailed within this report, and which Lithos believes are reliable. Reasonable care and skill has been applied in examining the information obtained. Nevertheless, Lithos cannot and does not guarantee the authenticity or reliability of the information it has relied upon.

The report represents the findings and opinions of experienced geoenvironmental consultants. Lithos does not provide legal advice and the advice of lawyers may also be required.

Intrusive investigation can only investigate shallow ground beneath a small proportion of the total site area. It is possible therefore that the intrusive investigation undertaken by Lithos, whilst fully appropriate, may not have encountered all significant subsurface conditions. Consequently, no liability can be accepted for conditions not revealed by the exploratory holes. Any opinion expressed as to the possible configuration of strata between or below exploratory holes is for guidance only and no responsibility is accepted as to its accuracy

It should be borne in mind that the timescale over which the investigation was undertaken may not allow the establishment of equilibrium groundwater levels. Particularly relevant in this context is that groundwater levels are susceptible to seasonal and other variations and may be higher during wetter periods than those encountered during this commission.

Where the report refers to the potential presence of invasive weeds such as Japanese Knotweed, or the presence of asbestos containing materials, it should be noted that the observations are for information only and should be verified by a suitably qualified expert.

This report assumes that ground levels will not change significantly from those existing at present and that houses will be of two storey construction. If this is not to be the case, then some modification to this report may be required.

Lithos cannot be responsible for the consequences of changing practices, revisions to waste management legislation etc that may affect the viability of proposed remediation options.

Lithos reserve the right to amend their conclusions and recommendations in the light of further information that may become available.

GEOENVIRONMENTAL APPRAISAL
of land at
WESTGATE, CLECKHEATON

1 INTRODUCTION

1.1 The commission and brief

1.1.1 Lithos Consulting Limited were commissioned by Strata Homes to carry out a geoenvironmental appraisal of land off Westgate, Cleckheaton.

1.1.2 This document is a revision of the Geoenvironmental Appraisal (Report 3043/2b) issued by Lithos in November 2020; Report 3043/2b is now superseded. The only significant revisions to 3043/2b have been made to Drawing 3043/2 and 3043/12.

1.1.3 Correspondence regarding Lithos' appointment, including the brief for this investigation, is included in Appendix C. The agreed scope of works included:

- A review of third-party reports.
- A site walkover and inspection.
- An assessment of the land use history.
- Determination of the site's environmental setting.
- A mining risk assessment in accordance with Coal Authority guidance.
- An intrusive ground investigation comprising 77 trial pits, 20 rotary open probeholes, 10 groups of 'stitch' probeholes and 9 cable percussion boreholes including 3 cable percussion boreholes with rotary cored follow-on.
- Assessment of the geotechnical properties of the near surface deposits to enable provision of foundation and highway recommendations.
- A qualitative assessment of contamination risks.
- Recommendations for the necessary site preparatory and remediation works.

1.1.4 Primary aims of this exploratory phase of investigation were to identify salient geoenvironmental issues in order to support the submission of a planning application, and also to enable Strata to obtain budget costs for: foundations; gas protection measures; and site preparatory and remediation works.

1.2 The proposed development

1.2.1 It is understood that consideration is being given to redevelopment of the site with a total of 200 'traditional' two/three storey domestic dwellings with associated gardens and adoptable roads and sewers. A site layout has been provided 'Westgate, Cleckheaton, sketch layout', ref. 18-CL2-SEGB-WE-01 Rev P, dated April 2021 which is reproduced in Drawing 3043/2 in Appendix B to this report.

1.3 Report format and limitations

1.3.1 All standard definitions, procedures and guidance are contained within Appendix A, which includes background, generic information on:

- Assessment of the site's environmental setting
- Ground investigation fieldwork
- Geotechnical testing
- Contamination testing
- Hazardous gas

1.3.2 General notes and limitations relevant to all Lithos geoenvironmental investigations are described in the Foreword and should be read in conjunction with this report. The text of the report draws specific attention to any modification to these procedures and to any other special techniques employed.

2 SITE DESCRIPTION

2.1 General

2.1.1 The site's location is shown on Drawing 3043/1 presented in Appendix B to this report. Site details are summarised in the table below:

Detail	Remarks
Location	1km west of Cleckheaton town centre.
NGR	SE 184 250
Approximate area	6.5 ha (16 acres).
Known services	Underground electric, water, BT, sewer and gas.

2.2 Site features

2.2.1 Lithos undertook a walkover survey on the 13th December 2018, and subsequently returned to complete further works in January 2019 and September 2020.

December 2019

2.2.2 Existing salient features, at the time of the initial walkover are presented on Drawing 3043/3 in Appendix B to this report and are summarised in the table below:

Feature	Remarks
Current access	Off Westgate (road to the north), via two estate roads; Stone St. & Iron St.
Topography	Undulating across much of the site with plateaus corresponding to historic land uses. Steep embankments in the south-east (within Area C); land in the south-east is 3m to 6m lower than adjacent land to the north & west. Retaining wall identified to south of former chemical works and in location of former malt house. Site levels tie into surrounding land to the to north and east. Land to the south slopes up to grazing pasture beyond Blacup Beck.
Approximate areas	6,500m² buildings & 6,500m² concrete slabs 51,500m² hardstanding and rough ground
Nature of boundaries	No consistent boundaries, mixture of wire fencing, metal palisade fencing and open access. All fenced areas have been breached with open public access to the entire site.
Surrounding land uses	North & east – residential properties. South – rough grassed pasture land. West – industrial units beyond Brick Street

2.2.3 A selection of site photographs are included on Drawing 3043/5.

2.2.4 Access can be gained off Stone Street (centre-north) and Iron Street (northwest). Both streets open onto Westgate which runs east to west beyond the northern boundary.

2.2.5 The site can be considered as **four** distinct areas; each area is shown on Drawing 3043/3. Areas are based on former land uses (described further in Site History; see Section 3 below) which still dominate the current site features.

- Area A (1.1 ha) - former chemical works in the north-west.
- Area B (1.7 ha) - former rolling mill in the south & south-west.
- Area C (2.0 ha) - former Scrap Yard, Malthouse, Brickworks and Quarry in the east.
- Area D (1.6 ha) - industrial area in the centre-north

Area A (Former Chemical Works)

2.2.6 Occupied by Ward Fabrication with a single warehouse and rough concrete hardstand yard. Numerous skips and trailers were located around the boundary to provide makeshift security to the perimeter of Area A. No access to the building was gained during the walkover, but it is understood the company store automotive parts and fabricate trailers.

2.2.7 To the south, all former buildings have been demolished and the area is heavily overgrown and undulating, with small trees and rough grasses; little evidence of the former chemical works remains.

2.2.8 Area A lies approximately 1m above Brick Street to the west and the former Mills to the south. A c. 1.0m high retaining wall, which is of brick and sandstone block construction, runs roughly east to west along the southern boundary of the area.

2.2.9 During the site investigation a former tenant of Area A indicated that the old buildings within this area had basements which he had filled in. The basements are suggested to have been located to the south of the remaining warehouse building in Area A; see Drawings 3043/3 & 3043/4. The former tenant also suggested that an unknown quantity of asbestos was dumped within Area A by another party, which he then filled over. The exact location of this 'burial pit' is unknown.

2.2.10 Areas of hardcore around the existing building is understood to have been 'levelled' by importing burnt shale (origin unknown) which has been spread out and tracked in using a wheeled excavator.

Area B (Rolling Mill and Wharfe Mill)

2.2.11 The footprint of the former Rolling Mill is still evident and is surrounded by piles of bricks, presumably from demolition works. OS plans (see Section 3) show a reservoir (footprint c. 1,000m^2) in the north-west of Area B, but it is no longer evident and is heavily vegetated. Part of the former Wharfe Mill is still standing, surrounded by concrete hardstanding - evidence of the extent of the entire Mill. Anecdotal evidence suggests that the reservoir was associated with the chemical works (Area A) rather than the former mills.

2.2.12 About 50% of the Wharfe Mill building remains and comprises a single brick-built building with a sheet metal/stone tile clad roof. The building appears to be in fairly poor repair with visible deformation of the walls and rooflines.

2.2.13 The Wharfe Mill Building remains in use by a company who repair and refurbish large lorry trailers. Processes within the building comprise:

- Deconstruction and assembly of trailers.
- Painting and spraying.
- Draining and refilling of hydraulic systems.
- Fabrication of wooden and metal components.
- Operation of towing and lifting plant (lorries & forklifts)
- Parking of trailers and lorries/commercial vehicles.

2.2.14 The area surrounding the buildings is level, although there is an incline from the north of Wharfe Mill toward the former quarry in Area C.

2.2.15 Blacup Beck flows east across Area B, coming out of culvert in the south west corner and returning to culvert south of Rolling Mill. The condition of the un-culverted section of beck was poor with much fly tipping which obstructed surface water flow.

Area C (Former Scrap Yard, Malthouse, Brickworks and Quarry)

2.2.16 An earth bund separates Area C from the rest of the site. Levels across Area C vary by up to 6m, with steep embankments in the south-east where land is 3m to 6m lower than adjacent land to the north & west.

2.2.17 Part of a retaining wall of the former Malthouse is still evident. Little evidence of historic activities remain, with much of the site covered with dense vegetation and small trees.

2.2.18 A former Quarry lies within of Area C (see Section 4.3) but is no longer evident; the area is now covered by rough tarmac chippings.

2.2.19 The southwest of the area is surfaced by macadam chippings (hardcore) which makes up an area of hardstanding used for parking and trailer storage.

Area D (industrial area, centre-north)

2.2.20 This area is a mix of hardstanding, fly tipped waste and old cobble tracks. Evidence of former buildings can be seen where slabs remain.

2.2.21 The north of Area D is surfaced my macadam chippings (hardcore) and is used as a car park. The car park is secured by a combination of metal bollards, concrete barriers and a security gate around the perimeter. Access to the car park is gained off Stone Street (in turn accessed off Westgate).

2.2.22 Garnett Wires still occupy the central warehouse and a car park has been established on the northern boundary between Iron Street and Stone Street.

2.2.23 Again, levels across Area D undulate, likely where demolition and other waste material have been placed and covered by vegetation.

2.2.24 Vehicle access to both Wharfe Mill and Ward Fabrication is via Stone Street, to the rear of Garnett Wire and back up Iron Street.

September 2020

2.2.25 At the time of Lithos' supplementary visits to the site the following significant changes were noted:

- Garnett Wires no longer occupied buildings in Area D; these buildings were out of use, fenced off with heras fencing, and in a generally poor state of repair.
- The building in Area A was no longer in use by the fabrication company, but was partly occupied by a company which stripped vehicles for cosmetic parts (panels, bumpers etc). A caravan was located in Area A which was used to provide overnight security.
- External areas had become broadly more overgrown with semi-mature self-seeded trees, grasses, weeds and shrubs.
- Several trailers were parked across hardcore in the southwest of Area C which had been vandalised and burnt.

2.3 Site operations

2.3.1 At the time of the initial walkover the site is used by Ward Fabrication, Garnett Mill and individuals in Wharfe Mill (operations unclear).

2.3.2 The car park in the north of Area D is used by a confectionary factory located off-site to the north for employee parking.

3 SITE HISTORY

3.1 Site centred extracts from Ordnance Survey (OS) plans dating back to 1854 have been examined. Some of these plans are presented in Appendix D to this report.

3.2 The table below provides a summary of the salient points relating to the history of the site. It is not the intention of this report to describe in detail all the changes that have occurred on or adjacent to the site. Significant former uses/operations are highlighted in **bold** text for ease of reference.

Date	Site	Surrounding land
1854	Open fields with **sandstone quarry** labelled in the east.	Brook Mill 130m east. Open fields to the south and west. Westgate Road to the north. **Colliery** approximately 200m north including a number of wells and shafts.
1894	Three areas of **quarrying** are shown: • Brickworks Quarry (c. 9,000m²) in the east (Area C), including a rectangular area (c. 100m by 22m) in the south, with cliff faces shown. • An oval-shaped area (c. 750m²) in the centre-north (Area D), between Stone St and Iron St. • An oval-shaped area (c. 350m²) in the north-west (within Area A). **Quarry Maltkilns** in northeast with **Quarry Brickworks** shown to the south west with Quarry terrace to the south of the Brickworks. Housing in central north along Lime Street and Roberts Street with **Westgate Chemical works** in the centre and west. **Wharfe Works (Machine)** and **Old Rolling Mill (Iron)** are located along the southern boundary. **Blacup Beck** transects the south of the site, flowing in an easterly direction **Reservoir** (c. 1,000m²) located in south west corner	**Britannia Mills (card**) adjacent to east boundary and Clarence Woollen Mill and associated mill ponds approximately 60m to the east. **West End Mills (Woollen)** opposite Brick Street on western boundary. Housing to the north (along Westgate) Open fields to the south, beyond Blacup Beck.

Date	Site	Surrounding land
1907	The rectangular area within Brickworks Quarry had widened to c. 35m, but appears to be 'ponded'. The quarry in Area A has been backfilled and partially built over. Quarry Maltkilns now **malthouses** **Westgate Chemical Works** extended to north west between Iron Street and Brick Street **Brickworks** no longer shown. **Chimney** shown to south of reservoir and in location of former brickworks	No significant changes
1922	Northern parts of the Brickworks Quarry had been backfilled, with batter roughly following the line of the break of slope still present in the south of Area C, and a pond in the southern half of the rectangular area. Quarry in Area D is no longer shown. Wharfe Works now **textile machinery**	Britannia Mills now **textile machinery**.
1938	The southern, ponded, part of Brickworks Quarry now backfilled and partially built over. **Numerous storage tanks** and chimneys surrounding Westgate Chemical Works Building now located over the former Brickworks Quarry southern boundary	**Quarry** shown to the south, beyond Blacup Beck
1958	Blacup Beck appears to be culverted below Wharfe Works	No significant changes
1971	Malthouses no longer shown, **Wharfe Works** extended to the north between Iron Street and Stone Street **Westgate Chemical Works** no longer shown **Factory** shown in north adjacent to Roberts Street Small units located adjacent to former Malthouse	Housing built north of site
1978	No significant changes	Housing built 25m southeast of site
1979		No significant changes
1981		**Paragon Wire works** built to the east of Roberts Street
1989	**Depot** shown in north of former Westgate Chemical Works along northern boundary	Textile Mill no longer shown
1992	Small units located adjacent to former Malthouse no longer shown	All quarries and pits to the south no longer shown
1999	Aerial photo indicates **scrap yard** in location of former Malthouse and numerous buildings / warehouses across	No significant changes.
2018	Site labelled **Celette Industrial Park**	

3.3 Westgate Chemical Works (also referred to as Cleckheaton Chemical Company) was established prior to 1894 and remained on site until its closure in the 1970s. There is very little data about the operations of the chemical works, although AIG (Report 1245, discussed further in Section 5 below) reference the 1927 and 1936 Kelly Directories which lists the Cleckheaton Chemical Co, present at Westgate, as an Acid Works.

3.4 Internet searches link Westgate Chemicals with Henry Ellison Limited, predominantly involved in manufacturing dyestuffs by distillation of timber products.

3.5 Anecdotal evidence suggests that Westgate Chemical Works also made sulphuric acid, most likely via the lead chamber process which involved sulphur dioxide and nitrogen dioxide introduced as steam into large chambers lined with lead. The gases would then be sprayed down with water. The sulphur and nitrogen dioxide would dissolve and sulphur dioxide is oxidised to sulphuric acid. It was also common for spent oxide, from gas works, to be used in the process.

3.6 Wharfe Works (textile engineering) was one of several textile mills in the area. Theses mills predominantly produced serviceable yarn from raw materials. This may have included shrinking of the yarn and dyeing. The location of the chemical works in relation to the textile mills is unlikely to be coincidental and may have provided chemicals to Wharfe Mill and numerous other mills surrounding the site.

3.7 Old Rolling Mill (Iron works) is likely to have included one or more blast furnaces to produce pig iron (or cast iron) and may have also included a number of pudding furnaces or a foundry where pig iron was further processed to form wrought iron. Furnaces were most commonly fuelled by coal. Further processing of the iron was usually carried out away from the iron works.

3.8 Lithos are aware from previous reports that the majority of central and western parts of the site were occupied by Celette (Industrial Housing) Ltd during the late 1990s, with a metal scrap yard to the east. Celette (Industrial Housings) Ltd imported drums of resins, dyes and acetone, and rolls of glass fibre, required for the manufacture of glass reinforced buildings.

3.9 Later, post 2000, the site is recorded as Celette Industrial Estate. Multiple businesses are recorded to operate from the industrial park. These are listed below;

- Ward Fabrication- auto parts store
- Garnett Wire
- Williams Automotive Engineering- vehicle repair shop
- Lonsdale- precision engineer
- Stables Garage- vehicle repair shop, authorised for respraying of vehicles
- Wilkinson & Sons- scooter repair shop
- Angels tyres- tyre shop
- Shingleton J T & Sons- waste collection service
- IPM Workshop services- educational supply shop

3.10 The location of those recent industries, listed above, still operating on site are shown on Drawing 3043/3. Former building and quarry footprints are shown on Drawing 3043/4.

4 ENVIRONMENTAL SETTING

4.1 General

4.1.1 Notes describing how the site's environmental setting has been assessed are included in Appendix A to this report. Extracts from the response received from Landmark, and responses from the Coal Authority, the BGS and the Environment Agency are presented in Appendix E. These responses are summarised below, together with the findings of our own "desk study" investigation.

Issue	Data reviewed	Summary
Geology	1:50,000 BGS map (Sheet 77) 1:10,000 BGS map (Sheet SE 12 NE) Coal Authority	Drift – None recorded. Solid – Clifton Rock (Sandstone). Shallowest coal seam – 32 Yard coal at about 20m depth. Faults – none shown.
Mining		This site is located within a Coal Mining Development Low Risk Area. Past and present workings – present 100m south of site. Opencast – none recorded. Mine entries – nearest is 25m southeast of site,
Quarrying	Historical OS plans	Numerous disused quarries on site, predominantly to the south east associated with the former Brickworks. Smaller quarries recorded in the centre and north west.
Landfills	Envirocheck Public Health England Environment Agency	Historic landfill 280m east. Francis W Birkett and Sons Limited inert waste input from 1984 to 1990.
Radon		The site lies in an area where 1-3% of homes are estimated to be above the action level. Therefore, no measures required.
Hydrogeology		Source Protection Zone? none. Secondary A Aquifer (Solid). Groundwater abstractions? None within 250m.
Hydrology		Nearest watercourse(s) – Blacup Beck along southern boundary. Joins Water Framework Directive operational catchment Spen Beck from source to River Calder approx. 1km to the east. Water quality - moderate. Pollution incidents? Nearest is category 1 incident 18m southwest, industrial effluent into surface water. Abstractions? None within 1km. Discharge consents? Nearest is 266m east, Yorkshire Water storm tank into Syke Beck.
Flood risk		The majority of the site lies in Flood Zone 1, where the risk of flooding from rivers or the sea is classified as low. However, the southern section of the site is within flood zones 2 and 3, likely due to the presence of Blacup Beck. In accordance with Chapter 10 of the National Planning Policy Framework, a site-specific flood risk assessment is required for proposals of 1 hectare or greater in Flood Zone 1, or in an area within Flood Zone 1 which has critical drainage problems (as notified to the local planning authority by the Environment Agency); new development in Flood Zones 2 and 3.

4.2 Coal & mining

4.2.1 This site is located within a Coal Mining Development Low Risk Area - within the defined coalfield, but no known defined risks have been recorded by the Coal Authority; there may still be unrecorded issues.

4.2.2 The CA mining report indicates the presence of two mine shafts; both off site. The closest is approximately 20m to the south of Area B, beyond Blacup Beck. The second is c. 60 to the north of Area D in a residential area.

4.2.3 The CA mining report states that:

- There is known, past underground mining recorded within 1 seam at approximately 62m depth directly beneath the site
- There are no unrecorded shallow mine workings
- There are no spine roadways recorded at shallow depth
- There are no reported coal outcrops on site
- There are no former opencast mines (within 500m of the site boundary)
- There are no future planned mines beneath the site
- No notices have been given, under Section 46 of the Coal Mining Subsidence Act 1991, stating that the land is at risk of subsidence
- The property in not in an area where a notice to withdraw support has been given

4.2.4 The shallowest coal seam is the 32 Yard Coal at approximately 20m depth. The geological memoir for the area records the 32 Yard Coal as being between 0.1m and 0.3m thick. Such a thin seam is not likely to have been worked.

4.2.5 The shallowest known workable seam is the Black Bed coal at around 60m depth, this concurs with the CA's mining report that 'past underground mining recorded within 1 seam at approximately 62m depth directly beneath the site'.

4.2.6 Further to this a previous phase of investigation by AIG in 2001 (see Section 5) advanced 3 rotary probeholes to at least 30m depth; no evidence of any coal seams were recorded.

4.2.7 Given the above it is deemed highly unlikely that the site is at risk from shallow coal workings and as such should not pose a risk to surface stability.

4.3 Quarrying

4.3.1 This site has been subject to quarrying for Sandstone and/or Clay, with three areas of quarrying shown on the 1894 OS plan:

- Brickworks Quarry (c. 9,000m^2) in the east (Area C), including a rectangular area (c. 100m by 22m) in the south, with cliff faces shown. By 1907, the rectangular area had widened to c. 35m, but appears to be 'ponded'. By 1922, northern parts had been backfilled, with batter roughly following the line of the break of slope still present in the south of Area C, and a pond in the southern half of the rectangular area. This pond had been backfilled and partially built over by 1938.
- An oval-shaped area (c. 750m^2) in the centre-north (Area D), between Stone St and Iron St. By the 1920s this quarry is no longer shown, and by the 1970s, Wharfe Works (now Garnett Wire) had been built over it.
- A roughly square-shaped area (c. 1500m^2) in the north-west (within Area A); looks to be 'ponded'. This quarry had been backfilled and partially built over by 1907.

4.3.3 Recent 3rd party intrusive investigations (see Section 5) suggest the following depths of backfill:

- Brickworks Quarry: 15m to 17m at northern end of the rectangular area, but 9m at southern end. Variable (7m to 18.5m) within irregular quarried area to north.
- Centre-north: not proven, >2m.
- North-west (within Area A): not proven, >3m.

4.4 Landfills

4.4.1 The Environment Agency do not hold any records of known areas of landfill in, or within 250m of, the site's boundary.

4.4.2 However information provided by Kirklees MBC to Encia in 2004 (see Section 5) suggests that a refuse tip is located immediately beyond the southern boundary, although this is not shown on historical or BGS mapping or EA records. The tip is believed to pre-date 1980 and has been monitored for hazardous ground gasses by Kirklees MBC (no significant gasses recorded). Based on topography the refuse tip is likely to be a land 'raise' rather than a land 'fill'; i.e. material has been placed on top of existing levels rather than being placed into a hollow such as a disused quarry.

4.4.3 Areas of deep made ground associated with backfilled quarries are present across much of the site's area.

4.4.4 Whilst the adjacent refuse tip is unlikely to pose a significant risk of hazardous ground gasses areas of deep made ground within the site's boundary may pose a more significant hazard.

4.4.5 The site is considered at risk of hazardous ground gasses and risk assessment is required (see Section 11).

4.5 Scrap yard permit

4.5.1 The former scrap yard (in the east) was owned and run by H. Smith and Son. Review of the Environment Agency public register has confirmed that two permits were issued to the site. The public register records both permits as still active and this has been confirmed by the Environment Agency.

4.5.2 The permits are for activities: A14 - transfer station taking non-biodegradable wastes; and A20 - metal recycling.

4.6 Groundwater and Surface water

4.6.1 The site is directly underlain by the Clifton Rock Secondary A aquifer, part of the Pennine Lower Coal Measures. It is likely that the Clifton Rock does include shallow groundwater. Indeed, groundwater level data from Encia (Report 6171, reviewed further in Section 5 below), indicates that a continuous groundwater table is present at approximately 90mAOD (approximately 3 – 9mbgl). Groundwater appears continuous suggesting water recorded in made ground is in hydraulic continuity with groundwater in the Sandstone bedrock.

4.6.2 There is no formal level data available for Blacup Beck, however former topographical survey reported the Beck to lie at approximately 93.5mAOD. These levels suggest that the Beck and bedrock groundwater are unlikely to be in hydraulic continuity. However, this would need further assessment to establish definitively.

4.6.3 In Area B the Beck enters a culvert, with an observed drop of approximately 1m. The reduced level of the Beck below Wharfe Mill may potentially result in some connectivity between the bedrock groundwater and beck. This would need to be considered further once the site is vacated and the culvert traced.

5 PREVIOUS INVESTIGATION FINDINGS

5.1 General

5.1.1 Lithos have been provided with copies of the following reports:

- Geo-environmental Appraisal of land at Westgate, Cleckheaton, prepared by AIG Consultants Ltd (Ref. R1245/3), dated April 2001
- Geo-environmental report to support surrender of Waste Management Licenses relating to transfer station, Robert Street, prepared by Encia Consulting (Ref. 6171/1), dated October 2004
- Phase 1 desk study for Celette Industrial Estate, Cleckheaton prepared by Rogers Geotechnical Services (RGS) (Ref. J1432/09/EDS), dated July 2009
- Geo-environmental Investigation for Celette Industrial Estate, Cleckheaton prepared by Rogers Geotechnical Services (RGS) (Ref. J1432/09/E), dated September 2009

5.1.2 All exploratory locations discussed below and included in each of these third-party reports are shown on Drawing 3043/7, included in Appendix B of this report.

5.2 Summary of AIG findings (2001)

5.2.1 The AIG report available for review is incomplete and only includes the main text, and some drawings, but not appendices. Therefore, whilst a summary has been provided below, no raw data is available to cross reference. AIG's investigation considered the entire site (Areas A to D).

5.2.2 A summary of ground conditions has been provided and included in the table in Annex I, but again this does not include direct reference to the exploratory logs and has been taken directly from the text of AIG's report.

5.2.3 AIG's ground investigation works comprised:

- Trial pits (TPs 1 to 33) excavated to depths between 0.7 to 4.6m
- Cable percussive boreholes (BHs 1 to 5) sunk to depths between 5.3 to 18.6m.
- Rotary probeholes (PH1 to PH5) to depths between 18 to 30m.
- Window Sample boreholes (WS1 to WS20) to depths between 1.35 to 5.3m.
- Monitoring wells were installed in all boreholes (BH1 to BH5) to monitor groundwater and gas; response zones are unknown. No levelled groundwater dip data was available for review, although the report does suggest that localised perched water was identified in some areas of Made Ground, with deeper groundwater recorded in bedrock.
- Geotechnical classification tests (Atterberg Limits, pH, soluble sulphate etc).
- SPTs were taken in boreholes at 1.5m intervals and U100 samples taken in cohesive soils.
- Chemical laboratory tests (included 32 made ground / natural soils scheduled for metals, PAH & cyanide; 7 for combustibility, 15 for TPH and 7 for VOC, 2 for sVOC and 7 for PCB's. A further 7 groundwater and 2 surface water samples were scheduled for a range of organics, metals, sulphate, cyanide and phenols). Head space tests, to monitor volatile organic compounds using a PID, were undertaken during site works
- Gas monitoring; 6 visits during one month, results are not available but the report summarised that no elevated ground gases were recorded.

5.2.4 Within the text of their report, AIG refer to the cable percussion boreholes with a prefix of SA in places, but BH in others. The hole location plan and logs use a prefix of BH.

5.2.5 Made ground was encountered in all exploratory locations and comprised granular gravel with varying amounts of Ash & Clinker.

5.2.6 Black sand (blast sand), reported by AIG to be associated with Stables Garage was encountered in WS8 to a depth of 3.2m. WS8 is understood to be located within the remaining Wharfe Mill building in Area B. Given the blast sand was located at depth it may be a waste product of the former Mills as opposed to more recent activity.

5.2.7 AIG recorded soft clays (Alluvium) to depths between 2.5 and 3.5m associated with Blacup Beck, within about 30m of the southern boundary, but extending up to about 70m in the south-west, encroaching into the south of Area A; see Drawing 3043/7. Elsewhere, natural soils comprised firm to stiff Clay (weathered Coal Measures), over Sandstone bedrock.

5.2.8 The depth of natural soils varied across the site; in the west (Areas A & D) clays were recorded between 1.0 and 4.4m, but at shallower depth (0.5 to 2.0m) in the car park on the northern boundary in Area D. AIG recorded Clay in the former scrap yard (Area C) between 2.6 to 3.1m.

5.2.9 Rockhead was encountered at approximately 16m in BH2, beneath Ash & Clinker fill. BH2 is located to the south of Area C, within a former quarry, in an area currently approximately 5m higher than adjacent land to the south and east.

5.2.10 Within a backfilled reservoir (spanning the boundary between Areas A & B), made ground was encountered to depths of up to 4.4m.

5.2.11 Visual and olfactory evidence of contamination was noted during AIG's investigation and is summarised below:

Area	Exploratory Hole	Observation
A	TP4	Clayey fill had an organic odour between 1.1 and 1.8m and an ammonia odour between 1.8 and 3.3m. Perched groundwater had an oily sheen.
	TP6	Perched groundwater had an oily sheen. Reservoir sediment between 1.6 and 2.6m had an organic odour.
	TP19	Slight sulphurous odour noted in made ground between ground level and 1.6m.
	SA3	Slight hydrocarbon odour noted from groundwater
	WS18	Clayey gravel fill had an organic odour between 1.7 and 2.9m
B	TP2	Creosote staining in made ground between 1.2 and 2.4m. Perched groundwater had an oily sheen and odour
	TP3	Reservoir sediment between 4.3 and 4.4m had an organic odour.
	WS9	Slight solvent odour noted in natural clay between 3.6 and 4.4m.
	WS13	Clay fill between 1.2 and 2.7 had a slight hydrocarbon odour. Natural clay between 2.7 and 3.2 had a hydrocarbon odour.
	PH1	Slight hydrocarbon odour noted from groundwater
C	TP28	Local oil staining noted in made ground between ground level and 0.6m.
	SA2	Ash and clinker fill had an oily sheen between 12.5 and 14.0m.
D	PH3	Slight hydrocarbon odour noted from groundwater

5.2.12 AIG's laboratory data indicates that most of the Made Ground sampled across all areas yielded elevated concentrations of metals and organic determinants. Of particular relevance are elevated concentrations of chlorinated solvents in WS13, located in the Old Rolling Mill in Area B. Chlorinated solvents are often used as degreasers in metal workings but can also be added to hydraulic oils to increase heat resistance in machinery.

5.2.13 Elevated concentrations of metals, organics and chlorinated solvents were also detected in groundwater samples recovered from PHs 1 & 2 (Area C) and PH3, BH2 & BH3A (Area B).

5.2.14 No contamination was detected in the upstream or downstream sample from Blacup Beck.

5.3 Summary of Encia findings (2004)

5.3.1 Encia's investigation was limited to the former scrap yard and brickworks within Area C; it did not include land in the west of Area C.

5.3.2 The report was commissioned to support the surrender of H. Smith & Son permits and considers potential impacts from the permitted activity, and historic land uses. Encia's ground investigation works comprised:

- 15 trial pits (TPs 201 to 215) excavated to depths between 1.8 to 6.4m, all terminated in Made Ground.
- 9 Rotary Probeholes (PHs 6 to 13 & 8S) sunk to depths between 5 to 23m.
- Monitoring wells were installed in PHs 6 to 11 & 8S, with response zones sealed in both Made Ground and Sandstone.
- Geotechnical classification tests (Atterberg Limits, pH, soluble sulphate etc).
- Chemical laboratory tests (including 22 Made Ground for metals, 16 Made Ground for leachable metals & 20 Made ground for organics; 2 samples of natural ground were also scheduled for a range of organics).
- No gas monitoring was undertaken.

5.3.3 Ground conditions encountered are summarised in the tables in Annex I.

5.3.4 Made Ground was recorded in all exploratory locations, the deepest was recorded in PH9 at 18.5m, PH12 at 17m, PH11 at 11m & PH13 at 10.5m. These probeholes are located in the north and central area of the scrap yard (to the west of the former Malthouse), within a former quarry in an area currently about 5m higher than adjacent land to the south and east.

5.3.5 Made Ground encountered in Area C included a high proportion of Ash & Clinker.

5.3.6 Natural ground was encountered in most exploratory locations at depths ranging from 2 to 17m and was described as either weathered Coal Measures (Clay) or Sandstone with bands of Mudstone and Siltstone. Bedrock was shallowest in the north east corner, the area of the former Malthouse.

5.3.7 Asbestos was analysed for in 5 samples of made ground, but no fibres were detected. A further 9 samples of Ash & Clinker were also tested for combustibility, all were considered non-combustible.

5.3.8 Chemical analysis confirmed elevated concentrations of metals and hydrocarbons (TPH) in Made Ground and visual and olfactory evidence of petroleum hydrocarbons were noted in a range of trial pits.

5.3.9 Seven boreholes were installed with groundwater monitoring standpipes, with response zones sealed in both Made Ground and Sandstone bedrock. Levelled dip data has been summarised below and indicates a continuous groundwater table.

Hole ID	Response zone	Depth to Groundwater (mbgl)	Depth to Groundwater (mAOD)
PH6	Clifton Rock Sandstone (3.5 – 21m)	7.40	92.56
PH7	Clifton Rock Sandstone (3.5 – 15m)	5.37	90.12
PH8	Clifton Rock Sandstone (6 – 15m)	3.10	89.86
PH8S	Made Ground (quarry backfill) (2 – 5m)	3.01	89.88
PH9	Made Ground (quarry backfill) (5 – 14m)	9.76	90.85
PH10	Clifton Rock Sandstone (2.5 – 21m)	9.40	90.82
PH11	Made Ground (quarry backfill) (0.1 – 11m)	8.70	89.93

5.3.10 Water samples were taken from monitoring locations. The most significant groundwater contamination was recorded as lubricating range organics in PH11 sealed within Made Ground, and chlorinated solvents in PHs 9 & 10 (sealed in Made Ground and Sandstone respectively). These contaminants could be associated with the former use as a scrap yard, but elevated concentrations of metals and hydrocarbons can also be attributed to the Ash & Clinker in made ground.

5.3.11 As the report was produced to support surrender of a permit rather than a development, no geotechnical test data was included.

5.4 Summary of RGS findings (2009)

5.4.1 The RGS reports consider all areas (A to D). The preliminary appraisal is generally consistent with Lithos review included in Sections 1 to 4 of this report.

5.4.2 RGS include reference to 3 tanks in the area of the former chemical works; 2 with unknown contents, the 3rd containing plastic additives. However, photographs of the tanks included in the RGS report resemble trailer tankers and may in fact be associated with Ward Fabrication Ltd as opposed to chemical storage. No further consideration of the suspected tanks was given in the preliminary appraisal or ground investigation report.

5.4.3 RGS's ground investigation comprised:

- 16 trial pits (TPs 1to 16) excavated to depths between 0.8 to 3.4m.
- 3 cable percussive boreholes (BHs SA1 to SA3) to depths between 6.11 to 19.7m.
- 3 rotary probeholes (RT 1 to 3) with core recovery to depths between 8.7 and 14m
- 10 window sample boreholes (WS1 to 10) to depths between 2.4 to 4.0m
- Gas monitoring standpipes were installed in all 10 WS locations, with response zones sealed predominantly in Made Ground, but spanning Made Ground and natural, where natural was encountered (WS3, 6 & 7).
- 10 dynamic penetration tests alongside WS locations & SPT's at regular depths in the 3 BH's and 3 PH's
- Geotechnical classification tests including sulphate, pH, 3 particle gradings on ash, moisture contents, plasticity limits and linear shrinkage.
- Chemical laboratory tests (including metals, organics (TPH and PAH) & cyanide), combustibility.
- Gas monitoring; 2 visits between August and September 2009, with atmospheric pressures in range 1004mb to 1023mb. No flows or methane was recorded. Carbon dioxide concentrations ranged from 0.1 to 8.7%v/v.

5.4.4 Made ground was encountered across the entire site and typically extended to between 2m to 3m in Areas A, B & D, described as fine to coarse gravel of mixed lithologies, often including cobble to boulder sized brick, concrete with some Ash & Clinker.

5.4.5 Made Ground in Area C was recorded up to 17.3m. Made Ground within the upper 1m to 2m was described as a fine to coarse gravel with brick, concrete, slag, tarmac, metal, glass and pottery. Deeper Made Ground was predominantly described as Ash & Clinker including some fragments of brick and concrete.

5.4.6 The deepest Made Ground recorded is in SA3 (likely within the backfilled quarry in Area C). RGS' exploratory location plan shows two SA1 locations (the one close to the eastern boundary is likely the correct one), and not SA3 location. Lithos Drawing 3043/7 shows presumed locations of SA1 and SA3.

5.4.7 Natural ground was proven in a minimum of two exploratory locations in all Areas. Natural ground was encountered as a weathered horizon described as Clay with both Sandstone and Mudstone lithorelicts.

5.4.8 Chemical analysis identified metals, TPH and PAH across the site at varying concentrations which is to be expected given the nature of the made ground. No distinction between areas can be made based on this data. No visual or olfactory evidence of contamination was recorded by RGS.

5.4.9 The analytical test suite was not tailored to account for previous or current uses and can only be considered to represent a generic screen. Whilst the exploratory logs provide useful information regarding the depths, distribution and nature of made ground and natural ground, little reliance should be placed on the contaminant summary, risk evaluation or conclusions of the RGS report.

5.5 Lithos comments

5.5.1 Ground conditions encountered in all previous phases of intrusive investigation are summarised in the tables in Annex I, and all exploratory locations are shown on Drawing 3043/7 in Appendix B.

5.5.2 The 3rd party reports include useful information to support the design of further intrusive investigations. All reports identify significant thicknesses of Made Ground in all areas, although the deepest is within the former quarry in Area C. However, many exploratory holes failed to fully penetrate made ground (often a consequence of the significant thicknesses present), in summary:

Area	No. of exploratory holes	No. of holes where MG fully penetrated (and % of holes)	Range of made ground thicknesses recorded /m	Estimated average thickness of made ground
A	26	9 (35%)	1.0 to 7.6	3m to 4m
B	22	18 (82%)	0.1 to 4.4	2m Up to 4.4m within backfilled reservoir
C	54	29 (54%)	0.5 to 18.5	3m to 4m beyond quarry 12m to 15m within quarry
D	15	9 (60%)	0.2 to >5.3	2m

5.5.3 Whilst the reports describe the nature and thickness of made ground, the extent of quarries, in particular the edge of the quarries (high walls) has not been investigated. Steep high walls can have significant implications for foundation design.

5.5.4 A range of geotechnical tests have been undertaken and results in natural strata provide some indication of the Clay properties. However, geotechnical tests (particularly SPTs) undertaken in Made Ground are likely to be unreliable - exploratory logs indicate Made Ground is heterogenous and includes cobble and boulder sized fragments of bricks and concrete which would give a false reading.

5.5.5 Although a range of chemical tests were undertaken, these were not specifically targeted to known activities in each area, rather a 'default' suite of tests was adopted. A generic approach, when looking at the site as a whole, makes it difficult to identify potential source areas or provide any detailed consideration of contamination identified.

5.5.6 Historic plans identify a range of tanks located around the chemical works (Area A). These locations have not been targeted, nor has the presence of below ground tanks and pipelines been discussed. Equally the location and state of features such as furnaces in the former Iron Mill have not been considered.

5.5.7 Groundwater has been considered in detail in the Encia investigation, with levelled dip data and sealed response zones. However, although AIG and RGS discuss the possible presence of perched water in Made Ground and deeper groundwater encountered in natural deposits, none of the installations are surveyed and no levelled dip data is available.

5.5.8 It would be prudent to undertake further investigation, targeted within each Area, to identify and delineate sources, consider risks to groundwater and surface water and provide more detailed data on made ground depths and quarry high walls. This will also allow remediation options to be developed.

6 GROUND INVESTIGATION DESIGN

6.1 Anticipated ground conditions & potential issues

6.1.1 Based on the data reviewed in Sections 4 (Environmental Setting) and 5 (Previous Investigation Findings), anticipated ground conditions are expected to comprise:

Anticipated condition	Remarks
Area A Former Chemical Works	
Made ground	Across entire area, granular and cohesive with some Ash & Clinker. Depths typically 1.5 to 2.5m, locally extending to 7.6m.
Natural soils / Bedrock	No drift, weathered Coal Measures from approximately 3m, with more competent bedrock below.
Groundwater	No reliable data available. Perched water recorded in shallow below ground obstructions.
Area B Former Rolling Iron Mill and Wharfe Textile Mill	
Made ground	Across entire area, granular and cohesive with 2m thick bands of Ash & Clinker. Depths typically less than 1.5m, locally extending to 4.4m (within backfilled reservoir).
Natural soils / Bedrock	Alluvium recorded with depths up to 3.5m, over weathered Coal Measures from approximately 3m.
Groundwater	No reliable data available. Perched water recorded in below ground obstructions. Consideration should be given to interaction between groundwater and Blacup Beck.
Area C Former Scrap Yard, Malthouse, Brickworks and Quarry	
Made ground	Predominantly Ash & Clinker with some deep granular and cohesive material. Depths are highly variable and significant (up to 17m) in areas of former quarries, but as shallow as 1m in other parts.
Natural soils / Bedrock	No drift, weathered Coal Measures
Groundwater	Continuous groundwater table recorded at approximately 90mAOD (approximately 3 – 9mbgl). Groundwater recorded in made ground is considered to be in hydraulic continuity with groundwater in the Sandstone bedrock.
Area D Central Industrial Units	
Made ground	Across entire area, granular and cohesive with some Ash and Clinker. Depths typically 0.5 - 2m, locally extending to 5m.
Natural soils / Bedrock	No drift, weathered Coal Measures recorded from approximately 2m.
Groundwater	No reliable data available. Perched water recorded in below ground obstructions.

6.1.2 Based on the data above and that in Sections 2 (Site Description) and 3 (History), potential ground-related issues associated with this site are likely to include:

Type of issue	Specific issue	Remarks
Potential on-site contamination sources	1. ASTs/USTs and pipe lines (Area A) 2. backfilled reservoir/pits/quarries (all areas) 3. furnaces & dipping tanks (all areas but predominantly Area B) 4. raw material storage (all areas but predominantly Area A & C)	1. numerous tanks recorded in former chemical works. General location of each needs targeting 2. quarrying recorded across entire site, most significant in Area C; heterogeneous nature of infilled material, potential for contamination and ground gas 3. locations of blast furnaces and kiln furnaces needs identifying 4. chemicals are likely to have been used in all industries across the estate but may be most prolific in the former chemical works and scrap yard
Potential off-site contamination sources	1. landfill to the south 2. numerous textile and woollen mills	1. unlikely to be a concern for ground gas; tipped pre-1980 2. should be considered in terms of possible groundwater contamination
Potential geotechnical hazards	1. relict buried obstructions 2. deep made ground 3. steep slopes 4. soft ground	1. numerous associated with former buildings 2. associated with reservoir, quarries and brickworks (predominantly Area B & C) 3. associated with former quarry (Area C) 4. Alluvium recorded along southern boundary (Area B)
Other potential constraints	1. culverted section of Blacup Beck (Area B) 2. underground and/or overhead utilities 3. physical access 4. onsite-operations	1. beck runs along southern boundary and enters culvert south of Rolling Mill 2. likely electric, gas, water, sewer and BT 3. access for a drilling rig would prove difficult across much of the site 4. parts of Area A, B & D are still occupied, limiting access for investigation

6.2 Preliminary conceptual site model

6.2.1 A preliminary conceptual site model, presented as Drawing 3043/6 in Appendix B, has been prepared after consideration of all the data presented in Sections 2 to 6.1 inclusive of this report.

6.2.2 An assessment of potential contaminants associated with the former uses has been undertaken with reference to CLR8 and the following DETR Industry Profiles: *chemical works (organic chemical manufacturing); metal manufacturing (iron and steel); textile and dye works; metal recycling site*. As a consequence of this assessment, anticipated potential contaminants, within soil and/or groundwater include:

- Areas A & B – volatile and semi volatile organics, chlorinated solvents, acids, coal tar constituents, cyanide, metals, asbestos and petroleum products
- Area C – metals, PAH, petroleum products (predominantly lubricating oils), asbestos, combustible Ash & Clinker
- Area D – metals, PAH, petroleum products, asbestos

6.2.3 The most significant receptors are likely to be controlled waters (surface and groundwaters) and post development, residents.

6.2.4 Historical plans show the presence of: tanks (Area A); a backfilled reservoir (Area B); and clay pits/quarries in Areas A, C & D.

6.3 Ground investigation design & strategy

6.3.1 The preliminary conceptual site model was used as the basis for design of an appropriate ground investigation. Lithos' works were designed in two stages; an initial exploratory investigation (in January 2019) and a supplementary investigation (September 2020). The scope of Lithos' works (as a whole) are summarised in the table below:

Exploratory holes	Purpose
About 75 trial pits	To determine the general nature of soils underlying the site, including the: • Nature, distribution and thickness of made ground • Nature, degree and extent of contamination • Proportion of undesirable elements e.g. biodegradable matter, foundations etc • Suitability of the ground for founding structures and highways
Including trenches	To identify high walls associated with former quarries and reservoir
9 cable percussion boreholes	To retrieve geotechnical data from depth in backfilled quarries & areas with soft alluvial deposits and to install monitoring wells to: • To determine groundwater depth & flow direction • To monitor for hazardous ground gasses
3 rotary cored boreholes	(following on from CP BHs) to determine to nature of bedrock beneath the site.
About 20 rotary open probeholes	To determine the depth to bedrock within quarries and to install monitoring wells to: • To determine groundwater depth & flow direction • To monitor for hazardous ground gasses
About 10 groups of stitch probeholes	To determine the location & dip of buried quarry highwalls
Surface water sampling	Retrieve upstream and downstream water samples from Blacup Beck on up to 6 occasions to reflect seasonal changes in water levels

6.3.2 The aims of the ground investigation are to enable a specialist brownfield contractor to cost the necessary remediation/preparatory works, to support an application to planning and to inform the developer with likely foundation solutions etc.

7 FIELDWORK

7.1 Objectives

7.1.1 The original investigation strategy is outlined in Section 6.3 above.

7.1.2 The additional exploratory holes listed below were advanced in light of ground conditions actually encountered.

Exploratory holes	Purpose
TP444 to 449	To enable better delineation of the quarry/reservoir high walls (Areas A & B).
PHs 503 & 504	To delineate deep made ground associated with a former quarry (Area C).
TPs 524 & 525	To enable further sampling & description of materials in the former reservoir (Area B).
TPs 526 & 527	To delineate Alluvium in the south (Area B).

7.2 Exploratory hole location constraints

7.2.1 No access was available inside any of the buildings which remained standing at the time of Lithos' investigation (as shown on Drawing 3843/3) either as they remained in use or because the condition of the buildings made investigation works unsafe and/or impractical.

7.3 Scope of works

7.3.1 Fieldwork was supervised by Lithos in two phases; the first (exploratory) phase was completed from the 9th to the 15th January 2019; the second (supplementary) phase was completed between the 14th and the 23rd September 2020.

7.3.2 For ease of reference exploratory holes advanced in 2019 have been referenced in a **'400'** series whilst exploratory holes advanced in 2020 have been referenced in a **'500'** series. In total, fieldwork comprised the exploratory holes listed below:

Technique	Exploratory holes	Final depth(s)	Remarks
Trial pitting (machine excavated)	TPs 401 to 410, 412 to 427, 429 to 430, 432 to 449 & 501 to 528.	0.4m to 5.0m (ave. c. 3.0m)	Vane tests where possible in cohesive soils.
Trial trenches (machine dug)	TTs 401, 411, 428 & 431	2.5m to 5.1m	Vane tests where possible in cohesive soils. Undertaken to identify high walls where possible.
Cable percussion boreholes	BHs 501 to 509.	4.4m to 12.0m	Boreholes typically advanced to refusal in bedrock. SPT tests undertaken throughout drilling. Monitoring wells installed.
Rotary cored boreholes	BHs 501 to 503.	15.4m to 17.2m	Rotary coring followed on from CP BHs 501 to 503.
Rotary open probeholes	PHs 501 to 520	5.0m to 12.0m	Monitoring wells installed.
Stitch probeholes	'Groups' ST501 to 510	3.5m to 20m	Undertaken in 'groups' across anticipated line of highwalls.

7.3.3 Notes describing ground investigation techniques, in-situ testing and sampling are included in Appendix A to this report.

7.3.4 Exploratory hole logs are presented in Appendix F to this report. These logs include details of the:

- Samples taken
- Descriptions of the solid strata, and any groundwater encountered.
- Results of the in-situ testing
- The monitoring wells installed

7.3.5 Exploratory hole locations are shown on Drawing 3043/8 presented in Appendix B.

8 GROUND CONDITIONS

8.1 General

8.1.1 A complete record of strata encountered beneath the proposed development site is given on the various exploratory hole records, presented in Appendices F to H.

8.1.2 Typical ground conditions encountered at the site are described below in Sections 8.2 (made ground) and 0 (natural ground), with a summary provided in the table in Annex II.

8.2 Made ground

8.2.1 The made ground on site is a heterogeneous mixture of materials and it is unlikely, even with a huge amount of sampling, that it could be accurately characterised. Nonetheless, the bulk of the made ground can be categorised as one of the following broad types within each area:

Area A (chemical works)

8.2.2 Area A was formerly occupied by a chemical works; made ground across the area is likely to be (at least partly) sourced from former chemical work processes.

8.2.3 Made Ground has been encountered across the entirety of Area A to depths of between 1.3m (TP436) and 10.7m (BH501) and can be grouped as one of 6 main 'types' as outlined below:

- **Hardcore:** Encountered in BH501 & TPs 502 to 4504m to a typical depth of 0.3m (max 0.4m) comprising sandy gravel of macadam chippings, sandstone, brick & burnt shale.
- **Burnt Shale:** Encountered in TP 503 to 505, 508, 510 & 514 to a typical depth of 1.0m (max 1.6m – TP508) comprising gravel of predominantly burnt shale.
- **Cohesive Made Ground:** Encountered in 13 of 25 exploratory holes to depths of between 0.3m (TP443A) and 7.2m (BH501), typically about 2.0m, comprising sandy clay occasionally with gravel of sandstone & mudstone. With rare cobbles of brick.
- **Granular Made Ground:** Encountered in 18 of 25 exploratory holes to between 1.2m (TP508) 10.7m (BH5010, typically about 2.5m, comprising gravelly sand/sandy gravel of brick, concrete, mudstone, sandstone & occasional glass, pottery. Occasional with fragments of wood, metal & plastic.
- **Brickfill:** Encountered in 11 of 25 exploratory holes to between 0.8m (TP436) to 3.5m (TP437), typically about 2.5m) comprising gravel & cobbles of brick, sandstone & mortar.
- **Filter Sand:** Encountered in BH501 & TPs 439, 502, 503 & 508 to between 1.8m (TP503) & 5.2m (BH501), typically about 3.5m, comprising grey sand with occasional gravel of sandstone, mudstone & limestone with yellow discolouration and precipitate and a sulphurous smell throughout.

8.2.4 It is understood that the Burnt Shale and Hardcore across Area 1 was imported to the site (source unknown) in the early 2000s and spread across external areas to create a level running surface which was suitable for vehicles etc to traffic.

8.2.5 The Filter Sand might be associated with the production of sulphuric acid at the chemical works; sand was used as a filter medium which the raw acid was passed through to enable precipitation of impurities. Yellow discolouration of the sand and the sulphurous smell noted within the filter sand is likely the remnants of sulphur precipitates which became mixed in with the Filter Sand.

Area B (rolling mill & textile works)

8.2.6 Made Ground has been encountered across Area B to between 0.4m (TT428) and greater than 3.5m (TP524) and can be grouped as one of 4 main types as outlined below:

- **Cohesive Made Ground:** Encountered in 9 of 18 exploratory holes to between 0.3m (TP427) & 3.4m (TP525), typically about 1.0m, comprising black/grey clay or soft silt with sand filled fissures & evidence of hydrocarbon staining.
- **Granular Made Ground:** Encountered in 9 of 18 exploratory holes to between 0.1m (TP528) & 3.5m (TP524), typically about 2.0m, comprising sand & gravel of limestone, concrete, sandstone and burnt shale. Occasionally with cobbles of brick & fragments of plastic, wood and metal.
- **Ash & Clinker:** Encountered in 8 of 18 exploratory holes to between 0.4m (TT428) & 2.4m (TP419) depth, typically about 1.0m, comprising ash sand & gravel of clinker and occasional slag, concrete & mudstone. With occasional fragments of wood and cobbles of brick.
- **Brickfill:** Encountered in 6 of 18 exploratory holes to between 0.4m (TP424) & greater than 2.0m ((TP418) depth, typically about 1.0m, comprising gravel & cobbles of brick and occasional mortar, sandstone & concrete.

8.2.7 In addition to the above Hardcore (gravel of macadam/sandstone, brick & concrete) was encountered in TPs 526 & 527 from surface to a maximum depth of 0.4m.

8.2.8 Some made ground, most notably Brickfill, is likely to have been placed across the site prior to construction, and then following demolition, of the former rolling mill and textile works buildings. Cohesive Made Ground (and some Brickfill) has been placed to fill in the former reservoir in the west of the Area.

Area C (quarry, malthouse, brickworks & scrapyard)

8.2.9 Made Ground has been encountered in Area C to between 0.8m (TP404) and 12.0m (BH504) and can be grouped as one of two main types as outlined below:

- **Granular Made Ground:** Encountered in 10 of 24 exploratory holes to between 0.2m (TP408) & 4.0m (TP516), typically about 1.0m, comprising sand with gravel of clinker, sandstone & occasional brick & burnt shale.
- **Ash & Clinker:** Encountered in 21 of 24 exploratory holes to between 0.9m (TP414) & 12.0m (BH504) depth, typically about 10.0m, comprising ash sand & gravel of clinker and occasional slag, concrete, coal & mudstone.

8.2.10 In addition to the above Hardcore (gravel of macadam) was encountered in TPs 404 and 516 to a maximum depth of 0.1m; Cohesive Made Ground (clay with gravel of brick & sandstone) was encountered in BHs 504 & 505 to 9.0m depth & TPs 447 to 449 in a thin (0.2m thick) layer to a maximum depth of 1.2m. Brickfill (gravel and cobbles of brick, concrete, mortar & sandstone) was encountered in TPs 407 and 516 to greater than 2.2m and 0.4m depth respectively.

8.2.11 The Ash & Clinker appears to have been mainly spread across Area C to backfill the former areas of quarrying. Granular Made Ground is generally present from surface to shallower depths and was likely placed as a means of levelling off the site and creating a trafficable surface.

Area D (industrial area & car park)

8.2.12 Made Ground has been encountered across Area D to between 0.6m (TP517) and 9.0m (BH506) depth and can be grouped as one of 4 main types as outlined below:

- **Cohesive Made Ground:** Encountered in 8 of 24 exploratory holes to between 0.6m (TP517) & 9.0m (BH506), typically about 2.3m, comprising sandy clay occasionally with gravel of sandstone & mudstone. With rare cobbles of brick.
- **Granular Made Ground:** Encountered in 9 of 24 exploratory holes to between 0.2m (TP519) and 4.3m (BH506) depth, typically about 2.0m, comprising sand & gravel of limestone, concrete, sandstone & burnt shale. Occasionally with cobbles of brick & fragments of plastic, wood and metal.
- **Ash & Clinker:** Encountered in 16 of 24 exploratory holes to between 0.7m (TP22) & 10.4m (BH509) depth, typically c. 5 to 10 to the base of former quarries, comprising ash sand and gravel of clinker and occasional slag, burnt shale, mudstone, sandstone & concrete.
- **Brickfill**: Encountered in 5 of 24 exploratory holes to between .0m (TP521) & greater than 2.6m (TP433), typically about 1.5m, comprising gravel and cobbles of brick and mortar, concrete and sandstone.

8.2.13 In addition, TPs 517 & 518 encountered Sub-Base (sandy gravel of limestone) to up to 0.3m depth.

Summary of made ground

8.2.14 Review of the exploratory hole logs suggests that made ground across the whole site varies in thickness from less than 0.5m to 12m depth. The deepest made ground has been encountered in the footprints of former quarries which have been backfilled with a mixture of Ash and Clinker, Granular Made Ground, Cohesive Made Ground, Filter Sand and Brickfill.

8.2.15 The table below summarises average thickness of made ground within each area:

Site area		Average thickness of made ground (m)	
		Average	Maximum
A	Beyond footprint of former quarry	2.5	3.8
	Within footprint of former quarry in NW (c. 1500m², according to historical OS plans)	10.0	10.7
B	Beyond footprint of former reservoir in NW (c. 1,000m², according to historical OS plans)	1.5	3.2
	Within footprint of former reservoir	4.0	4.4
C	Beyond footprint of former Brickworks Quarry in west (c. 9,000m², according to historical OS plans)	1.5	>4.4
	Within footprint of former quarry	10.0 to 15.0	17.1
D	Beyond footprint of former quarry in centre-north (c. 750m², according to historical OS plans)	1.7	2.9
	Within footprint of former quarry	>9.0	>9.0

8.2.16 Made ground thicknesses are:

- >2.5m across an area of c. 26,000m² (c. 40% of the total site area). It is likely that made ground across an area of c. 9,000m² (within former Brickworks Quarry) is 10m to 18m deep.
- 1.5 to 2.4m across c. 12,500m² (c. 20%)
- <1.5m across c. 26,500m² (c. 40%)

8.2.17 The approximate distribution of made ground thicknesses is shown on Drawing 3043/10.

8.2.18 Quarry backfill in Areas A, C & D is predominantly granular, mostly Ash & Clinker in Areas C & D and Granular Made Ground/Filter Sand in Area A.

8.2.19 Whilst not encountered during this investigation, the possibility of asbestos sheeting (used as shuttering), and/or fragments of asbestos sheeting within the hardcore beneath concrete slabs may be present, certainly fragments of suspected asbestos was included in fly tipped material across all areas. Additionally, limpet asbestos (often sprayed in older buildings to provide fire protection on steel and reinforced concrete beams/columns and on underside of floors) on the hardcore surface beneath concrete slabs, cannot be entirely discounted.

8.2.20 Anecdotal evidence suggests an unknown quantity of asbestos was dumped within Area A although to date the exact location has not been found.

8.3 Obstructions

8.3.1 It is apparent from a review of historical OS Plans (see Section 3) and the site visit that buildings have been present on about 35% of the site area. Furthermore, concrete hardstand, which is typically 0.2m thick, covers approximately 12,000m². Drawing 3043/4 shows the footprints of the former structures, and areas of hardstand.

8.3.2 Trial pits have been excavated along the lines of former building foundations, beneath former concrete slabs and along the line of former tanks.

8.3.3 Numerous obstructions were encountered from ground level and to depths of around 2.5m, including former **walls**, former **basement** floors and former **tanks**.

8.3.4 TPs 407 & 432 were undertaken through former cellars/basements, whilst TPs 437, 438 and 439 are all thought to have encountered former below ground tanks associated with the chemical works (possibly lead chambers).

8.3.5 A list of below ground obstructions encountered are provided in the table below:

Hole ID	Area	Depth (m)	Obstruction encountered
TP437	A	0.8m - 2.7m	Curved brick chamber, likely former UST
		2.4m - 2.5m	Former concrete floor slab or basement floor slab
TP438		1.6m - 4.0m	Concrete slab with concrete sides, 2.5m wide with brick lining on its eastern side, possible former UST
TP439		1.4m - 2.3m	Curved brick chamber with layer of wood at 1.8m and former pipe work at 2.3m, likely former UST
TP442		0.0m - 0.7m	Brick wall 0.3m wide
TP503		1.5m - 2.1m	Poorly bonded brick wall on concrete footing orientated east – west in centre of trial pit.
TP504		1.4m - 1.5m	Concrete slab.
		1.5m - 2.3m	Poorly bonded brick & mortar wall o.4m wide orientated north-south uncovered in side of trial pit.
TP506		0.5m	Solid concrete obstruction; trial pit refused & was moved 2.0m south.
TP507		1.0m - 4.0m	Concrete slab in base of trial pit

Hole ID	Area	Depth (m)	Obstruction encountered
		1.5m - 2.7m	Brick & mortar built arched tunnel orientated north to south (possible former sewer or drainage flue).
TP508		1.6m - 2.3m	Brick & mortar built arched tunnel orientated north to south (possible former sewer or drainage flue).
TP512		1.7m - 1.9m	Concrete slab.
		1.9m - 2.4m	Poorly bonded brick & mortar wall 0.4m wide orientated east to west.
TP513		1.3m - 2.3m	Brick & mortar built arched tunnel entrance with brick & mortar walls in trial pit walls. Orientated north to south (possible former sewer or drainage flue).
		2.8m	Poorly bonded brick & mortar wall.
TP514		0.4m - 0.6m	Concrete slab.
		2.0m - 2.2m	Poorly bonded brick 7 mortar relict floor slab with black bituminous coating.
TP520		0.25m - 1.8m	Poorly bonded brick & mortar wall in eastern wall of trial pit.
TP418	B	0.4m - 2.0m	Brick chamber with former drainage pipe 0.2m wide at base
TP421		0.35m - 1.8m	Brick wall in W trial pit face
TP422		0.2m - 1.2m	Brick chamber along W trial pit face
TP525		1.0m - 1.8m	Brick & concrete structure in southern end of trial pit (likely relict reservoir wall or similar).
TP526		0.3m	Concrete slab.
TP527		0.4m	Concrete slab.
TP402	C	0.2m - 0.7m	Sandstone and brick wall 0.2m wide
TP404		0.1m - 0.6m	Concrete slab, 0.1m thick with brick wall below 0.3m wide
TP406		0.2m - 0.9m	Brick wall 0.4m wide to 0.7m with 0.2m thick concrete slab below
TP416		0.2m - 1.2m	Brick wall 0.6m wide
TP426	D	1.1m - 1.25m	Former concrete floor slab at least 0.15m thick
TP430		0.3m - 2.0m	TP excavated along brick wall
TP432		0.2m - >2.6m	Excavated through basement/cellar, brick walls in N and E TP faces, with a doorway in N TP face, depth to base no proven due to constant spalling of made ground
TP522		0.2m - 1.0m	Poorly bonded brick & mortar wall orientated north to south through centre of trial pit.
TP522		1.8m - 2.5m	Poorly bonded bricks and cobbles of sandstone wit mortar in northern wall of trial pit (relict footing).

8.3.6 Given the above, it is apparent that whilst some former buildings have been demolished (although several still remain), substantial foundations, bases etc remain below ground.

8.3.7 In addition to the obstructions described above large oversize materials such as masonry boulders and stone lintels were encountered, most notably within the Granular Made Ground (Area B & D) and Brickfill (Areas A & B). It is estimated that within these made ground types approximately 30% of the material is coarser than a house brick.

8.3.8 Given the redevelopment proposals, removal of obstructions and oversize will be required.

8.4 Natural soils

8.4.1 Natural ground was encountered in the majority of pits beyond the footprints of former quarries/reservoir, and typically comprised the following ground types:

Area A (chemical works)

- **Cohesive Residual Soil:** encountered within the majority of pits from between 0.9m (TP442) and 3.8m (TP439) (average depth encountered from 2.5m). Typically, firm to stiff gravelly clays.

Area B (rolling iron mill and textile works)

- **Cohesive Alluvium:** encountered in approximately half of the pits where made ground was less than around 2m thick, from 0.4m to 2.4m (average depth encountered from 1.5m, average depth encountered to 3.0m). Typically, a soft grey and brown clay underlying all but the centre-north and far south of Area B; extent (c. 12,500m^2 shown on Drawing 3043/11 in Appendix B.
- **Cohesive Residual Soil:** encountered in TPs 419, 421, 424 & 425 from between 1.1m and 3.5m depth (average depth encountered from 2.2m). Typically, firm to stiff gravelly clay.
- **Granular Residual Soil:** encountered in TPs 420 & 423 only from 0.8m and 1.4m respectively as clayey gravel.

8.4.2 A total of three cable percussion boreholes were advanced to target the Alluvial Deposits in Area B; BHs 507 to 509. BH507 did not encounter Alluvium; deep made ground was found to directly overlie residual soils. BHs 508 & 509 did encounter Alluvium which was found to be of low strength.

Area C (former quarry, malthouse, brickworks and scrap yard)

- **Cohesive Residual Soil:** encountered within the majority of pits beyond the quarry footprint from between 0.8mm and 1.6m (average depth encountered from 1.2m) as firm to stiff gravelly clay.
- **Granular Residual Soil:** encountered within TPs 406, 447 & 449 only from 1.3m to 2.2m (average depth encountered from 1.8m) as clayey gravel.

Area D (industrial area, centre-north)

- **Cohesive Residual Soil:** encountered in the majority of pits beyond the quarry footprint from between 0.7m and 2.9m depth (average depth encountered from 1.5m) as firm to stiff gravelly clay.
- **Granular Residual Soil:** encountered in TPs 414, 433 & 435 only from 1.5m to 2.8m (average depth encountered from 2.0m) as clayey gravel.

8.5 Bedrock

8.5.1 Coal Measures (bedrock) was encountered:

- Area A: within TPs 436, 440 & 442 only from an average depth of 3.0m
- Area B: in TPs 420 & 423 to 427 & BHs 507 to 509 from an average depth of 3.0m.
- Area C: within TPs 403, 404 & 406 only from an average depth of 1.75m.
- Area D: within the majority of pits beyond the quarry footprint from an average depth of 2.6m.

8.5.2 BHs 501 to 503 were advanced from rockhead using rotary coring methods. At least 5.0m of intact core was recovered from all three boreholes. Bedrock was found to comprise medium strong grey fine-grained sandstone with closely spaced discontinuities, over weak to medium strong (typically moderately weak), grey, thinly laminated mudstone with very closely spaced discontinuities.

8.5.3 Discontinuities within the sandstone were generally rough and closed with brown penetrative staining, whilst discontinuities in the mudstone were generally smooth with grey clay on surfaces.

8.5.4 Typical fracture spacings in the sandstone were between 2cm and 10cm, whilst typical fracture spacings within the mudstone were between 1cm and 4cm.

8.6 Visual & olfactory evidence of contamination

8.6.1 Exploratory locations where evidence of significant contamination was noted are summarised below:

Area	Hole ID	Material	Depth (m)	Observation
A	TP438	Ash & Clinker	2.0m	Sweet solvent odour
	TP439	Ash & Clinker	2.4m	Slight solvent odour
	TP440	Ash & Clinker	2.4m	Faint hydrocarbon odour
	TP442	Granular Made Ground	1.0m	Slight hydrocarbon odour
		Coal Measures	3.0m	Groundwater inflow with oily sheen and hydrocarbon odour
	TP444	Granular Made Ground	1.2m	Groundwater seepage with slight hydrocarbon odour and oily sheen
	BH501	Filter Sand	4.0m – 5.2m	Sulphurous odour throughout strata,
		Granular Made Ground	7.6m	Faint hydrocarbon odour.
		Granular Made Ground	0.0m to 1.5m	Glass fibre tank excavated with black oily sludge in base.
	TP501	Granular Made Ground	1.1m	Hydrocarbon odour.
	TP512	Granular Made Ground	2.4m	Faint hydrocarbon odour.
	TP514	Cohesive Made Ground	2.8m	Faint hydrocarbon odour.
		Cohesive Made Ground	3.0m – 3.5m	Oily sheen & hydrocarbon odour.
	TP517	Made Ground Topsoil	0.2m	Sulphurous odour.
	TP518	Granular Made Ground	1.8m	Hydrocarbon odour.
B	TP420	Cohesive Made Ground	0.6m	Groundwater seepage with oily sheen and hydrocarbon odour
	TP425	Ash & Clinker	0.2m to 1.1m	Strong hydrocarbon odour
	TT428 N	Granular Made Ground	1.4m	Major inflow of black groundwater with oily sheen and strong hydrocarbon odour
	TT428 S	Cohesive Alluvium	1.2m	Slight groundwater seepage with oily sheen
		Granular Made Ground	1.4m	Major inflow of black groundwater with oily sheen and strong hydrocarbon odour
	TP429		2.8m	
	TP524	Cohesive Made Ground	2.0m – 2.7m	Hydrocarbon odour & staining of soil matrix.
C	TP402	Ash & Clinker	2.5m to 2.8m	Faint hydrocarbon odour
	TP403	Granular Made Ground	0.1m to 1.0m	Hydrocarbon odour and groundwater seepage with oily sheen
D	TP430	Ash & Clinker	0.9m to 1.5m	Strong hydrocarbon odour
	TP446	Ash & Clinker	1.0m	Slight solvent odour

8.6.2 Selected samples of the potentially contaminated materials listed above were scheduled for chemical testing, along with samples of made ground from across the rest of site.

8.7 Groundwater

8.7.1 Groundwater was encountered within the majority of exploratory holes excavated across Areas D and B as seepages and inflows from around 2.0m; most notably in the south (Area B). Excavations in Areas A and B generally remained dryer with groundwater ingress comprising relatively minor seepages where encountered.

8.7.2 Localised perched waters were encountered within backfilled features (basements, former reservoir etc).

8.7.3 Groundwater levels recorded in the monitoring wells are summarised below:

Hole ID	Response zone (depth range & strata)	Groundwater body	Typical standing water level	
			m bgl	m AoD#
BH501	4.0m – 10.0m (various made ground).	Perched.	4.33	96.68
BH502	3.0m – 6.0m (Ash & Clinker).	Perched.	4.40	91.66
BH503	2.8m – 8.8m (Cohesive Made Ground).	Perched.	8.47	92.07
BH504	6.0m – 12.0m (Ash & Clinker).	Perched.	-	-
BH505	2.8m – 8.6m (Ash & Clinker).	Perched.	8.34	90.66
BH506	3.0m – 9.0m (Cohesive Made Ground).	Perched.	6.81	93.73
BH507	1.5m – 3.0m (Granular Made Ground).	Perched.	0.26	94.70
BH508	2.2m – 2.8m (Cohesive Alluvium).	Drift Aquifer.	0.84	94.01
BH509	1.5m – 3.0m (Cohesive Alluvium).	Drift Aquifer.	0.93	93.66
PH501	6.0m – 9.0m (Sandstone).	Bedrock aquifer.	5.08	95.19
PH502	2.5m – 5.5m (Cohesive Made Ground).	Perched.	-	-
PH505	3.0m – 6.0m (Ash & Clinker).	Perched.	-	-
PH506	3.0m – 6.0m (Cohesive Made Ground).	Perched.	-	-
PH507	3.0m – 6.0m (Ash & Clinker).	Perched.	-	-
PH508		Perched.	-	-
PH509		Perched.	5.71	91.46
PH510	3.0m – 6.0m (Cohesive made Ground).	Perched.	-	-
PH511	3.0m – 6.0m (Ash & Clinker).	Perched.	-	-
PH512	1.5m – 4.5m (Granular Made Ground).	Perched.	4.01	95.78
PH513	3.0m – 9.0m (Sandstone).	Bedrock aquifer.	4.43	101.23
PH514	3.0m – 6.0m (Granular Made Ground).	Perched.	-	-
PH515	3.0m – 9.0m (Sandstone & Mudstone).	Bedrock aquifer.	4.67	96.54
PH516	3.0m – 6.0m (Granular Made Ground).	Perched.	4.60	96.64
PH517	1.5m – 4.5m (Granular Made Ground).	Perched.	4.23	96.68
PH518	4.5m – 7.5m (Sandstone).	Bedrock aquifer.	5.72	95.03
PH519	1.2m – 2.7m (Granular Made Ground).	Perched.	1.26	97.66
PH520	4.5m – 7.5m (Sandstone).	Bedrock aquifer.	2.24	95.68

Note: boreholes in red have not been successfully monitored to date due to vandalism making monitoring impossible. During visits Lithos has worked to repair monitoring wells where reasonably practical.

8.7.4 Based on the findings of monitoring to date groundwater lies at levels of between c. 90.6mAOD and 101.2mAOD and flows to the south broadly following topography.

8.8 Stability

8.8.1 Spalling and overbreak of excavations occurred in the majority of trial pits within the made ground, particularly where coarse granular soils (Granular Made Ground & Brickfill) were encountered.

8.8.2 Excavations through the soft Alluvial deposits also exhibited some instability, however, excavations in firm/stiff clays and clayey gravels (Residual Soils) should remain stable during the construction phase in the short term.

8.9 Investigation of quarries & high walls

8.9.1 Three areas of known quarrying are shown on the 1894 OS plan:

- Brickworks Quarry (c. 9,000m^2) in the east (Area C).
- An oval-shaped area (c. 750m^2) in the centre-north (Area D).
- A roughly square-shaped area (c. 1500m^2) in the north-west (within Area A).

8.9.2 A total of 19 trial pits, 3 trial trenches, 5 cable percussion boreholes and 10 'groups' of stitch probeholes (ST501 to ST510) were advanced within, and across the highwalls of quarries in Areas A, C & D. Findings are summarised in the table below:

Location	Hole ID	Final depth (m)	Depth to base of made ground (m)	Remarks
Quarry in Area A	BH501	17.2	10.7	Advanced within quarry footprint through base of quarry.
	TP501	3.8	>3.8	Excavated within quarry footprint.
	TP502	4.5	>4.5	
	TP503	4.2	>4.2	
	TP504	3.4	>3.4	
	TP505	5.2	>5.2	
	ST510	-	-	Quarry highwall encountered between STs 510B & 510C.
	TT401	3.0	1.6	As trenched east depth to natural ground became deeper, initially at a steady slope of around 7°, then much steeper at up to 55°
	TT401E	5.1	>5.1	Far eastern end of TT401, within quarry footprint
	TP402	4.2	>4.2	Excavated beyond supposed quarry footprint but still in made ground at 4.2m depth
	TP404	2.1	0.8	Excavated just beyond supposed quarry footprint
	TP406	1.9	0.9	
	TP408	4.4	>4.4	Excavated within quarry footprint
	TP409	3.8	>3.8	
	TP410	3.6	>3.6	
	TT411	1.6	1.0	As trenched west depth to natural ground became deeper, at a steady slope or around 7° then increases up to around 20°
	TT411W	2.7	>2.7	Far western end of TT411, within quarry footprint
	TP412	2.1	1.7	Excavated just beyond quarry footprint
	TP413	3.6	>3.6	Excavated within quarry footprint
	TP414	2.6	0.9	Excavated just beyond quarry footprint
	TP415	3.6	>3.6	Excavated within quarry footprint
	TP416	3.4	>3.4	
	TP447	2.8	1.3	Excavated just beyond indicative quarry footprint

Location	Hole ID	Final depth (m)	Depth to base of made ground (m)	Remarks
	TP448	3.3	>3.3	
	TP449	2.9	1.2	
	BH503	15.4	9.0	Advanced within quarry footprint.
	BH505	9.5	8.8	
	TP523	3.8	>3.8	Excavated within quarry footprint
	ST501	-	-	Quarry highwall encountered between STs 501B & 501C
	ST502	-	-	Quarry highwall encountered between STs 502H & 502I
	ST503	-	-	Quarry highwall encountered between STs 503F & 502G
	ST504	-	-	Quarry highwall encountered between STs 504B & 502C
	ST505	-	-	Quarry highwall encountered between STs 505D & 505E
	ST506	-	-	Quarry highwall encountered between STs 506A & 506F
	ST507	-	-	Unclear exactly where highwall lies based on drilling to date.
	ST508	-	-	Quarry highwall encountered between STs 508D & 508E
Quarry in centre-north (Area D)	TT431	3.6	3.4	Excavated within quarry footprint, natural encountered at 3.4m depth, however still within made ground at 3.4m, 8.2m from E trial trench face, presence of road and services prevented further trenching
	TP445	4.9	>4.9	Excavated just beyond indicative quarry footprint, made ground too deep to trench
	TP446	3.1	1.5	Excavated beyond indicative quarry footprint
	BH506	9.0	>9.0	Advanced within quarry footprint.
	TP515	3.7	>3.7	Excavated within quarry footprint
	ST508	-	-	Quarry highwall encountered between STs 508D & 508E
	ST509	-	-	Quarry highwall encountered between STs 509G & 508H

Note: Text in blue represents exploratory holes which are thought to be beyond the quarry/reservoir footprints. Text in red highlights pits that encountered significant thicknesses of made ground.

8.9.3 Illustrative cross sections of quarry highwalls which were encountered during drilling of the stitch probeholes are included with the PH logs in Appendix H.

Quarry in north-west (Area A)

8.9.4 A roughly square-shaped area (c. 1500m^2) is shown on OS plans in the north of Area A. This quarry had been backfilled and partially built over by 1907.

8.9.5 The base of this quarry has been proven in BH501 and STs 510 to depths of 10.7m and 9.5m respectively.

8.9.6 Stitch PHs suggest that highwalls are very steep with a gradient of at least 70^0.

Brickworks Quarry (Area C)

8.9.7 According to OS plans, Brickworks Quarry occupied an area of c. 9,000m^2, including a rectangular area (c. 100m by 22m) in the south, with cliff faces shown.

8.9.8 Successful trenches were undertaken on the north-western and eastern boundary. TT01 to the north-west indicates an initial gradual slope of around 7° before becoming much steeper at just over 50°. TT11 indicates the eastern face of the quarry was shallower at an angle of up to around 20°.

8.9.9 To the south-east it appears as though the quarry has been 'over-tipped' - a steep c. 6m high embankment is present. Pits at the foot of the slope (with the exception of TP448) encountered shallow natural deposits at between 1.2m and 1.3m.

8.9.10 The depth to made ground in TP448 was much deeper (>3.3m) compared to TP449 which encountered natural residual soils at 1.2m depth only 5m south-east. This suggests the quarry extended slightly further south-east than is shown on OS plans.

8.9.11 The depth to the base of the quarry has been proven in BHs 502 & 503, PHs 501 to 511 and in STs 501 to 507 to between 9.0m and 16.4m.

8.9.12 Stitch drilling located the northern and eastern extents of the quarry highwall. The highwall is generally very steep in all stitch probeholes with a minimum gradient of 60^0 and a typical gradient of 70^0. The highwall encountered in ST506 appears to be irregular with a possible ramp or crest. Investigation at the line of ST506 was constrained by the presence of vegetation, trailers and concrete walls. It is tentatively suggested that the highwall encountered in ST06 may represent an 'entrance ramp', benched highwall or similar feature.

8.9.13 TPs 414 & 415, excavated approximately 5m apart, indicated the possible presence of the high wall in the centre-west. However, services prevented further trenching this area.

Quarry in centre-north (Area D)

8.9.14 An oval-shaped area (c. 750m^2) is shown on OS plans in the centre-north of Area D, between Stone St and Iron St. By the 1970s, Wharfe Works (now Garnett Wire) had been built over this quarry.

8.9.15 Much of the supposed quarry footprint is beneath one of the on-site building which is yet to be demolished, hence trenching and stitch probeholes were limited to the western edge of the quarry.

8.9.16 The base of the quarry was proven in STs 509 & 510 to 12.0m depth.

8.9.17 TP445 was excavated approximately 6m north of TT431 and encountered made ground to depths of 4.9m. TP445 was expected to lie beyond the quarry footprint but it is considered likely that TP445 lies within the quarry footprint.

8.9.18 TP446 was then excavated a further 10m north and encountered natural residual deposits at around 1.5m depth, indicating the quarry high wall runs between TPs 445 & 446.

8.9.19 Stitch probeholes located the northern and southern extents of the quarry highwalls. The southern highwall has a gradient of 45^0 while the northern highwall has a steeper gradient of at least 70^0.

8.9.20 The footprint of this quarry is significantly larger than historical mapping suggests.

8.10 Investigation of Reservoir (Area B)

8.10.1 According to historical OS plans, a former reservoir occupied an area of c. 1,000m², in the north-west of Area B. Anecdotal evidence suggests that the reservoir was associated with the chemical works rather than the former mills.

8.10.2 A total of 7 trial pits and one trial trench were advanced within and adjacent to the backfilled reservoir. Findings are summarised in the table below

Location	Hole ID	Final depth (m)	Depth to base of made ground (m)	Remarks
Reservoir in Areas A & B	TP427	3.5	1.3	Excavated beyond indicative reservoir footprint
	TT428N	2.5	>2.5	Far northern end of TT428, within reservoir footprint
	TT428S	2.8	0.4	As trenched north, depth to natural ground became deeper, at a steady slope of around 20° then increases up to 25°, major groundwater inflow prevented further trenching
	TP429	3.2	>3.2	Base of reservoir not proven due to major groundwater inflow
	TP443	1.4	>1.4	Beyond indicative reservoir footprint, groundwater inflow from old drain prevented further excavation
	TP443a	2.4	>2.4	Possibly beyond indicative reservoir footprint, groundwater inflow prevented further excavation
	TP444	3.4	2.5	Attempted to trench out, but major groundwater inflow at 1.3m as trenched south
	TP524	3.5	>3.5	Base of reservoir not proven.
	TP525	3.4	>3.4	Base of reservoir not proven due to groundwater inflow.

Note: Text in blue represents exploratory holes which are thought to be beyond the quarry/reservoir footprints. Text in red highlights pits that encountered significant thicknesses of made ground.

8.10.3 The southern edge of the reservoir high wall was identified within TT428, which showed made ground becoming thicker northwards, the angle of the slope is relatively shallow (between c. 20° to 25°) rather than a steep 'cliff-face'.

8.10.4 Major inflows of groundwater prevented deep trenching in the reservoir. Similarly, inflows of groundwater prevented the base of the reservoir being identified within TP429, along with the northern reservoir high wall within TPs 443, 443a & 444. However, 3rd party holes by AIG suggest the reservoir extends to depths of up to around 4m in its centre.

8.10.5 The reservoir high walls could not be identified to the east and west due to a large c. 1.5m high soil bund and a drainage ditch.

8.10.6 Whilst it is unclear whether TPs 443 & 443a were beyond the recorded reservoir footprint (both terminated before encountering natural ground due to groundwater inflows) it is likely that TP444 was excavated within the reservoir footprint given the material encountered.

8.11 Revised conceptual ground model (ground conditions)

8.11.1 The Preliminary Conceptual Site Model has been revised in light of data obtained during the ground investigation, most notably with respect to:

- The nature and distribution of made ground, including the presence of significant buried obstructions
- The strength, nature and depth of underlying natural strata
- The nature and distribution of contamination (based on visual/olfactory evidence only)

8.11.2 Further refinement of the Conceptual Site Model is presented in Section 10.2, where the results of laboratory testing for contaminants have been considered.

9 CONTAMINATION (ANALYSIS)

9.1 General

9.1.1 The site has been formerly used as:

- Chemical works
- Rolling iron mill
- Textile mill
- Scrap yard
- Malthouse
- Brickworks
- Quarry

9.1.2 The exact raw materials stored and used on site are unknown. However, given the wide range of previous uses it is expected some ground contamination will exist. Anticipated contaminants in Areas A to D are included in Section 6.2, and those tested for are listed in Section 9.2 below.

9.1.3 In the context of risks to human health associated with residential redevelopment, the Tier 1 Soil Screening Values referenced in this report have been derived via the CLEA default conceptual site model (CSM) used for generating SGVs, but amended, where appropriate, to be more specific to redevelopment within the planning process.

9.1.4 Where available, Category 4 Screening Levels (C4SL) have also been referenced.

9.1.5 Generic Note 04 in Appendix A provides further details with respect to current guidance and the interpretation of analytical data.

9.2 Testing scheduled

9.2.1 Based on the above assessment, Lithos submitted a test schedule (summarised in the table below) to a UKAS accredited laboratory. Account has also been taken of visual and olfactory evidence recorded during the ground investigation.

Soil type	No. of samples	Determinands
Made ground	98	pH, water soluble boron, and total metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc) & asbestos ID TOC, banded total petroleum hydrocarbons, speciated PAH Semi-Volatile Organic Compounds (sVOC), includes PAHs Total cyanide, pH, sulphide, carbonate & conductivity Speciated phenols, VOCs & sVOCs Water soluble sulphate, chloride, nitrate and magnesium
Natural ground	13	TOC, Speciated TPH, sVOCs, VOCs, speciated phenols Total Cyanide and Total Sulphur.
Surface water	2	pH, water soluble boron, and total metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc) & Asbestos ID Water soluble sulphate, chloride, nitrate and magnesium

9.2.2 Account was taken of previous uses in specific areas, with cyanide and sulphur analysis concentrated on samples recovered from Area A (given the suspected use of spent oxide in the production of sulphuric acid); and speciated phenol and sVOC analysis concentrated on samples recovered from Areas A & B (given the increased possibility of a range of solvents being linked to previous land uses).

9.3 Soil contamination results

9.3.1 The soil contamination test results are summarised in the tables in Annex II. Whilst chemical testing was targeted based on previous land uses, initial review of the results indicated that inorganic and organic contamination was consistently identified across all areas.

9.3.2 Therefore, to avoid repetition, all areas have been considered together for the initial review of inorganic and organic determinants.

9.3.3 Where chemical testing has been scheduled only in one area (such as cyanide in Area A), this has been discussed separately.

9.3.4 Significant regrade across the site will be required and it is apparent that, irrespective of contamination loading, made ground in Areas A to D contain a high percentage of anthropogenic material that would be undesirable in near surface deposits in garden and landscaped areas.

9.3.5 Furthermore, given the heterogenous nature of made ground, further areas of contamination, not yet identified, should be anticipated.

9.3.6 Laboratory test certificates, as received from the laboratory, are presented in Appendix G to this report.

Inorganic determinands

9.3.7 Of the 88 samples of made ground analysed for inorganic parameters from Areas A to D, 24 can be classified as uncontaminated and 64 could be classified as contaminated.

9.3.8 These samples have been classified by comparison with Tier 1 Soil Screening Values for an end use including domestic gardens and any area where plants are to be grown (the most sensitive of the proposed end-uses).

9.3.9 The most common contaminants are arsenic (49 exceedances), copper (17 exceedances), lead (51 exceedances) and zinc (25 exceedances)

9.3.10 Whilst the made ground encountered on site has been grouped into soil types (Ash & Clinker, Granular Made Ground etc), a great deal of heterogeneity exists within each soil type. Fragments of metal, plastic and wood are frequently recorded in all soil types, but are not consistently found in each excavation.

9.3.11 Given this high degree of variation, statistical analysis of the made ground is not deemed appropriate. It would not be possible to determine if samples belonged to the same sample population in such heterogenous material.

9.3.12 Further to this over two thirds of the samples were contaminated with one or more of the aforementioned contaminants and 18 of the samples recorded concentrations over 5x the Lithos' Tier 1 screening value. Therefore, some remediation in respect to inorganics within made ground will be required to break potential pathways to the end-user (residents).

Asbestos

9.3.13 Of the 77 samples of made ground analysed for asbestos fibres, only 4 yielded a positive ID. Subsequent quantification was scheduled, the results of which are shown below:

Hole ID	Depth (m)	Strata	Asbestos type & quantification (% mass)
TP402	0.4	Granular Made Ground	Chrysotile (<0.001)
TP436	0.1		Amosite (0.001)
TP524	0.5		Chrysotile (0.62)
TP512	1.0	Cement sheet (recovered from Granular Made Ground)	Chrysotile

9.3.14 The results of the quantification revealed that only trace fibres of asbestos were identified within the made ground matrix. However, larger fragments of asbestos containing material (cement sheet) are present and do contain a significant portion of chrysotile.

9.3.15 During the walkover sheets/fragments of potentially asbestos containing material (ACMs) were noted across site. Furthermore, anecdotal evidence suggests asbestos sheeting was buried within Area A (although it was not encountered during the investigation).

9.3.16 Therefore, there is a high probability that more significant amounts of fragmented ACM (and possibly significant concentrations of free fibres) will be encountered during the site preparatory earthworks than have been found during this investigation.

Cyanide & total sulphur

9.3.17 Cyanide is an acute toxin, as such Lithos have not derived a Tier 1 screening value (screening values assume a long-term exposure that would not be appropriate for acute toxins). Deriving a Tier 1 value is beyond the scope of this report and would require a site-specific risk assessment.

9.3.18 Similarly, whilst total sulphur is not typically considered an acute toxin, it is not a commonly encountered contaminant and as such does not have a generic Tier 1 screening value.

9.3.19 The results of the cyanide and total sulphur are included within the inorganics summary tables in Annex II. Positive identifications were recorded, but these were typically below 5mg/kg and are unlikely to be of concern. Nonetheless, a remedial target concentration should be derived via detailed site-specific risk assessment.

Organic determinands

9.3.20 This site is brownfield and underlain by made ground which has yielded elevated concentrations of a number of inorganic determinands. Consequently, for organic compounds, the Tier 1 Soil Screening Values used in this report have been derived with reference to a CSM that assumes a minimum 600mm of clean soil cover will be placed in gardens/landscaped areas (Lithos Scenario B). This depth is assumed for generic risk assessment purposes, cover depths may need to be increased in some areas and would certainly form just one part of a wider remediation scheme.

9.3.21 Lithos have used the CLEA model to derive risk-based screening values for hydrocarbons, in accordance with the methodology detailed by the TPHCWG, and reviewed by a UK workshop of experts with respect to UK adoption of the method.

9.3.22 However, these screening values assume a Soil Organic Matter (SOM) of 6% (equivalent to a TOC of 3.5%). Many organic contaminants are more mobile when the SOM is lower, and consequently comparison of soil results with lower screening values may be required.

9.3.23 In order to check the validity of Lithos' Tier 1 Soil Screening Values, the average TOC for each common fill type (beyond any areas of obvious hydrocarbon impact) have been determined.

Fill type	Typical TOC (%)	Comparison of soil results with revised screening value necessary?
Ash & Clinker	8%	No.
Brickfill	9%	
Cohesive Made Ground	2.5%	Yes, see table below, but no significant organic contamination was recorded in this soil type. All determinands well below "4.3%" screening value; most below limit of detection, revised screening values adopted.
Filter Sand	7%	No.
Granular Made Ground	5%	
Macadam	5%	
Made ground Topsoil	8%	
Cohesive Alluvium	0.5%	Yes, see table below.
Cohesive Residual Soil	1%	
Granular Residual Soil	0.8%	

9.3.24 Table of revised screening values:

Fill type	Revised Screening Value[1]									
	Benzene	Toluene	Ethyl Benzene	Xyl'ene	Phenol	BaP	Naph'ne	GRO	LRO	DRO
Cohesive Made Ground	0.37	2283	673	236	1817	25	7	25	112	1,000
Cohesive Alluvium	0.13	287	76	27	563	25	0.7	4	26	1,000
Cohesive Residual Soil	0.13	287	76	27	563	25	0.7	4	26	1,000
Granular Residual Soil	0.13	287	76	27	563	25	0.7	4	26	1,000

Notes: [1] Revised Screening Values assume residential with gardens end-use and minimum 600mm clean cover.

Hydrocarbons (TPH & PAH)

9.3.25 A mixture of both simple banded & speciated TPH, sVOCs and VOC's were scheduled as per the table in Section 9.2 given:

- previous uses of site; the likely presence of underground tanks (probably chemical storage tanks in Area A, and fuel tanks in other Areas); and
- olfactory evidence of hydrocarbon contamination.

9.3.26 Where olfactory evidence of hydrocarbon contamination was encountered both made and natural ground were submitted for fully speciated TPH, along with sVOCs and VOCs.

Total petroleum hydrocarbons

9.3.27 Where no olfactory or visual evidence of petroleum contamination was noted, samples were initial scheduled for a total petroleum hydrocarbons (TPH) screen. This assessment includes an aggressive extraction of all hydrocarbons in a soil sample and will report all sources (not just petroleum products).

9.3.28 Of the 56 samples of made ground scheduled for TPH, 7 could be classified as contaminated, including:

- DRO in three samples of Ash & Clinker from Areas C and D;
- DRO in one sample of Granular Made Ground in Area A;
- DRO in one sample of Cohesive Made Ground in Area A;
- GRO, DRO & LRO in one sample of Granular Made Ground; and
- GRO, DRO & LRO in one sample of bituminous sealant material from Area A.

9.3.29 TPH can be associated with a variety of sources such as Ash & Clinker, Coal fragments, fire ash, burnt plastics and elevated TPH concentrations do not automatically infer a petroleum product is present. This is also supported by laboratory identification of potential sources, requested on TP512 in Area A where significantly elevated DRO was recorded, but which the laboratory confirmed was not due to a petroleum source but due to elevated PAHs.

9.3.30 Whilst not necessarily associated with a petroleum product, the significance of these hydrocarbons, with respect to health, should still be assessed. Providing no other sources are present within these samples (solvents, degreasers etc, of which no olfactory evidence was noted), it can be assumed that the most problematic compounds detected within the banded TPH screen are polycyclic aromatic hydrocarbons (PAHs - see below).

Polycyclic Aromatic Hydrocarbons (PAH)

9.3.31 The significance of PAHs can be determined by considering indicator compounds. In most cases, benzo(a)pyrene (BaP) is adopted as an indicator (due to the wealth of toxicological data available) and has been used by various authoritative bodies to assess the carcinogenic risk of PAHs in food.

9.3.32 A C4SL toxicity assessment using the surrogate marker approach can be used to estimate the significance of a mixture of PAHs in soil, using toxicity data for indicator compounds within that mixture. Exposure to the indicator (or surrogate marker) is assumed to represent exposure to all PAHs in that matrix.

9.3.33 The sample profiles here are sufficiently similar to the toxicity study adopted for the C4SL assessment and therefore the C4SL surrogate marker approach can be adopted.

9.3.34 Whilst classed as a PAH, naphthalene is more volatile and mobile in the environment than other PAHs. As such the significance of naphthalene cannot be considered within the surrogate marker approach. Consequently, naphthalene has been considered individually against Lithos' Tier 1 Value.

9.3.35 A total of 2 samples returned values for BaP in excess of Lithos' Tier 1 values; one spot sample of bituminous sealant, and one sample of Granular Made Ground, both recovered from Area A.

9.3.36 Both of these samples, and two further samples of Ash & Clinker from Area A yielded elevated concentrations of naphthalene

9.3.37 No other samples recovered from across the remainder of the site (Areas B – D) returned concentrations of PAHs which exceed the relevant Tier 1 screening values.

Speciated total petroleum hydrocarbons

9.3.38 Where olfactory evidence of hydrocarbon contamination was noted within made or natural ground, speciated TPH was scheduled. Speciated testing focuses on chemicals identified by the TPH Criteria Working Group as commonly occurring in petroleum-based fuels and oils.

9.3.39 Assessment of speciated TPH has been undertaken in accordance with a 3-step approach, (outlined in Generic Note 04 in Appendix A). The first two steps involve review of speciated results. The third step assesses cumulative effects.

9.3.40 Step 1 – Consideration of Indicator Compounds. (BTEX, naphthalene & BaP). A total of 6 samples from across all areas included elevated TPH results and yielded concentrations of benzo(a)pyrene above the relevant Lithos Tier 1, one also exceeded the relevant Tier 1 value for Naphthalene. These exceedances were all restricted to the made ground. See the attached Table within Annex III.

9.3.41 Typically, once an indicator compound is identified above its screening value, it would be assumed that site specific risk assessment and/or remedial activity would be required and the assessment would not proceed to Steps 2 & 3. However, this development will require a minimum 600mm clean soil cover in garden and landscaped areas due to elevated inorganic determinants. This cover would also effectively break plausible pathways with benzo(a)pyrene (although not necessarily naphthalene). Therefore Step 2 and 3 have been undertaken to ensure the implications of elevated TPH fractions and cumulative effects are considered.

9.3.42 Step 2 – TPH Fractions (does any individual fraction exceed Tier 1?). Two samples of Granular Made Ground recovered from Area A (TP501 at 1.2m & TP512 at 2.3m) exceed the individual TPH fraction screening values. The laboratory identified contamination in TP501 as diesel; contamination in TP512 was identified as PAHs and not likely to be petroleum fuel.

9.3.43 None of the other samples included fractions which exceeded the relevant Tier 1 values.

9.3.44 Step 3 – Assessing Cumulative Effects. The third step assesses the cumulative risk from all of the fractions identified. This is because each TPH fraction comprises a range of different substances, and a number of these can affect the same 'target organ' (i.e. cause skin irritation or affect the liver), resulting in cumulative effects.

9.3.45 The cumulative effect, associated with each source material, has been assessed via calculation of a Hazard Index (HI): HI < 1 indicates no cumulative effects; HI > 1, cumulative risk requires further consideration.

9.3.46 HI calculation results are presented in in Annex II. The HI for all samples excluding those which failed Step 2 and was known to be diesel (Granular Made Ground recovered from TP501 in Area A) is less than 1, therefore cumulative risks are not considered plausible.

Phenols

9.3.47 Phenols were scheduled in all areas, but predominantly within Areas A & B given the possible presence of solvents used within production processes. Of the 50 samples of made and natural ground tested for speciated phenols, all yielded results lower than the relevant Lithos Tier 1, however a range of phenol compounds were recorded in TP505, including 2 & 4 methyl phenol and 2,4 dimethyl phenol.

9.3.48 Methylphenols are also termed creosols and are used in a range of industries including in the production of dyes. The presence of creosols in Area A may indicate the use, and possible continued presence, of creosote and other gas works waste in the chemical works.

9.3.49 2,4-dimethylphenol is an isomer and is used as a pesticide, also found in disinfectants & solvents, as well as dyestuffs.

9.3.50 All phenols are volatile and soluble in water. Whilst only low concentrations were recorded, further consideration of the risk to groundwater and the surface water would be prudent and should be considered in any future site-specific risk assessment.

VOCs & sVOCs

9.3.51 Of the 101 samples of made ground scheduled for VOCs and sVOCs most yielded results below the laboratory's limit of detection.

9.3.52 However, notable exceptions were in TP501, 505, 512 & 513 in Area A where low level concentrations of VOC and sVOCs were detected, including:

- 1,3,5 trimethylbenzene
- 1,2,4 trimethylbenzene
- Tert-butylbenzene
- 2-methylnaphthalene
- Dibenzofuran
- Carbazole

9.3.53 All these compounds are used in the manufacture of dye and within the chemical industry generally and are all constituents of coal tar. The identification of these compounds in Area A provides evidence that coal tar may have been stored and used on site and that the chemical works most likely manufactured a range of products; whilst important in the chemical industry, coal tar is not usually associated with the manufacture of sulphuric acid.

9.3.54 As with phenols, VOCs and sVOCs are volatile and soluble in water. Whilst only low concentrations were recorded, further consideration of the risk to groundwater and the surface water would be prudent and should be considered in any future site-specific risk assessment.

9.4 Water contamination results

9.4.1 Chemical data indicates elevated concentrations of inorganic and organic contaminants in made ground soils (all areas), with a range of coal tar derived compounds also identified in Area A.

9.4.2 The possibility of contamination impacting groundwater and surface water will be influenced by a range of factors including:

- the concentration and extent of the source,
- depth and flow direction of groundwater
- continuity of groundwater
- solubility of contamination and
- natural degradation rate of contamination.

9.4.3 Some **surface water** monitoring has already been undertaken and the test results from Blacup Beck are summarised in the table within Annex III.

9.4.4 Samples were taken upstream, where Blacup Beck enters site and where it enters culvert in Area B. The location at which the beck exits site could not be safely identified.

9.4.5 The significance of the results has been assessed by comparison with an appropriate environmental quality standards (EQS); see Generic Note 04 in Appendix A.

9.4.6 The samples were tested for metals, total cyanide, pH sulphides & carbonates, sVOCs and VOCs. All determinants yielded concentrations below the laboratory limit of detection.

9.4.7 An initial round of **groundwater** samples has been taken from selected boreholes installed in Alluvium and Sandstone beds within bedrock. Samples were scheduled for metals, VOC & sVOCs and results were received just as this Report was being issued.

9.4.8 A cursory review of the groundwater data indicates low concentrations of VOCs (BTEX & trimethylbenzene) in Area A and some evidence of chlorinated solvents in Area B. Two further rounds of groundwater sampling are yet to be completed and are required in order to support the production of a detailed controlled waters risk assessment.

9.4.9 However, it is considered likely that even if a quantitative risk assessment is not required to facilitate remediation, a qualitative review of groundwater movement and interaction with surface water would be included in the site-specific risk assessment.

10 CONTAMINATION (QUALITATIVE RISK ASSESSMENT & REMEDIATION)

10.1 Summary of significant contamination

10.1.1 Deep made ground (typically c. 10m; max. 17m) is present within footprint of former quarries in Areas A, C & D. Beyond the identified quarries (and backfilled reservoir), the average thickness of made ground is approximately 2m. Localised areas of deeper made ground exist beyond the quarries; made ground in excess of 3m depth was encountered across much of the southern half of Area A.

10.1.2 Made ground has yielded elevated concentrations of a number of inorganic determinands, including arsenic, copper, lead, nickel and zinc, as well as sporadic fragments of asbestos containing materials and trace amounts of free asbestos fibres. Further asbestos than that encountered to date should be anticipated.

10.1.3 Gross contamination with organic determinands was encountered in Area A where samples of Granular Made Ground and bituminous sealant exceed the relevant Tier 1 screening values.

10.1.4 No further grossly organic contaminated soil was found across Areas B, C or D.

10.1.5 Although Lithos' investigation was extensive and expanded on other third-party investigations, the heterogenicity of made ground reduces the degree of certainty that can be drawn from ground conditions and laboratory data.

10.1.6 Given previous uses across the site, further, more significant areas of hydrocarbon contamination cannot be ruled out. Nor can the presence of asbestos burial pits (suspected in Area A). Indeed, frequent suspected asbestos fragments were noted on the ground surface during the walkover (predominately in Areas A & D).

10.1.7 At this stage, no significant surface water contamination has been identified. However, the absence of significant contamination within groundwater has not yet been confirmed (see Section 9.4) and whilst the following recommendations relate to remediation of the soils, further remediation may be required following groundwater sampling which will inform a detailed quantitative risk assessment.

10.2 Revised conceptual ground model (contamination)

10.2.1 The preliminary Conceptual Site Model has been amended in light of data obtained during the ground investigation, most notably with respect to the distribution of made ground and contaminants.

10.2.2 A revised Conceptual Site Model is presented as Drawing 3043/9 in Appendix B. The Model includes the contaminants described in Section 10.1 above, and potential contaminant linkages (summarised below in Section 10.4).

10.3 Environmental setting & end use

10.3.1 As discussed in Section 10.1 above, contamination exists in the soil beneath this site. In order to assess the significance of this contamination, consideration must be given to the site's environmental setting and the proposed end use.

10.3.2 The underlying Coal Measures bedrock is classified as a Secondary A aquifer. The nearest surface watercourse is Blacup Beck, which is partially culverted flows and in an easterly direction, through Area B. Therefore, the site's environmental setting is considered to be moderate sensitivity.

10.3.3 With respect to human health, the proposed end use (residential) is considered sensitive.

10.3.4 Transient risks to construction workers can be addressed by the adoption of appropriate health and safety measures, see Section 14.6.

10.4 Contaminant linkages

10.4.1 In terms of a proposed redevelopment of this site, plausible contaminant linkages can be summarised as follows.

Contaminants

10.4.2 Contaminants have been summarised in Section 10.1 above.

Pathways

10.4.3 Potential contaminant pathways include:

- Ingestion
- Dermal contact
- Inhalation of contaminated particulates
- Inhalation of vapours
- Surface water run-off, including existing drainage infrastructure
- Downward infiltration of leachable/mobile contaminants to groundwater

Receptors

10.4.4 Potential contaminant receptors include:

- The environment – Secondary A aquifer and Blacup Beck
- End users of the site (residents)

10.4.5 It can be concluded that there are plausible pathways between the soil contaminants summarised in Section 10.1 above and potential receptors. Consequently, some remediation will be required; either treatment/removal of the contaminant, or "breakage" of the pathway.

10.5 Potential remediation options

General

10.5.1 Given the constraints discussed in Section 7.2 (existing buildings in parts of Areas A & D), a simple post-demolition trial pit investigation will be required before more definitive recommendations are given.

10.5.2 Furthermore, an indication of final development levels will be required. Given the uneven landform at present, consideration must be given to the appropriateness and implications of moving material between areas to achieve a sustainable earthworks solution.

10.5.3 However, at this stage, it should be assumed that some deep excavation and treatment of contaminated arisings will be required and some dewatering of hydrocarbon impacted water is likely. Consideration of plausible remediation techniques for soils and groundwater should in included in the remediation strategy, following completion of a detailed site-specific risk assessment.

Asbestos

10.5.4 CL:AIRE has published a Joint Industry Working Group (JIWG) guidance1 document with the support of the Health & Safety Executive which provides an explanation of how legal requirements of the Control of Asbestos Regulations 2012 have been interpreted to be more directly applicable to the risks associated with asbestos contaminated soil and construction & demolition materials.

10.5.5 Fibres were identified in 4 of the 77 samples of made ground screened for asbestos. Results were generally associated with fragments of asbestos-cement sheeting (ACMs) in the soil; quantification of free fibres within the soil matrix gave 'trace' results. Therefore, the volume of free asbestos within the soil matrix is of limited significance although fragments of ACM are expected. Risks associated with trace amounts are negligible and the proposed 1,000mm cover will afford additional protection.

10.5.6 Further to this as previously stated potential ACM cement sheeting fragments were noted across site, so whilst minimal fibres were identified within made ground samples, it is likely further free fibres exist.

10.5.7 Samples of soil and/or construction & demolition material recovered from brownfield sites may exhibit a wide range of concentrations of asbestos contamination. Due consideration should therefore be given to the interpretation of any 'trace' concentrations in the wider context of the site. Guidance prepared by the JIWG asbestos suggests that judgements on the nature, degree and significance of contamination present should not be made on the basis of individual samples alone.

10.5.8 Nonetheless, made ground soils with only a trace of asbestos still have the potential to be hazardous to human health. This is because soil with a low asbestos content of say 0.001% may contain thousands, possibly hundreds of thousands, of potentially respirable asbestos fibres per gram of soil. However, asbestos fibres only pose a risk if they are allowed to become airborne, and release from soil to air can only occur if the soil is dry and then agitated (e.g. by vehicle movement, excavation, wind etc).

[1] *Control of Asbestos Regulations 2012: Interpretation for Managing and Working with Asbestos in Soil and Construction & Demolition materials: Industry Guidance*

10.5.9 Provided soils are kept damp the risk of airborne fibre release, even during disturbance associated with excavation, should be negligible, and certainly below the control limit (as set by the Control of Asbestos Regulations 2012) of 0.1 f/cm3 airborne fibres averaged over a 4-hour period.

10.5.10 In our experience, damp soils do not allow the release of asbestos fibres, even from soils that contain concentrations in excess of the hazardous waste threshold (0.1%).

10.5.11 There may be transient risks during the excavation of made ground soils. Exposure to asbestos of personnel involved in these excavation works is considered likely to be sporadic and of low intensity (provided soils are kept damp). Therefore in accordance with Regulation 3(2) of the Control of Asbestos Regulations (2012), exemption from Regulations: 9 (notification of work with asbestos); 18(1)(a) (asbestos areas); and 22 (health records and medical surveillance) should apply, provided it is 'clear from a suitable and sufficient risk assessment that the control limit of 0.1 f/cm3 airborne fibres averaged over a 4-hour period will not be exceeded'.

10.5.12 Nonetheless, risks must be mitigated by appropriate measures (principally damping down), working procedures, and PPE. Method Statements and Risk Assessments should be prepared by the Contractor, and then be reviewed by the Client and Lithos.

10.5.13 Any fragments of asbestos cement sheeting encountered during the excavation works, should be gathered by hand and placed in double sealed bags. Personnel involved in this activity must be equipped with an appropriate respirator (i.e. a FFP3 or better), in addition to their "standard" PPE. The bags of asbestos waste should be placed in a sealed skip for off-site disposal at a suitably licensed landfill site; such material will be classified as hazardous waste.

10.5.14 It should be noted that ACMs were commonly used as shuttering beneath concrete slabs, and to form ducts, and it is important that this is kept in mind when breaking through concrete slabs.

10.5.15 Made ground where asbestos has been positively identified, should ultimately be isolated beneath a minimum 1,000mm thick surface cover of "clean" soil (garden/landscaped areas), or hardstand (parking areas), or floor slabs (buildings) and therefore there will be no risk of release of asbestos fibres from the ground.

10.5.16 If made ground is placed within 1,000mm of proposed final levels within gardens and landscaped areas, it would be prudent to place a minimum 150mm "hard dig" layer of crushed demolition arisings immediately beneath the soil cover. Alternatively, a high-visibility contaminated ground warning / marker barrier, such as Lotrak Alarm18 could be placed beneath the soil cover.

10.5.17 New utilities should be laid in trenches reinstated with 'clean' backfill in order to prevent exposure to maintenance workers in the future.

10.5.18 See also comments in the 'Waste Classification' Section 10.7.

Inorganic contamination

10.5.19 The made ground has yielded elevated concentrations of a number of metals; most notably arsenic, copper, lead, nickel and zinc. 18 of the 64 samples of made ground tested included significantly elevated concentrations (i.e. > 5 times Tier 1 values).

10.5.20 Given the volume of made ground across all four areas it would not be possible to simply isolate made ground below areas of hardstanding. Therefore, it would be prudent to allow for a minimum 150mm thick "hard dig" layer of crushed demolition arisings immediately beneath 1,000mm soil cover in all garden and landscaped areas. Alternatively, a high-visibility contaminated ground warning / marker barrier, such as Lotrak Alarm18, could be placed beneath the soil cover.

Organic contamination

10.5.21 Gross organic contamination was encountered in two samples recovered from Area A (TPs 501 & 512), low concentrations of volatile compounds, possibly associated with coal tar creosote were also noted in this area.

10.5.22 Slightly elevated concentrations of naphthalene were recorded in two samples of Ash & Clinker both from TP438. Further assessment of possible vapour risks should be undertaken; this should be incorporated into the detailed site-specific risk assessment following gas a vapour monitoring across the site.

10.5.23 No further areas of gross hydrocarbon contamination were encountered in Areas B, C or D during Lithos' site investigation. However, localised areas of more onerous contamination than that identified to date may be present.

10.5.24 Given the site's former usage and fieldwork constraints, it would be prudent to allow for the off-site disposal of some grossly contaminated soil. Further advice should be sought from a specialist contractor, with experience of brownfield remediation, regarding an appropriate contingency.

Groundwater & surface water

10.5.25 As discussed in Section 10.1 above, no significant surface water contamination has been encountered to date. However, further detailed consideration of groundwater contamination is required.

10.6 Summary of potential contaminant linkages & mitigation

10.6.1 In terms of the proposed redevelopment plausible contaminant linkages, and feasible remediation options, can be summarised as follows:

Receptors	Pathways	Contaminants	Plausible contaminant linkage? (and remediation options where required)
Human health (Future residents) ◊	Consumption of contaminated vegetables	Metals, asbestos fibres in the made ground	Yes, isolation beneath at least 1000mm clean soil cover in garden and landscaped areas with 150mm hard dig layer below or Lotrak Alarm 18 contaminated soil warning barrier
	Ingestion		
	Dermal contact		
	Inhalation (dust)		
	Inhalation of vapours	Hydrocarbons and degradable material in made ground (Area A)	Unknown – further detailed assessment required, monitoring ongoing
	Migration of ground gases		
Controlled waters (surface and groundwater)	Lateral and vertical migration	Inorganic and organic contamination in made ground	Unknown – current groundwater sampling indicates some elevated inorganics and low concentrations of BTEX & chlorinated VOCs. Further detailed assessment required following additional groundwater monitoring.

◊ transient risks to construction workers will be addressed by the adoption of appropriate health and safety measures in accordance with the Health and Safety at Work Act 1974 and regulations made under the Act including for example the COSHH Regulations.

10.6.2 Site-specific risk assessment is required in order to determine:

- remedial target concentrations (health) of acute toxins (namely cyanide & sulphur), although neither is expected to be problematic;
- remedial target concentrations (health) for a range of VOC/sVOCs;
- risk to groundwater and the surface water posed by the presence of phenols, VOCs and sVOCs (albeit recorded at low concentrations to date).

10.7 Waste classification

10.7.1 Disposal of the made ground off site is generally not considered appropriate, economically viable, nor in line with current Government philosophy regarding sustainable development. However, some excess arisings may be generated by excavations for foundations, sewers etc. Disposal to landfill (or an appropriate soil / aggregate transfer station) may be the most practical solution, if redistribution and retention on site is not feasible.

10.7.2 Following excavation and stockpiling, sampling will be required prior to disposal.

10.7.3 As there is no WRAP protocol for soils, the characterisation, sampling and classification of soils arising from brownfield sites has been incorporated within the Environment Agency's Technical Guidance WM3[2]. Classification of soils as inert, non-hazardous or hazardous in accordance with WM3 is quite a complex process.

10.7.4 If waste soil is classed as hazardous following classification under WM3, and destined for landfill, waste acceptance criteria (WAC) leachate testing will need to be undertaken. However, non-hazardous soil waste can go to a non-hazardous landfill facility; no further testing (e.g. WAC) is required.

[2] Technical Guidance WM3 – Guidance on the classification and assessment of waste. Environment Agency 2015

10.7.5 WAC analysis is different to the 'routine' laboratory testing (such as that included earlier in this Section) undertaken in order to determine hazardous properties. Lithos typically only include WAC analysis if significant off-site disposal (of soil classified as hazardous waste) is anticipated.

10.7.6 It is critical if material is to be exported from site that this is allocated an appropriate waste code, following the steps within WM3. Waste carriers transporting, and sites accepting, this material should have a corresponding code within their permits. It is the responsibility of those generating the waste (i.e. the site), to ensure that the waste is handled and disposed of appropriately.

10.7.7 Soil treatment facilities (STFs) provide an alternative to landfill. STFs are regulated by the Environment Agency and allow soils to be treated and screened (effectively recycled to be used at other sites). Export to an STF does not require WAC testing and suitability of various soil types will be dependent on material waste codes, which may be allocated after consideration of the data in Section 9 but will often need supplementing with further testing after soils have been stockpiled (see also advice in Section 14.3).

10.7.8 Most STFs are permitted to accept soils with waste code 17 05 04 (i.e. soils which do not exhibit hazardous properties). Lithos has a list of permitted STFs and can help identify one local to this development site.

10.7.9 With respect to asbestos, waste soils will be classed hazardous if the soil mass contains more than 0.1% asbestos fibres that are free and dispersed. However, WM3 states that where the waste contains identifiable pieces of asbestos (i.e. any particle of a size that can be identified as potentially being asbestos by a competent person if examined by the naked eye), then the waste is hazardous if the concentration of asbestos in the pieces alone is 0.1%. If a stockpile of soil contained rare fragments of broken asbestos-cement sheeting, the whole stockpile would be classed as hazardous unless all the fragments could be picked-out (even though the concentration of asbestos in the soil mass might be orders of magnitude less than 0.1%).

10.7.10 As discussed in Section 8.2, tarmac hardstand is present in Area C and surrounding the Ward Fabrication building in Area A.

10.7.11 This tarmac could be recycled and crushed to yield a 6F3 selected granular material, provided the recovered bitumen content is less than 10% (determined in accordance with BS598-1:2011). Crushed tarmac could also be blended with crushed concrete etc to generate 6F2 graded material. 6F2 can contain up to 50% recycled tarmac/asphalt (provided it does not pose a contamination risk to controlled waters and, if the proportion of asphalt is greater than 20%, the recovered bitumen content is less than 2%).

10.7.12 However, if off-site disposal is anticipated, tarmac assessment is based on the amount of coal tar present, this will vary depending on the age of the tarmac. The assessment is based on the amount of benzo(a)pyrene and has a concentration limit of 50mg/kg.

10.7.13 Contractors exporting waste from the site should review the site investigation data and make their own assessment. Alternatively, Lithos could undertake this assessment once exported waste streams have been identified.

11 HAZARDOUS GAS

11.1 General

11.1.1 Consideration of the conceptual site model and potential linkages has enabled a preliminary qualitative assessment of risks associated with gas:-

Source	Receptors	Hazard	Pathway	Initial risk
On-site made ground	Human health	Asphyxiation & explosion	Vertical migration, ingress & accumulation	**Low**: made ground essentially inert, with little degradable matter
	Buildings	Explosion		

11.1.2 Given the above gas monitoring wells have been installed in 28 boreholes/probeholes across the site. Details of the installations are given on the exploratory hole logs presented in Appendices G and H to this the report.

11.1.3 The generation potential of the gas source was initially considered to be Low and this has been confirmed by the monitoring results obtained. Consequently, in accordance with CIRIA Report C665[3], given the proposed residential end use, 9 visits have been scheduled over a 6-month period.

11.2 Scope of works

11.2.1 To date, the wells have been monitored on two occasions for groundwater levels and soils-gases, and the results are presented in Appendix K.

11.2.2 Due to vandalism and destruction of the wells, monitoring results to date are of relatively poor quality (gas taps/bungs of several wells were 'missing' and had to be replaced immediately prior to monitoring). Lithos returned to site on the 13th November 2020 to repair monitoring installations.

11.2.3 A standard procedure was followed, in accordance with CIRIA guidance:

- Ambient oxygen concentration
- Atmospheric temperature & pressure
- Methane, oxygen and carbon dioxide concentrations and flow rates using a Gas Data GFM436 infra-red gas analyser
- Standing water level using a dipmeter
- Ambient oxygen concentration (check for instrument drift)

11.2.4 Slightly elevated concentrations of naphthalene were recorded within Ash & Clinker (TP438). Gas monitoring should include assessment of organic vapours.

11.3 Monitoring results

11.3.1 The results of the monitoring completed to date are summarised below.

Hole ID	Response zone	Range of methane concentrations (% v/v)	Range of carbon dioxide concentrations (% v/v)	Range of steady flow rates (litre/hour)
BH501	4.0m – 10.0m (various made ground).	ND	0.2 - 1.0	ND
BH502	3.0m – 6.0m (Ash & Clinker).	NR	NR	NR
BH503	2.8m – 8.8m (Cohesive Made Ground).	ND	0.5 - 14.8	ND
BH504	6.0m – 12.0m (Ash & Clinker).	NR	NR	NR

[3] CIRIA C665: Assessing risks posed by hazardous ground gases to buildings (2007).

Hole ID	Response zone	Range of methane concentrations (% v/v)	Range of carbon dioxide concentrations (% v/v)	Range of steady flow rates (litre/hour)
BH505	2.8m – 8.6m (Ash & Clinker).	ND	0.9 – 4.7	ND
BH506	3.0m – 9.0m (Cohesive Made Ground).	ND	ND – 0.1	ND
BH507	1.5m – 3.0m (Granular Made Ground).	NR	NR	NR
BH508	2.2m – 2.8m (Cohesive Alluvium).	ND	0.7 – 3.3	ND
BH509	1.5m – 3.0m (Cohesive Alluvium).	ND	ND – 0.9	ND
PH501	6.0m – 9.0m (Coal Measures Sandstone).	ND	ND	ND
PH502	2.5m – 5.5m (Cohesive Made Ground).	NR	NR	NR
PH505	3.0m – 6.0m (Ash & Clinker).	ND	0.1 - 4.0	ND
PH506	3.0m – 6.0m (Cohesive Made Ground).	ND	ND – 0.4	ND
PH507	3.0m – 6.0m (Ash & Clinker).	ND	2.8 – 3.1	ND
PH508		NR	NR	NR
PH509		ND	9.2 - 11.4	ND
PH510	3.0m – 6.0m (Cohesive made Ground).	ND	2.5 - 3.1	ND
PH511	3.0m – 6.0m (Ash & Clinker).	ND	10.4	ND
PH512	1.5m – 4.5m (Granular Made Ground).	ND	0.8 – 1.1	ND
PH513	3.0m – 9.0m (Coal Measures Sandstone).	ND	3.3	ND
PH514	3.0m – 6.0m (Granular Made Ground).	ND	2.1 - 3.9	ND
PH515	3.0m – 9.0m (Coal Measures Sandstone & Mudstone).	1.5 - 2.0	4.4 - 17.9	ND
PH516	3.0m – 6.0m (Granular Made Ground).	ND	4.4 – 4.7	ND
PH517	1.5m – 4.5m (Granular Made Ground).	ND	2.3 - 5.7	ND
PH518	4.5m – 7.5m (Coal Measures Sandstone).	ND	1.1 - 9.0	ND
PH519	1.2m – 2.7m (Granular Made Ground).	ND	3.1 - 14.8	ND
PH520	4.5m – 7.5m (Coal Measures Sandstone).	ND	ND – 1.2	ND

Note: boreholes in red have not been successfully monitored to date due to vandalism making monitoring impossible. During visits Lithos has worked to repair monitoring wells where reasonably practical.

11.4 Discussion

11.4.1 Generic Note 05 in Appendix A outlines how monitoring results are interpreted.

11.4.2 A hazardous gas risk assessment incorporating all of the results will be issued on completion of monitoring in April 2020.

11.5 Radon

11.5.1 Requirements with respect radon measures are set out in Building Regulations Approved Document C. Probability bandings (based on the proportion of properties in a given area that exceed the Action Level; currently 200 $Bq.m^{-3}$) are used to determine whether a property requires no, basic or full measures.

11.5.2 At present Approved Document C advocates basic measures for the probability banding 3% to 10% (full measures if >10%). However, Public Health England would like to see all new build include basic measures.

11.5.3 The Public Health England UK radon map and the Landmark report indicate that the site is in an area where **between 1% and 3%** of homes are estimated to be above the action level.

11.5.4 Consequently, basic radon protection measures are not required. However, in light of Public Health England advice, the Developer might consider providing all new dwellings with basic radon protection measures.

12 GEOTECHNICAL TESTING

12.1 General

12.1.1 A total of 50 samples of natural soil were delivered to a suitably accredited laboratory with a schedule of geotechnical testing drawn up by Lithos.

12.1.2 The geotechnical laboratory test results are presented in Appendix J to this report.

12.2 Atterberg limits

12.2.1 The plasticity indices of 18 samples of cohesive soil have been determined; results are summarised below.

Soil type	No. samples tested	Moisture content range (average)	Range of Plasticity Indices* (average)	Shrinkability
Alluvium	8	17 – 29 (36)	16 – 31 (22)	Medium
Residual Soil	17	14 – 40 (21)	8 – 38 (20)	

* Modified where appropriate in accordance with Chapter 4.2 of the NHBC Standards.

Note. The term Shrinkability is equivalent to the term Volume Change Potential used in Chapter 4.2.

12.2.2 For the purposes of foundation design, it is recommended that all cohesive soils be regarded as being of medium shrinkability.

12.3 Particle size distribution

12.3.1 The grading of 15 samples has been determined by wet sieving and the results are summarised in the table below:

Sample & depth	Field description	% passing 37.5mm sieve	% passing 20mm sieve	% passing 2mm sieve	% fines	Material description (based on grading & plasticity)
TP402 - 3.0m	Ash & Clinker; ashy gravelly SAND.	97	89	62	20	Very gravelly clayey SAND.
TP408 - 1.4m	Ash & Clinker; ashy slightly gravelly SAND.	90	80	50	14	Very sandy clayey GRAVEL.
TP413 - 1.2m	Ash & Clinker; ashy gravelly SAND.	96	90	47	19	
TP416 - 2.8m		100	93	47	11	
TP423 - 0.9m	Ash & clinker; ashy slightly gravelly SAND.	68	60	39	16	Very sandy clayey GRAVEL with medium cobble content.
TP431- -1.8m	Ash & Clinker; ashy gravelly SAND.	100	77	35	7	Very sandy clayey GRAVEL.
TP437 - 0.8m	Granular Made Ground; clayey gravelly SAND with low boulder content.	91	81	50	19	
TP444 - 0.7m	Cohesive Made Ground; sandy gravelly CLAY.	98	88	63	38	Very gravelly sandy CLAY.
TP445 - 1.0m	Ash & Clinker; ashy gravelly SAND.	100	95	63	19	Very gravelly clayey SAND.
TP447 - 1.5m	Cohesive Residual Soil; gravelly CLAY.	93	87	75	58	Very gravelly sandy CLAY.
BH501 – 4.0m	Filter Sand; very clayey gravelly SAND.	96	90	65	27	Very clayey SAND & GRAVEL.

Sample & depth	Field description	% passing 37.5mm sieve	% passing 20mm sieve	% passing 2mm sieve	% fines	Material description (based on grading & plasticity)
TP504 – 1.0m	Granular Made Ground; slightly clayey GRAVEL with high cobble content.	70	57	31	10	Very sandy clayey GRAVEL. Medium cobble content.
TP508 – 0.4m	Granular Made Ground; sandy GRAVEL with low cobble content.	92	85	49	21	Very sandy very clayey GRAVEL. Rare cobbles.
TP511 – 0.8m	Sandy GRAVEL with medium cobble content.	97	88	41	18	Very sandy clayey GRAVEL.
TP514 – 1.0m	Granular Made Ground; very clayey sandy GRAVEL.	87	75	46	16	Very sandy clayey GRAVEL.

12.3.2 NHBC Chapter 4.2 considers shrinkable soils to be those containing more than 35% fines and having a Modified Plasticity Index greater than 10%.

12.4 Soluble sulphate and pH

12.4.1 In accordance with BRE Special Digest 1:2005, this site has been classified as brownfield with a mobile groundwater regime.

12.4.2 It is envisaged foundations will extend through made ground and natural strata and samples taken from this depth range have been submitted for pH and water-soluble sulphate (2:1 soil/water extract).

12.4.3 The concentrations of sulphate in the aqueous natural soil extracts of 27 samples were determined. In addition, 50 samples of made ground were tested as part of the contamination suite. The pH value of each sample has also been determined.

12.4.4 The highest water-soluble sulphate concentration and the lowest pH value for each soil type analysed are shown in the table below.

Soil type	No. samples tested	Lowest pH values	Highest soluble sulphate concentration (mg/l)	Highest equivalent soluble sulphate concentration (mg/l)
Alluvium	8	6.2	90	-
Ash & Clinker	6	4.4	1,100	2,250
Coal Measures bedrock	6	7.0	1,100	-
Cohesive Made Ground	10	3.5	710	15,094*
Cohesive Residual Soil	15	4.4	3,200	790
Filter Sand	1	5.1	1,600	1,600
Granular Made Ground	22	4.0	9,300	1,400
Granular Residual Soil	1	4.3	1,000	1,000

Notes: *See comments below in 12.4.7 & 12.4.8. Equivalent soluble sulphate concentration is calculated by the addition of the chloride and nitrate results.

12.4.5 A number of samples yielded pH values below 5.5, therefore supplementary analysis to determine the concentrations of magnesium, chloride and nitrate was scheduled. The results of which are presented in the table above.

12.4.6 In accordance with Tables C1 and C2 of SD1, sub-surface concrete in contact with made ground soils (Areas B, C & D) should be Design Sulphate Class DS-3 and ACEC Classification of AC-5. Sub-surface concrete in contact with natural ground soils in all areas should be Design Sulphate Class DS-2 and ACEC Classification of AC-5z.

12.4.7 The highest soluble sulphate concentration for Cohesive Made Ground is 15,000mg/l, recorded in TP436 at 0.9m in Area A. It is understood sulphuric acid was manufactured at the former chemical works, and therefore this result might not be wholly anomalous. Further samples of made ground tested from Area A often gave high sulphate results (generally well above 1,000mg/kg). Further sampling/testing of the made ground during the site preparatory works would be prudent.

12.4.8 If the significantly elevated soluble sulphate concentration recorded in TP436 is found to be typical of made ground soils in Area A, sub-surface concrete in contact with made ground here should be Design Sulphate Class DS-5, and ACEC Classification of AC-5.

12.5 Compaction tests

12.5.1 Laboratory compaction tests are useful wherever ground improvement is anticipated, for example to provide a satisfactory CBR beneath proposed highways.

12.5.2 In accordance with BS5930:2015 engineered fill is defined as material which is selected, placed and compacted to an appropriate specification so that it will exhibit the required engineering behaviour.

12.5.3 Grading and moisture content control the degree to which materials can be effectively compacted. If the grading or moisture content of an in-situ material is not suitable to facilitate its compaction then screening, wetting, or lime addition may be required.

12.5.4 Laboratory compaction testing was scheduled on 9 samples of made ground and one sample of natural ground (using a 4.5kg rammer) to determine their suitability for re-engineering.

12.5.5 Laboratory compaction tests are only appropriate if:

- At least 90% of the material passes the 37.5mm sieve; and/or
- At least 70% of the material passes the 20mm sieve

12.5.6 It is apparent from the gradings tabulated in Section 12.3, that the samples scheduled for compaction tests are generally suitable with the exception of samples TP504 – 0.1m, TP423 – 0.9m and TP514 – 1.0m, which are all include slightly too great a coarse fraction.

12.5.7 Nevertheless, useful information can be determined.

12.5.8 The material particle density (Gs) is required in order to plot the 0, 5 and 10% air voids lines on the compaction graph for each material type.

Sample location & depth	Material	Gs (Mg/m³)	MDD (Mg/m³)	OMC (%)	Allowable mc range for 95% MDD & <5% air voids	Typical in-situ moisture content (%)
TP402, 3.0m	Ashy gravelly SAND	2.40	1.76	14	12.5 to 18.25	26
TP408, 1.4m	Ashy slightly gravelly SAND	2.15	1.37	24	23.75 to 29.25	
TP413, 1.2m	Ashy gravelly SAND	2.05	1.32	25	23.25 to 29.75	
TP416, 2.8m	Ashy gravelly SAND	2.00	1.28	27	25 to 31.25	

Sample location & depth	Material	Gs (Mg/m³)	MDD (Mg/m³)	OMC (%)	Allowable mc range for 95% MDD & <5% air voids	Typical in-situ moisture content (%)
TP431, 1.8m	Ashy gravelly SAND	1.95	1.38	20	18.75 to 23.75	
TP437, 0.8m	Clayey gravelly SAND with low boulder content	2.15	1.47	20	18.5 to 24.5	27
TP444, 0.7m	Sandy gravelly CLAY	2.50	1.83	13	12 to 17.5	19
TP445, 1.0m	Ashy gravelly SAND	2.15	1.45	22	20 to 26	26
TP447, 1.5m	Gravelly CLAY	2.65	1.95	12	11 to 16.75	21
BH501, 4.0m	Very clayey SAND & GRAVEL.	2.35	1.42	25	24.4 to 30.6	33
TP504, 1.0m	Very sandy clayey GRAVEL. Medium cobble content.	2.40	1.29	33	32.0 to 37.8	31
TP508, 0.4m	Very sandy very clayey GRAVEL. Rare cobbles.	2.41	1.51	21	21.4 to 28.4	21
TP511, 0.8m	Very sandy clayey GRAVEL.	2.41	1.52	20	20.8 to 26.0	18
TP514, 1.0m	Very sandy clayey GRAVEL.	2.40	1.04	52	50.2 to 57.6	61

12.5.9 The in-situ moisture content of the made and natural ground is typically slightly too wet to achieve 95% MDD. Therefore, all soils are likely to require some drying out before they can be utilised for engineered fill.

12.5.10 Drying out of these soils will require careful management on site. They should be placed in sealed stockpiles during periods of wet weather, or while the site is unattended. During periods of favourable weather (ideally warm & windy) the soils should be spread in thin layers over as wide an area as possible and aerated by turning with an excavator. Alternatively, consideration could be given to lime stabilisation

12.5.11 The made ground will also need to be screened in order to remove any unsuitable and oversize materials.

12.5.12 Acceptability of the made ground and natural soils for use in the proposed controlled earthworks will need detailed appraisal by the Earthworks Designer in light of the required performance characteristics.

12.6 Undrained shear strength testing

Hand shear vane testing

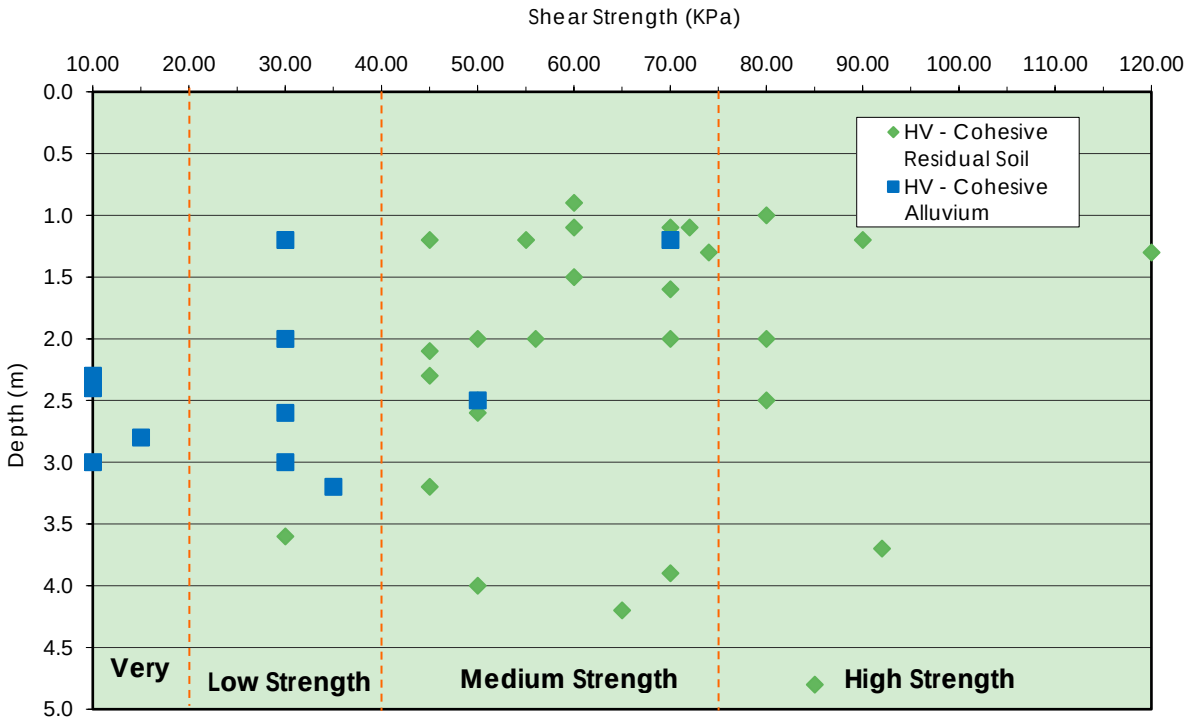
12.6.1 Hand shear vane testing was undertaken within trial pits in-situ to around 1.3m depth and from larger blocks of excavated clay below that depth.

12.6.2 The results are summarised within the plot below, within the Cohesive Alluvium deposits the results are generally very low strength to low strength.

12.6.3 For Cohesive Residual soils all the results are of at least medium strength except one which has fallen within the low strength category; this is likely because of a soft spot due to groundwater and/or higher sand content and is not thought to represent the true in-situ strength.

12.6.4 Below approximately 1.2m depth, undrained shear strength (Su) within Cohesive Residual soils is typically greater than 50kPa.

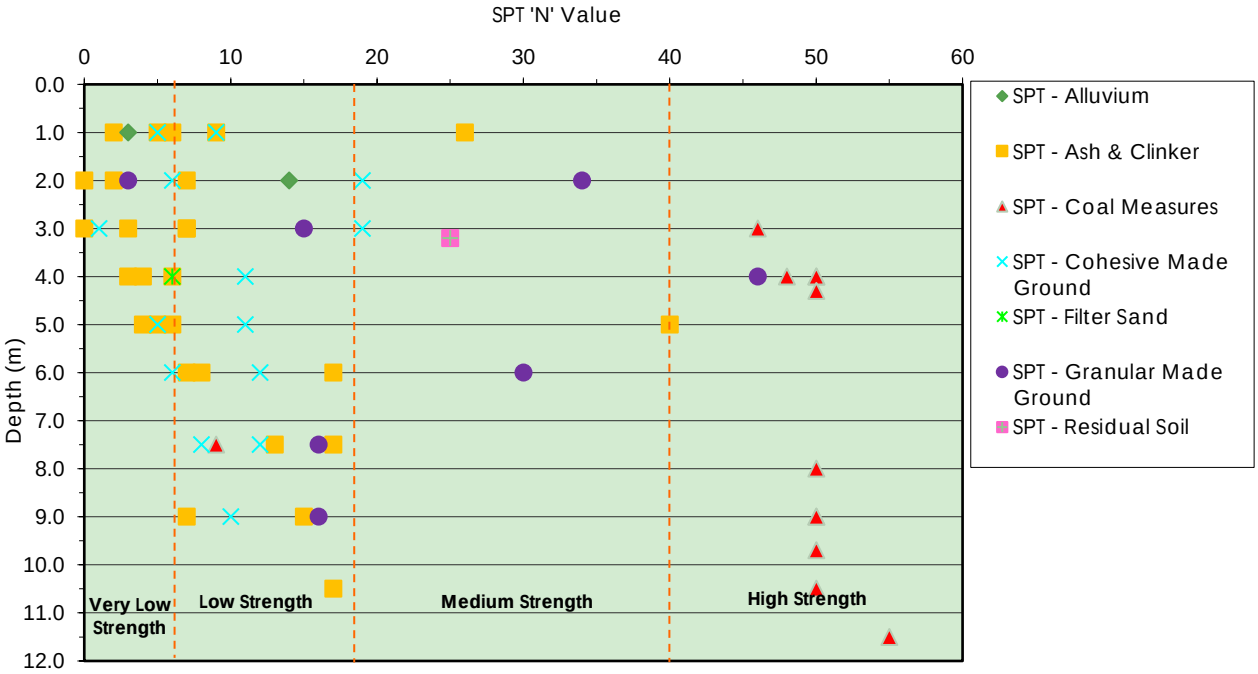
12.6.5 The plot below provides a summary of undrained shear strengths:



Standard penetration test (SPT)

12.6.6 The in-situ relative strength of both natural and made ground was established by carrying out Standard Penetration Tests (SPTs) during the drilling of the cable percussion boreholes (BHs 501 to 509).

12.6.7 The SPT test results are displayed on the plot below:



12.6.8 SPT tests show that all of the made ground types tested are generally of poor and variable strength. The Alluvium (where present) is alto of very low strength.

12.6.9 Residual soils are of medium strength and SPTs into bedrock (Coal Measures) typically refused after 50 blows. These readings support the descriptions given on the field logs.

12.6.10 High blow counts reported in the Granular Made Ground are likely the result of the test encountering coarse materials (cobbles, bricks etc) rather than the material actually being especially dense in-situ.

13 GEOTECHNICAL ISSUES

13.1 Conceptual site model

13.1.1 Made ground is present across the entire site. Beyond areas of quarrying (and the backfilled reservoir) it extends to average depths of 2m, although locally, within Area A, it is greater than 4.0m thick.

13.1.2 Review of the trial pit logs (and historical maps) suggests made ground thicknesses are:

- >2.5m across an area of c. 26,000m^2 (c. 40% of the total site area). It is likely that made ground across an area of c. 9,000m^2 (within former Brickworks Quarry) is 10m to 18m deep.
- 1.5 to 2.4m across c. 12,500m^2 (c. 20%)
- <1.5m across c. 26,500m^2 (c. 40%)

13.1.3 Significant obstructions are anticipated, including relict foundations from at least two generations of buildings, former basements and underground tanks; see Section 8.3.

13.1.4 Natural ground encountered typically comprises residual soils (completely weathered bedrock), with Coal Measures bedrock from an average depth of 2.5m (beyond backfilled quarries/reservoir).

13.1.5 An area of low strength cohesive Alluvium (typically, soft clay) underlies all but the centre-north and far south of Area B (c. 12,500m^2, close to Blacup Beck). The Alluvium extends to a typical depth of around 3.0m and is underlain by residual soils or bedrock.

13.2 Mining

13.2.1 The shallowest workable coal seam is believed to be the 32 Yard Coal at around 60m depth.

13.2.2 3rd party exploratory holes (AIG in 2001) suggest there are no coal seams within 30m depth of the surface.

13.2.3 Whilst the site lies within a Coal Authority Low Risk area, no significant risks have been identified.

13.3 Quarries/reservoir

Quarries

13.3.1 This site has been subject to quarrying for Sandstone and/or Clay, with three areas of quarrying shown on the 1894 OS plan:

- Brickworks Quarry (c. 9,000m^2) in the east (Area C), including a rectangular area (c. 100m by 22m) in the south, with cliff faces shown.
- An oval-shaped area (c. 750m^2) in the centre-north (Area D).
- A roughly square-shaped area (c. 1500m^2) in the north-west (within Area A).

13.3.2 In addition, there is a backfilled reservoir (c. 1,000m^2) in the north-west of Area B.

13.3.3 Quarries have been found to reach depths of up to up to 17.2m depth (in Area A), 9.0m (Area C) and 12.0m (Area D)

High walls

13.3.4 Highwalls have been located in trenches and stitched groups of rotary open probeholes. High walls associated with the brickworks quarry (Area C) in the north-west are quite steep (c. 55º) but appear to be shallower in the east (c. 20º) in the uppermost c. 3.0m.

13.3.5 At greater depths highwalls appear to be close to vertical in all three quarries investigated. Illustrative cross sections of quarry highwalls which were encountered during drilling of the stitch probeholes are included with the PH logs in Appendix H.

Reservoir (Area B)

13.3.6 According to historical OS plans, a former reservoir occupied an area of c. 1,000m^2, in the north-west of Area B.

13.3.7 A ''high wall'' was identified in the south, dipping at around 22°.

13.3.8 In the south, the reservoir is underlain by low strength Alluvial deposits.

13.3.9 Constant inflow of groundwater perched within the reservoir made it difficult to identify the depth of made ground backfill and the high wall to the north. However, previous investigations suggest a backfill depth of around 4m.

13.4 Potential issues associated with deep backfill

13.4.1 It is considered likely that the deep quarry backfill was placed without mechanical compaction in irregular and thick layers without any screening to remove oversized materials, degradable waste etc. Such material poses a risk to any proposed development due to the potential for differential settlement and long term 'creep' settlement.

13.4.2 At this site has likely been in place for at least 80 years. Settlement of deep made ground is initially (first 5 years or so) predominantly associated with inundation (caused by changes in the water table depth and/or surface water infiltration).

13.4.3 Consolidation settlement is associated with a reduction in volume caused by expulsion of water from soil pores and transfer of load from excess porewater pressure to soil particles. However, the backfill here is predominantly granular and consequently significant consolidation settlement is not anticipated.

13.4.4 Creep compression occurs as the particles of fill become more closely packed, under conditions of constant effective stress (arising from self-weight of the fill). Although the movements caused by creep are relatively small, often it is these long-term movements that are of most interest to foundation performance. Many coarse fills show a linear relationship between settlement and the logarithm of the time that has elapsed since the fill was placed (i.e. settlement that occurs during the first 10 years is similar to that from years 10 to 100).

13.4.5 Where development on deep fill takes place, in addition to any ongoing creep associated with self-weight, settlement is caused by the imposed foundation loads. This leads to some immediate compression and consolidation within stressed zones.

13.4.6 The strength/density of the backfill materials is likely to vary over relatively short distances, especially across the line of any buried highwalls.

13.4.7 At this stage, it is considered that the presence of deep backfill will have implications for:

- Foundations – likely piled; see further details in Section 13.6.
- Drainage – likely need for placement at maximum possible gradients using flexible connections to prevent any backfalls should differential settlement of the fill occur. Potential need for piling of manholes
- New utilities – should be constructed of flexible materials. Electricity and communications cabling should also be laid with sufficient 'slack' to accommodate a degree of movement. The use of flexible joints is recommended where possible, particularly where service connections extend across a rigid/flexible structure interface (e.g. from a piled foundation into a garden area)
- Highways - a specification will need to be agreed with the adopting authority, but reinforcement of the road construction will probably be required.

13.5 Site regrade and/or ground improvement

13.5.1 Made ground currently underlies the entire site, to an average depth of about 2m beyond infilled quarries/reservoir, and typically to around 10m (max. 17m) is present within footprint of former quarries.

13.5.2 This made ground is of variable and poor strength and is therefore not considered a suitable foundation material. It has also yielded elevated concentrations of a number of inorganic determinands and contains materials (e.g. brick, concrete, clinker, coal, etc), which would generally be considered undesirable as a near-surface material in garden areas.

13.5.3 Given the substantial volume of made ground present, export to landfill is not considered economically viable.

13.5.4 Consideration should be given to turnover (excavation, screening and replacement in engineered layers) of the full thickness of made ground (beyond the backfilled quarries). Within quarry backfill, it would be prudent to turnover the uppermost 3m of made ground.

13.5.5 Turnover is considered an appropriate ground improvement solution since significant excavation of the made ground will be required in any case to remove the relict foundations.

13.5.6 Because turnover enables inspection of the fill, the developer and their prospective property purchasers, are provided with the reassurance that no significant hazard is left undetected. This is considered advantageous from a perception viewpoint. Furthermore, any potential for surface water infiltration, which would drive potential leaching of contaminants, should be reduced by compaction.

13.5.7 Screened and engineered fill should yield CBR values in excess of 3%, thereby reducing abnormals associated with the construction of estate roads and car parking areas. Excavations through the engineered fill, for drainage etc and foundations will not encounter significant obstructions or grossly contaminated ground and should be stable with little overbreak.

13.5.8 Excavation of the uppermost 500mm or so of natural soils beneath made ground could be undertaken in order to generate a sufficient volume of 'clean' subsoil for placement across the proposed development in gardens and landscaped areas. This subsoil would be best placed during the construction phase; i.e. it should be left in stockpile(s) on completion of the site preparatory works.

13.5.9 There are a number of advantages to such a 'soil inversion' operation; most notably:

- Ground levels will remain essentially as existing (i.e. there is no need to raise levels by 600mm to accommodate soil cover).
- Reduced traffic movements - there should be no need to export any significant volume of made ground off-site, and no need to import subsoil to site.

13.5.10 The above solution is considered to be in line with current government philosophy regarding sustainable development. Turnover works should be undertaken in accordance with the CL:AIRE Code of Practice (v2, March 2011), and a Materials Management Plan (MMP) should be prepared prior to commencement.

13.5.11 Given existing topography, significant earthworks regrade is anticipated, especially in the south-east of Area C, with the potential need for underbuild and retaining walls.

13.5.12 Careful consideration will need to be given to earthworks design, and implications for slope stability, retaining walls, foundations, highway gradients and drainage.

13.5.13 Any digital terrain modelling undertaken or commissioned by the developer should consider implications for the foundation recommendations outlined below.

13.5.14 Wherever possible, Lithos recommend that excavated soils are retained on site. However, if this is not possible the comments in Section 10.7 should apply.

13.6 Foundation recommendations

General

13.6.1 Foundation recommendations assume that development will be two or three storey construction and that line loads will not exceed 90kN/m run. If this is not the case significant alteration to these recommendations will be required.

13.6.2 Sub-surface concrete in contact with the made ground should be Design Sulphate Class DS-3, with the site allocated an ACEC Classification of AC-5; sub-surface concrete in contact with natural ground should be DS-2, AC-5z.

13.6.3 Made Ground and Alluvium are not considered a suitable foundation material and foundations should therefore be taken through these materials into underlying natural strata of adequate bearing capacity.

13.6.4 Any plot layout for this site should take account of known quarry high walls. The lines of highwalls (proven & extrapolated) are shown on Drawing 3043/10.

13.6.5 It would be prudent to locate some public open space over areas of deepest made ground, i.e. the brickworks quarry in Area C.

13.6.6 Foundation solutions here are primarily driven by thicknesses of made ground (see Section 8.2 & Drawing 3043/10), and to a lesser extent by the presence of Alluvium in Area B.

13.6.7 The anticipated significant earthworks regrade should allow contouring of the base of made ground beyond the deep quarry backfill and this in turn should allow the preparation of a plot-specific foundation schedule.

13.6.8 In the meantime, options for two or three storey residential properties constructed on this site are discussed below.

Strip/trench fill footings

13.6.9 It is considered that shallow strip or deepened trench fill footings will be a suitable foundation solution where made ground is less than about 2.5m thick and underlying natural soils comprise medium strength Residual Soils (weathered Coal Measures) and not Alluvial Deposits (c. 40% of plots).

13.6.10 Reinforcement, as a precaution against differential settlement, is recommended only where foundation excavations encounter significant lateral and vertical variations in strata. One layer of B385 mesh placed 75mm above the base of the footing is likely to provide suitable reinforcement, but further advice should be sought from the Structural Engineer.

13.6.11 All concrete slabs and service ducts should be chased-out and removed during the necessary site preparatory works.

13.6.12 Foundations will be required to be placed below a line drawn up at 45° from the base of any service or similar excavation.

13.6.13 Overdeepened foundations should be stepped in accordance with NHBC Standards, Chapter 4.4.

13.6.14 In order to minimise softening and swelling of cohesive soils or loosening of granular soils, it is recommended that footings are cast as soon as formation level is reached (or alternatively formation could be blinded using concrete with as low a water:cement ratio as possible).

13.6.15 Whilst strip or trench fill footings generally represent a simple and inexpensive foundation solution, there are a number of potential disadvantages associated with their use on this site:

- The made ground contains elevated concentrations of some inorganic contaminants and a 1,000mm thick cover of clean soil has been recommended. Subject to final remediated development levels, this cover is likely to increase footing depth/underbuild.
- Disposal of arisings may be required.
- Foundation and drainage excavations may encounter significant obstructions resulting in significant overbreak.
- Foundation and drainage excavations will almost certainly require shoring in made ground.

Cohesive Residual Soil

13.6.16 Clay classification tests suggest that natural cohesive soils at the site should be regarded as being of medium shrinkability. A minimum founding depth of 0.9m is therefore recommended for all soils on the site where strip footings are proposed.

13.6.17 In accordance with NHBC Standards, founding depths in cohesive soils should be taken from original or finished ground level, whichever is the lower, to the underside of the footing.

13.6.18 Foundations should be deepened near trees in accordance with NHBC Standards Chapter 4.2.

13.6.19 A number of immature (likely self-seeded) trees were noted during the site walkover particularly to the east, south and west, these will require removal prior to construction. A number of these trees lie within the footprint of proposed plots. In theory, this could result in foundation depths of >2.5m. However, in accordance with NHBC Standards Chapter 4.2, if the trees are <50% of their mature height at the time of removal, a default distance to the proposed foundation of 2m can be applied to foundation depth calculations. This should be confirmed by a detailed tree survey prior to vegetation removal, and removal should take place as soon as possible.

13.6.20 Trench fill foundations should be designed in accordance with NHBC Standards, Chapter 4.2. Heave precautions (a suitable approved compressible void former) should be used on the internal face of all external walls where the foundation is within the zone of influence of trees and greater than 1.5m deep.

13.6.21 Any trench fill foundation deeper than 2.5m will need to be designed by a Chartered Engineer, whose status is accepted by NHBC (NHBC Standards, Technical Requirement R5).

13.6.22 It would therefore be prudent to prepare a detailed foundation schedule and seek approval from NHBC in order to determine likely foundation abnormals.

13.6.23 A safe bearing capacity of around 150kPa, allowing a maximum foundation line load of 90kN/m run, can be assumed if the following are true

- A foundation length of 10m
- A foundation breadth of 0.6m
- A foundation thickness of 225mm
- A foundation depth of 1.0m depth
- An undrained shear strength of 50kPa for the firm clay (typical minimum recorded on site)

13.6.24 Assuming the foundation geometry detailed above, minimal settlements would be anticipated. However, further advice should be sought from the Structural Engineer responsible for foundation design.

13.6.25 Further investigation should be commissioned if any apartment blocks with higher line loads (say >120kN/m run) are proposed. Such investigation would include cable percussion boreholes and geotechnical analysis (triaxial and oedometer testing) of recovered, undisturbed samples.

Granular Residual Soil

13.6.26 The granular residual soils are assumed to have a relative density of at least medium dense (in accordance with BS5930:2015).

13.6.27 A safe bearing capacity of around 150kPa, allowing a maximum foundation line load of 90kN/m run, can be assumed if the following are true:

- A foundation length of 10m
- A foundation breadth of 0.6m
- A foundation thickness of 225mm
- A foundation depth of 0.75m
- An angle of shearing resistance of ϕ=31° for the granular deposits

13.6.28 Assuming the foundation geometry detailed above, minimal settlements would be anticipated. However, further advice should be sought from the Structural Engineer responsible for foundation design.

13.6.29 Where plots are underlain by granular soil and within the influence of existing trees, footings can be cast in the granular soil at a "standard" depth of 0.75m, provided that all the following conditions are satisfied:

- consistent ground across the plot
- the depth of granular soil is greater than ¾ of the depth which would be computed if founding in shrinkable clay
- the thickness of granular soil beneath the footing is equal to or greater than the foundation width (i.e. usually >600mm)

Bedrock (Coal Measures)

13.6.30 The Coal Measures sandstone/mudstone bedrock is generally considered to have a safe bearing capacity of at least 300kPa and minimal settlements would be anticipated.

13.6.31 Where rock is encountered at shallow depth foundations should be placed entirely on rock and not partially on rock and partially on soil. This may, depending on surface gradient, necessitate significant overdeepening of foundations.

13.6.32 Bedrock at the site comprises mudstone which can be easily excavated using a backhoe excavator and will be recovered as a tabular gravel. Where in-situ mudstone is encountered at founding depth (minimum of 450mm), it will provide a suitable founding stratum for two or three storey dwellings and need only be penetrated by the proposed foundation thickness. Note: any overlying residual soil (typically clay with gravel-sized lithorelicts of mudstone) is likely to be a shrinkable soil; Mudstone is not.

Piled foundations

13.6.33 Piled foundations are likely to be required for the majority of two and three storey dwellings constructed on site (c. 60% of plots), largely due to deep made ground, and also soft Alluvial deposits in Area B.

13.6.34 Vibratory ground improvement might provide an alternative option to piles, but only for plots located wholly within the opencast backfill, and probably some distance from high walls. Further advice should be sought from a specialist vibro contractor.

13.6.35 The following general comments relating to piling are provided for guidance, and further advice should be sought from a specialist-piling contractor.

13.6.36 Turnover (excavation, screening and replacement in engineered layers) of the uppermost 3m of made ground beneath the site is anticipated in order to remove shallow **boulders**. However, it will not be feasible to turnover the full thickness of made ground and therefore some boulders may remain at depth. Consequently, some pre-boring or revision of the piling layout is likely to be required. Any revision of the piling layout might also require design of foundations able to span and/or cantilever as necessary.

13.6.37 As piles would be founded in bedrock, they will be essentially end-bearing.

13.6.38 Plots in the vicinity of steep **high walls** should ideally be set-back at least 3m from the high wall and founded entirely on bedrock or extend over the high wall by at least 5m. Piles for plots that only extend 1m or 2m over a steep high wall are more likely to encounter problems with socketing.

13.6.39 Where plots are founded close to or over any high walls associated with the former opencast, piles must be socketed into rock and not allowed to deflect off the high wall. This may require pre-drilling and casing of piles. An allowance should also be made for changing piling locations and ground beam design to account for any difficulties encountered with high walls associated with the former quarries.

13.6.40 NHBC generally require pile lengths to be at least 3m; therefore where plots cross a high-wall and rock is encountered at shallow depth (<3m) beyond the quarry, pre-boring of piles may be required to reach required depths.

13.6.41 If ground beams are found to span across the high wall it should be ensured that they span from the pile head onto competent rock.

13.6.42 An allowance should also be made for changing piling locations and ground beam design to account for any difficulties encountered with high walls.

13.6.43 Warranty providers generally require pile lengths to be at least 3m; therefore, where depths to bedrock vary significantly beneath a plot, pre-boring of piles may be necessary to reach required depths.

13.6.44 Given the presence of soft cohesive Alluvium particularly in the south, it is essential that pile design allows for downdrag (negative skin friction).

13.6.45 It is recommended that flexible service connections are used on this site, especially where they enter the buildings, in order to avoid any possible damage due to self-settlement of the weak strata once the site is developed.

13.6.46 Driven piles may lessen the volume of potentially contaminated made ground requiring off-site disposal (cf arisings associated with say trench fill). However, driving can induce some ground vibration. Assessment of any vibration risk to adjacent structures and/or existing site features should be undertaken by pile designer.

13.6.47 New houses can be built off ring beams designed to span the piles. In order to bond them to the piles, the tops of the piles must be broken out to expose the reinforcement, which can then be tied to that of the beams.

13.6.48 Given proposed turnover of the uppermost 3m of made ground, and the granular nature of the Quarry Spoil, the re-engineered fill should satisfy requirements for of a piling mat (working platform). However, further advice should be sought from the appointed specialist-piling contractor regarding the proposed plant loadings and resulting pressures. This data, together with a knowledge of the strength and variability of the near-surface ground conditions is required in order that design of a mat can be undertaken in accordance with guidance provided in the 2004 BRE document, "BR 470: Working platforms for tracked plant".

13.6.49 The design of working platforms for tracked plant is a geotechnical design process and should be carried out by a competent person. The following parties should have input into the design:

- Permanent works designer, to consider additional uses for platform material as part of the overall development
- Principal contractor, to define any other purposes for which the platform might be used
- Contractor or subcontractor, to specify requirements for the platform, including gradients, ramps and edges

13.6.50 The number of plots affected by piling will depend on layout proposals, however, it is considered unlikely to exceed 70% of the total number.

13.6.51 It may be more practical and economic to pile all the plots on this site, since mobilisation charges are likely to be similar regardless of how many plots are piled. A piled solution would also result in less disturbance than strip footings and negate the need to dispose of contaminated arisings.

13.6.52 Piles can provide an enhanced pathway for the vertical migration of mobile contaminants. The Environment Agency may therefore object to the adoption of piles as a foundation solution.

13.6.53 Pile design should be undertaken in accordance with the Environment Agency's guidance booklet "Piling into Contaminated Sites".

13.6.54 There is the potential for **settlement** of the ground in external areas around piled plots, and consideration should be given to mitigation, including:-

- Extending facing brickwork so that ground settlement does not result in exposing the underground portions of walls and foundations. Two additional courses should be more than adequate.
- Threshold issues
- Flexible connections (e.g. rocker pipes) in drainage and service pipes passing through the buildings.
- Ensuring drainage is laid with generous falls.

Summary of foundation recommendations

13.6.55 In summary, the following foundation solutions are likely to be most appropriate (subject to the developer preferences regarding site preparatory works, final levels & costs associated with each foundation option). Foundations given as a percentage of entire site area.

% of site	Foundation solution(s)	Remarks (influencing factors)
40%	Deep strips/trench fill at 0.9m to 2.5m	Natural soils at minimum founding depth and made ground <2.5m thick (following preparatory earthworks)
60%	Piles to between 4m and up to 17m	Deep made ground and shallow Alluvial soils

13.6.56 A 'simple' foundation zoning plan is presented as Drawing 3043/12 in Appendix B.

13.6.57 Lithos could prepare a detailed Foundation Schedule if provided with: an External Works Drawing (with proposed FFLs & infrastructure details); a topographic survey; an up to date tree survey.

13.6.58 The foundation solutions outlined in the above table assume that ground levels will not change significantly from those existing at present. If this is not to be the case, further advice should be sought from Lithos.

13.7 Floor slabs

13.7.1 Floors for low rise housing (2-3 storeys) constructed on piled foundations typically utilise reinforced concrete ground beams which rest on pre-cast or in-situ pile caps. A suspended 'Beam and Block' ground floor is then usually constructed using concrete or polystyrene blocks placed between further concrete beams suspended across the ring beams.

13.7.2 Suspended floor slabs should be utilised where the depth of made ground or engineered stone exceeds 600mm in accordance with NHBC Standards Chapter 5.1 (to negate potential settlement problems). The majority of made ground on this site is non-shrinkable, therefore the slabs could be cast in-situ.

13.7.3 It is estimated that the thickness of made ground is likely to exceed 600mm beneath nearly all of the plots, dependent on final development levels.

13.7.4 Where foundations are within the influence of existing or proposed trees, NHBC require a suspended floor slab, with sub-floor void. The floor slab is most commonly a precast block and beam construction, but alternatively could comprise a suspended timber floor, or a slab cast on a suitable compressible void former. Ground-bearing and cast in-situ suspended slabs (other than those cast on a void former) are not acceptable where foundations are within the influence of trees.

13.7.5 In accordance with NHBC Standards Chapter 4.2, a minimum void height of 250mm should be adopted for a precast block and beam (or suspended timber) floor; this includes a 150mm ventilation allowance. If a suspended, cast in-situ slab (on a void former) is proposed, a minimum clear void height of 100mm should be adopted; of course, the actual thickness of the void former will be significantly greater.

13.7.6 Floor slab design should be finalised/take account of the results of the gas monitoring and protection measures required, which are yet to be commenced. They should also take into account the high naphthalene concentrations within TP438, with plots within this area constructed with a hydrocarbon resistant membrane.

13.8 Designated concrete mixes

13.8.1 Designated mixes are considered in BRE Special Digest SD1 and BS 8500 -1:2015+A1:2016. However, in addition to soil chemistry (sulphate class), there are a number of other considerations relating to structural design that need to be taken into account when determining an appropriate concrete mix.

13.8.2 Consequently, the developer should seek advice from their appointed Structural Engineer.

13.9 Excavations

13.9.1 Groundwater should be controlled in accordance with CIRIA report 113 "Control of Groundwater for Temporary Works".

13.9.2 Based on the results of the investigation it is considered groundwater control over and above normal site pumping practices may be required for any excavations within Area B (most notably within the backfilled reservoir) in excess of 2m deep will be needed. Perched groundwater may be encountered within made ground across the rest of site, therefore an allowance should be made for pumping.

13.9.3 Bedrock was encountered in several exploratory holes, especially in the north. Based on the exploratory hole logs, excavation greater than 2.5m is likely to prove difficult across about 50% of the site. It would therefore be prudent to allow for excavation of hard rock in any deep excavations such as those that may be required for drainage etc.

13.9.4 Backfilled basements are anticipated in Area A to the south of the remaining warehouse building. Areas of deep made ground, including Brickfill and relict walls/foundations were encountered in TP's 503, 504 and 506 to 508 in the area of anticipated basements.

13.9.5 Backfilled basements should be anticipated in Area A (south of the remaining warehouse).

13.9.6 Coarse made ground (Brickfill) and brick structures, including tunnels (possible former sewers/chimney flus) is present across much or Area A which resulted in overbreak and instability during excavation.

13.10 Drainage

13.10.1 Given the significant thicknesses of made ground encountered, soakaway construction will not be possible; soakaway waters cannot be allowed to infiltrate into made ground due to the risk of settlement caused by wash out of fine soil particles.

13.10.2 Based on observations made during the investigation, soakaways are very unlikely to provide a suitable drainage solution for surface water run-off at the site. Consequently, it will be necessary to consider alternative sustainable drainage systems (SUDS), and there may be a need for surface water balancing.

13.10.3 Alternative SUDS options (see CIRIA C753:2015 for further details) include:

- Ponds – designed to have permanent pool of water, but with capacity to provide temporary storage-controlled discharge.

13.10.4 Yorkshire Water have published a guide[4] for developers and designers outlining their design requirements for surface water attenuation assets.

13.10.5 It is recommended that the developer contact Yorkshire Water Services with respect to capacity in existing foul and surface water sewers in the vicinity of the development area.

13.11 Highways

13.11.1 Made ground is present across the site and consultation with the adopting authority, regarding the specification of the highways, is strongly recommended.

13.11.2 The made ground present beneath this site is highly variable in terms of both composition, and strength/density. Furthermore, it often contains a significant amount of oversize (boulders etc) and obstructions (old foundations etc), which represent potential 'hard-spots'.

13.11.3 Consequently, where made ground is present its full thickness (up to a maximum of 2m - from existing ground level or proposed highway formation, whichever is the lower) should be excavated and either:

- replaced with suitable aggregate in accordance with Series 600 (Earthworks) of The Highways Agency (HA) "Specification for Highway Works" 1998; or
- screened, to allow selection of suitable material, before being replaced in engineered layers (in accordance with Series 600). Unsuitable materials include any soft or wet materials, biodegradables including topsoil, wood, scrap metal, frozen material and oversize.

13.11.4 Some refinement of the above advice might be possible after highways design (with consideration of the proposed formation level cf existing ground level), and via inspection (and usually CBR testing) of the proposed formation during site preparatory groundworks.

13.11.5 Any residual made ground materials in the base of the excavation should be inspected and (where necessary) any soft spots removed and replaced with suitable engineered fill.

13.11.6 Where the made ground is re-engineered it is considered that a CBR value of at least 3% should be achievable. However, this should be verified by field trials.

13.11.7 Crushing of demolition/hardstand/foundation arisings will generate aggregate, which (subject to confirmatory testing) should be suitable for use as unbound pavement materials within the highways.

[4] *Design Requirements for Surface Water Attenuation Assets, February 2017.*

13.12 External works

13.12.1 Any digital terrain modelling undertaken, or commissioned by Developer should be made available to their Engineering Designer prior to issue of an External Works Drawing.

14 REDEVELOPMENT ISSUES

14.1 General

14.1.1 This report has presented options with respect to foundation solutions, treatment of contamination etc that are considered technically feasible and in line with current good practice and identified further works considered necessary. Consequently, we would expect to obtain regulatory approval for whichever option is adopted, although this cannot be guaranteed. Copies of this report should be forwarded to the relevant regulatory authorities (Warranty Provider & Local Authority) for their comment/approval.

14.1.2 Even after an appropriate preliminary investigation and ground investigation, with exploratory holes on a closely spaced grid (say trial pits at 30m centres), a geoenvironmental appraisal is typically based on inspection of the ground underlying less than 0.5% of the total site area (and much less at depths in excess of about 3.5m). Consequently, there is always a possibility that unanticipated ground conditions will be encountered during the site preparatory works, this is particularly pertinent where such variable ground conditions are encountered.

14.2 Remediation strategy

14.2.1 Redevelopment of this site will certainly be subject to planning conditions relating to remediation and validation. Once a specific, preferred development strategy has been decided, Lithos could liaise with Local Planning Authority and Warranty Provider, agree further works and prepare a detailed Remediation Strategy document for approval.

14.2.2 The Remediation Strategy document would include:

- General background information, including site location, site description and a summary of ground investigation data
- An overview of existing constraints on development and the aims of the proposed remediation works
- Specific details of the anticipated site remediation/preparatory works
- Details of site supervision and verification
- A summary of implications for redevelopment

14.2.3 The Remediation Strategy will describe what is required, but not how it is achieved; the appointed Contractor would normally be expected to undertake an Options Appraisal, and then prepare a Method Statement.

14.2.4 A Remediation Strategy cannot be finalised prior to completion of the ongoing groundwater sampling programme and subsequent site-specific risk assessment. However, at this stage, anticipated remediation works are summarised below:

- General site clearance of surface materials and vegetation
- Demolition of remaining buildings
- Break-up of slabs and hardstand
- Post demolition investigation of the ground beneath the former buildings and slabs, which were inaccessible during the earlier investigations
- Crushing of all suitable artificial hard material (i.e. concrete/brick etc)

- Turnover (excavation, screening and replacement in engineered layers, with nominal compaction) of the full thickness of made ground (beyond deep quarry backfill), and the uppermost 3m of made ground within quarry backfill, to enable:
  - Removal of oversize materials from the made ground across the entire site
  - Removal of localised fuel/oil contamination; with subsequent treatment and/or off-site disposal (if encountered during turnover)
  - Inspection of the made ground
  - Removal of below ground obstructions
  - Preparation of the ground for highway construction
- Backfill of all resultant excavations, with appropriate compaction
- Re-grade of site to levels specified by the final developer
- Removal of underground tanks
- Provision of a minimum 1,000mm thick cover layer of 'clean' soils in all garden and landscaped areas with underlying 150mm hard dig layer or Lotrak Alarm 18 high visibility warning barrier

14.2.5 The remediation contractor should survey reduced levels during the proposed turnover, prior to the placement of any fill.

14.2.6 Where made ground is shallow, underlying natural strata could be excavated for use as subsoil in garden areas, subject to confirmatory testing. Subsoil excavated during the site preparatory works would be best placed during the construction phase; i.e. it should be left in stockpile(s) on completion of the site preparatory works.

14.2.7 It is strongly recommended that the demolition contractor should chase-out all significant buried structures, and survey-in the resultant excavations before making them safe by backfilling. At the very least, relevant features should be surveyed-in before "hiding" them beneath a veneer of rubble. Similarly, it would be prudent to complete a drainage survey prior to blading rubble across the site to leave it safe and secure.

14.3 Control of excavation arisings

14.3.1 Excavations into made ground are likely to yield contaminated arisings. The groundworker should carefully segregate (and stockpile separately) made ground arisings from arisings of "clean" natural soils, in order that an excessive volume of unsuitable material is not generated.

14.3.2 It should be ensured that the groundworker understands the need for good materials management. Most notably the importance of not mixing different materials within a given stockpile; i.e. there should be separate stockpiles of: grubbed-up concrete hardstand; tarmac; Ash & Clinker; fuel-contaminated soil (if encountered); excess clean, natural soil arisings; general construction waste etc.

14.3.3 Further characterisation of stockpiled materials is likely to be required if off-site disposal is proposed. See also comments in Section 10.7 regarding asbestos.

14.3.4 Made ground arisings could be:

- Placed in area deliberately left low on completion of the remediation works in order to accommodate construction arisings
- Redistributed beneath concrete oversite, or areas of hardstanding, where they would be satisfactorily isolated from end users; only if suitable (i.e. not compressible, rich in deleterious matter etc)
- Isolated beneath the 1,000mm thick cover layer in garden or landscaped areas
- Exported from site to a suitably licensed landfill facility

14.3.5 Natural ground arisings should be suitable for use as subsoil in the proposed soil cover.

14.4 Good practice guidance

14.4.1 The construction phase groundworker should follow good environmental practice to minimise the risks of spillage, leakage etc with reference, but not limited, to the following documents:

- CIRIA C502 'Environmental Good Practice on Site'
- EA Pollution Prevention Guidelines[5]:
  - PPG6 - Working at construction and demolition sites
  - PPG2 - Above ground oil storage tank
  - PPG7 – The safe operation of refuelling facilities.
  - PPG21 – Incident Response Planning

14.4.2 Site preparatory works associated with this project are likely to involve the re-use of both natural and made ground soils on site and the import of topsoil /subsoil from another development site. Therefore, the Contractor should prepare a Materials Management Plan (MMP) in accordance with the CL:AIRE Code of Practice (v2, March 2011).

14.4.3 The MMP will document how all of the materials to be excavated during the proposed site preparatory and remediation earthworks are to be dealt with.

14.5 New utilities

14.5.1 It is strongly recommended that all statutory service bodies are consulted at an early stage with respect to the ground conditions within which they will lay services in order to enable them to assess at an early stage any potential abnormal costs.

14.5.2 It is recommended that trenches for services including site drainage and water supply are cut over size in order to isolate pipe materials from potential contaminants and to enable maintenance to be conducted in "clean" material.

14.5.3 Water Companies have a statutory duty to supply wholesome water, which could be compromised by the selection of an inappropriate pipe material. For example, compounds such as petroleum hydrocarbons and solvents can permeate commonly used plastics pipes, and/or corrosive chemicals can reduce the service life of metallic pipes. Guidance has been developed for the selection of pipes in brownfield sites and is contained in a UKWIR Report[6].

14.5.4 This site is brownfield, and therefore consideration of soil contaminant concentrations is required. Samples taken must be representative of the soil conditions in which the water pipes are proposed to be laid; normally water pipes are laid 0.7m to 1.3m below finished ground level.

14.5.5 At the time of writing, significant remediation earthworks are anticipated, and ground currently present along proposed pipeline routes will almost certainly be redistributed. Consequently, to date laboratory testing of soil samples in line with UKWIR guidance has not been undertaken.

[5] *Whilst this has formally been withdrawn it can still be accessed via the EA archives and provides useful information on managing risks.*
[6] *UKWIR Report 10/WM/03/21 – 'Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites'.*

14.5.6 However, given the site's size, history, and ground conditions encountered, Yorkshire Water may require sampling within 15m of proposed water supply pipes, once infrastructure design has been completed. In the meantime, it is considered likely that Yorkshire Water will request the use of Protectaline mains, with plastic coated copper house connections, given that residual organic contaminants will still be present post-remediation, albeit at acceptable concentrations.

14.6 Health & safety issues - construction workers

14.6.1 Access into excavations etc. must be controlled and undertaken in accordance with the CDM Regulations 2015, most notably Regulation 22, to mitigate risk of collapse or asphyxiation.

14.6.2 Before site operations are started, the necessary COSHH statements and Health & Safety Plan should be drafted in accordance with the CDM regulations.

14.6.3 The bulk of the made ground will be retained on site. This made ground contains contaminants at concentrations above the guidance threshold values for an end use that includes domestic gardens. Workers involved in excavations for foundations, drainage, utilities etc are likely to come into direct contact with the made ground.

14.6.4 Consequently, during the remediation and construction phases of the site development it will be necessary to protect the health and safety of site personnel. General guidance on these matters is given in the Health and Safety Executive (HSE) document "Protection of Workers and the General Public during the Redevelopment of Contaminated Land". In summary, the following measures are suggested to provide a minimum level of protection:

- All ground workers should be issued with protective clothing, footwear and gloves. Personnel should be instructed in why and how they are to be used.
- Hand-washing and boot-washing facilities.
- Care should be taken to minimise the potential for off-site migration of contamination by the provision of dust suppression control and wheel cleaning equipment during the construction works.
- Good practices relating to personal hygiene should be adopted on the site.
- The contractor should satisfy the Health & Safety Executive with regard to any other matters concerning the health, safety and welfare of persons on the site.

14.7 Potential development constraints

14.7.1 Deep quarry backfill is present within Area C, and there are smaller backfilled quarries within Areas A & D. There is also a backfilled reservoir in Area B. Foundation abnormals associated with these features are likely to be significant and piling will be required.

14.7.2 Any plot layout for this site should take account of known quarry high walls, most notably those associated with Brickworks Quarry (c. 9,000m^2) in Area C, which includes a rectangular area (c. 100m by 22m) in the south, with cliff faces shown.

14.7.3 It would be prudent to locate some public open space over areas of deepest made ground, i.e. the brickworks quarry in Area C.

14.7.4 Plots in the vicinity of steep high walls should ideally be set-back at least 3m from the high wall and founded entirely on bedrock or extend over the high wall by at least 5m. Piles for plots that only extend 1m or 2m over a steep high wall are more likely to encounter problems with socketing.

14.7.5 Blacup Beck is culverted beneath the south of Area B, this will likely require relocation depending on final development proposals.

14.7.6 Numerous (most likely redundant) services are present across site including, electric, BT, water, sewer and gas, all of which will likely require consideration as part of any proposed re-development and may require diversion or stand-offs.

14.7.7 The environmental permit associated with the former scrap yard in Area C is still live. All environmental permits should be formally surrendered prior to any residential development commencing. Providing prior agreement is sought from the Environment Agency the surrender process could, potentially, run alongside planning consultation.

15 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

15.1 General

15.1.1 The site is located off Westgate approximately,1km west of Cleckheaton town centre, and comprises a single parcel of roughly square shaped former industrial land. The majority of the site is currently heavily overgrown, particularly in the south, east and west.

15.1.2 Historically the site has been used as a chemical works, brick works, malthouse, quarry, scrapyard, iron and textile mill, with at least two generations of buildings having been present.

15.1.3 Review of the trial pit logs (and historical maps) suggests made ground thicknesses are:

- >2.5m across an area of c. 26,000m^2 (c. 40% of the total site area). It is likely that made ground across an area of c. 9,000m^2 (within former Brickworks Quarry) is 10m to 18m deep.
- 1.5 to 2.4m across c. 12,500m^2 (c. 20%)
- <1.5m across c. 26,500m^2 (c. 40%)

15.1.4 Significant below ground obstructions were encountered across the site associated with former foundations and buildings.

15.1.5 Natural ground typically comprises residual soils (completely weathered bedrock), with Coal Measures bedrock from an average depth of 2.5m (beyond backfilled quarries/reservoir).

15.1.6 An area of low strength cohesive Alluvium (typically, soft clay) underlies all but the centre-north and far south of Area B (c. 12,500m^2 close to Blacup Beck). The Alluvium extends to an average depth of around 3.0m and is underlain by residual soils or bedrock.

15.1.7 Given existing topography significant earthworks regrade is anticipated, especially in the south-east of Area C.

15.1.8 Any plot layout should take account of the known quarry high walls, most notably those associated with Brickworks Quarry in Area C. It would be prudent to locate some public open space in this area.

15.2 Mining

15.2.1 This site is located within a Coal Mining Development Low Risk Area and the shallowest workable coal seam (Black Bed coal) is present at 60m depth. Therefore, risks associated with past shallow coal mining appears negligible.

15.3 Quarrying/reservoir

15.3.1 This site has been subject to quarrying for Sandstone and/or Clay, with three areas of quarrying shown on the 1894 OS plan:

- Brickworks Quarry (c. 9,000m^2) in the east (Area C), including a rectangular area (c. 100m by 22m) in the south, with cliff faces shown.
- An oval-shaped area (c. 750m^2) in the centre-north (Area D), between Stone St and Iron St. By the 1970s, Wharfe Works (now Garnett Wire) had been built over it.
- A roughly square-shaped area (c. 1500m^2) in the north-west (within Area A); looks to be 'ponded'. This quarry had been backfilled and partially built over by 1907.

15.3.2 High walls associated with the brickworks quarry (Area C) in the north-west are quite steep (c. 55^0) but appear to be shallower in the east (c. 20^0). No obvious high walls were encountered in Area D.

15.3.3 It is considered likely that quarry backfill was placed at least 80 years but without mechanical compaction in irregular and thick layers without any screening to remove oversized materials, degradable waste etc. Such material is prone to both ongoing creep, associated with self-weight, and settlement caused by any new loading.

15.3.4 At this stage, it is considered that the presence of deep backfill will have implications for foundations, drainage, new utilities and highways.

15.3.5 In addition, there is a backfilled reservoir (c. 1,000m^2) in the north-west of Area B. Previous investigations suggest a backfill depth of around 4m.

15.4 Hazardous gas

15.4.1 The site is in an area where less than 1% to 3% of homes are estimated to be above the radon action level.

15.4.2 The site is considered to have the potential to be at risk from hazardous ground gasses due to the presence of areas of deep made ground (backfilled quarries).

15.4.3 Gas monitoring wells have been installed in 28 boreholes/probeholes across the site and monitoring is now underway.

15.4.4 Slightly elevated concentrations of naphthalene were recorded within Ash & Clinker (TP438). Gas monitoring should include assessment of organic vapours.

15.4.5 A hazardous gas risk assessment will be issued on completion of the monitoring in April 2020.

15.4.6 At this stage, it would be prudent to assume all new dwellings will require Amber 1 gas protective measures. A proportion may require a hydrocarbon resistant membrane.

15.5 Contamination & remediation

15.5.1 Made ground has yielded elevated concentrations of a number of inorganic determinands, including arsenic, copper, lead, nickel and zinc, as well as sporadic fragments of asbestos containing materials and trace amounts of free asbestos fibres. Further asbestos than that encountered to date should be anticipated.

15.5.2 Gross contamination with organic determinands was encountered in Area A where samples of Granular Made Ground and bituminous sealant exceed the relevant Tier 1 screening values. No further grossly organic contaminated soil was found across Areas B, C or D.

15.5.3 Although Lithos' investigation was extensive and expanded on other third-party investigations, the heterogenicity of made ground reduces the degree of certainty that can be drawn from ground conditions and laboratory data.

15.5.4 Given previous uses across the site, further, more significant areas of hydrocarbon contamination cannot be ruled out. Nor can the presence of asbestos burial pits (suspected in Area A). Indeed, frequent suspected asbestos fragments were noted on the ground surface during the walkover (predominately in Areas A & D).

15.5.5 A minimum 1,000mm clean cover system is likely to be required, underlain by a 150mm hard dig layer or Lotrak Alarm 18 high visibility contaminated land marker barrier.

15.5.6 The results of the surface water sampling to date suggest no significant contamination within Blacup Beck.

15.5.7 Site-specific risk assessment is required in order to determine:

- remedial target concentrations (health) of acute toxins (namely cyanide & sulphur), although neither is expected to be problematic;
- remedial target concentrations (health) for a range of VOC/sVOCs;
- risk to groundwater and the surface water posed by the presence of phenols, VOCs and sVOCs (albeit recorded at low concentrations to date).

15.5.8 An initial round of groundwater samples has been taken from selected boreholes installed in Alluvium and Sandstone beds within bedrock. Two further rounds of groundwater sampling are yet to be completed and will be required in order to support the detailed controlled waters site-specific risk assessment and enable preparation of a Remediation Strategy.

15.6 Foundations

15.6.1 Foundation solutions here are primarily driven by thicknesses of made ground, and to a lesser extent by the presence of Alluvium in Area B.

15.6.2 It is considered that shallow strip or deepened trench fill footings will be a suitable foundation solution where made ground is less than about 2.5m thick (c. 40% of the total site area) and underlying natural soils comprise weathered Coal Measures (not Alluvium).

15.6.3 Piled foundations are likely to be required for the majority of two and three storey dwellings constructed on site (c. 60%), largely due to deep made ground, but also soft Alluvial deposits in Area B.

15.6.4 Any plot layout for this site should take account of the known high walls. Plots in the vicinity of steep high walls should ideally be set-back at least 3m from the high wall and founded entirely on bedrock or extend over the high wall by at least 5m. Piles for plots that only extend 1m or 2m over a steep high wall are more likely to encounter problems with socketing

15.6.5 Vibratory ground improvement might provide an alternative option to piles, but only for plots located wholly within the opencast backfill, and probably some distance from high walls. Further advice should be sought from a specialist vibro contractor.

15.6.6 The anticipated significant earthworks regrade should allow contouring of the base of made ground beyond the deep quarry backfill and this in turn should allow the preparation of a plot-specific foundation schedule.

15.7 Flooding

15.7.1 The EA indicate that the majority of site is not located within an indicative floodplain, however the south is located in Flood Zone 2 & 3 due to the presences of Blacup Beck.

15.8 Drainage

15.8.1 Due to significant thicknesses of made ground soakaways will not provide a suitable drainage solution at the site. Consequently, it will be necessary to consider alternative sustainable drainage systems (SUDS), and there may be a need for surface water balancing.

15.9 Highways

15.9.1 Made ground is present across the majority of the site, typically to depths of around 2m, and consultation with the adopting authority, regarding the specification of the highways, is strongly recommended.

15.9.2 Where made ground is present it should be excavated and either replaced with suitable aggregate, or screened, to allow selection of suitable material, before being replaced in engineered layers. Where the made ground is re-engineered it is considered that a CBR value of at least 3% should be achievable. However, this should be verified by field trials.

15.10 Further works

15.10.1 Further works required as a result of initial site investigation:

- A simple post demolition investigation (trial pits) following demolition of the remaining buildings
- A programme of monitoring for hazardous gas and organic vapours (ongoing)
- Groundwater sampling and analysis (ongoing; detailed risk assessment may be required)
- Site-specific risk assessment

15.10.2 Environmental Permits associated with the former scrap yard will need to be surrendered. Permit surrenders can take a considerable time and consideration should be given to running the surrender process parallel to any planning consultation period.

Annex I

Third Party Ground Investigation Data

Area A – Former Chemical Works

Area	Hole	Final depth	Depth of Made Ground	Maximum depth recorded						
				Granular Made Ground	Ash & Clinker	Granular Made Ground	Cohesive Made Ground	Alluvium	Weathered Coal Measures	Coal Measures
	TP11	2.0	>2.0	0.7	>2.0					
	TP12	1.2	>1.2	>1.2						
	TP13	0.8	>0.8	>0.8						
	TP14	2.0	>2.0	>2.0						
	TP16	3.0	>3.0	1.0	2.0				>3.0	
	WS8	2.7	>2.7		0.3	>2.7				
	WS9	2.8	>2.8		0.5	2.1	>2.8			
	RT2	8.7	2.5			2.5				>8.7
	RT3	13.4	4.5			3.8	4.5		5.2	>13.4
	WS16	1.9	>1.9		>1.9					
	WS17	1.4	>1.4		>1.4					
	WS18	2.9	>2.9		>2.9					
A	TP4	3.4	1.8		1.1	1.8		3.3	>3.4	
	TP5	1.1	>1.1			>1.1				
	TP6	3.2	2.6	0.9	1.6		2.6	>3.2		
	TP7	0.8	>0.8			>0.8				
	TP8	3.7	1.5	2.5	3.1		1.5		>3.7	
	TP9	1.8	>1.8	1.5	>1.8					
	TP10	1.7	>1.7			>1.7				
	TP19	3.4	>3.4		>3.4					
	TP32	3.2	1.0	1.0					>3.2	
	TP33	2.2	>2.2		>2.2		1.9			
	BH4	1.8	>1.8			>1.8				
	BH4A	5.4	3.8			3.8				>5.4
	PH4	30.0	7.6			7.6				>30

RGS data recorded in blue

AIG data recorded in brown

Area B - Former Rolling Iron Mill and Wharfe Textile Mill

Area	Hole	Final depth	Depth of Made Ground	Maximum depth recorded						
				Granular Made Ground	Ash & Clinker	Granular Made Ground	Cohesive Made Ground	Alluvium	Weathered Coal Measures	Coal Measures
B	TP15	0.5	>0.5	>0.5						
	WS3	4.0	1.8		1.8				3.0	>4.0
	WS4	4.0	>4.6	1.5	>4.6					
	WS7	2.6	1.8	0.2	0.9		1.8		2.2	>2.6
	WS7	5.3	2.7				2.7	3.4	>5.3	
	WS8	4.2	3.2	3.2					>4.2	
	WS9	4.5	2.6	0.6	2.6				>4.5	
	WS10	3.6	2.4	0.5	2.4				>3.6	
	WS11	2.5	1.3	1.3					>2.5	
	WS12	4.4	0.9	0.3			0.9		1.9	>4.4
	WS13	3.2	2.7		1.2		2.7		>3.2	
	WS14	1.4	0.3				0.3		>1.4	
	WS15	2.5	1.4		0.8		1.4		>2.5	
	WS19	2.1	0.1	0.1				0.3	>2.1	
	WS20	4.1	2.7		2.7		0.3	3.5	>4.1	
	BH3*	6.7	3.8				3.8		4.6	>6.7
	TP1	2.5	1.3		1.3			>2.5		
	TP2*	2.7	2.4		2.4		1.2	>2.7		
	TP3*	4.6	4.4	1.7			4.4		>4.6	
	TP16	1.7	>1.7	>1.7						
	TP17	2.9	0.7	0.2	0.7			2.4	>2.9	
	TP18	2.4	>2.4	1.7	>2.4					
	PH5	24.0	3.0	3.0						>24

* Likely within backfilled reservoir

RGS data recorded in blue

AIG data recorded in brown

Area C - Former Scrap Yard, Malthouse, Brickworks and Quarry

Area	Hole	Final depth	Depth of Made Ground	Maximum depth recorded						
				Granular Made Ground	Ash & Clinker	Granular Made Ground	Cohesive Made Ground	Alluvium	Weathered Coal Measures	Coal Measures
C	TP204	3.1	2.4		1.3	2.4			3.0	>3.1
	TP205	4.0	0.7		0.7				3.4	>4
	TP206	5.9	>5.9		5.0	>5.9	1.6			
	TP207	2.2	1.2	0.8			1.2			>2.2
	TP208	6.0	>6.0		>6.0					
	TP209	6.0	>6.0		5.9		>6.0			
	TP210	6.1	>6.1		>6.1					
	TP211	3.3	0.7		0.7				2.5	>3.3
	TP212	5.0	>5.0		1.3	>5.0				
	TP213	5.0	>5.0		2.1	>5.0				
	TP214	5.9	>5.9		4.0		>5.9			
	TP215	1.8	0.8		0.8				1.8	
	PH6	21.0	3.0			3.0				>21
	PH7	15.0	3.0			3.0				>15
	PH8	15.0	5.6			5.6				>15
	PH8S	5.0	>5.0			>5.0				
	PH9	23.0	18.5			18.5				>23
	PH10	21.0	5.2			5.2				>21
	PH11	12.0	11.0			11.0				>12
	PH12	18.0	17.0			17.0				>18
	PH13	12.0	10.5			10.5				>12
	TP1	2.2	>2.2			>2.2				
	TP2	2.7	>2.7			>2.7				
	TP3	2.2	>2.2			>2.2				
	TP4	1.3	0.8	0.8					1.2	>1.3
	TP5	3.4	>3.4		1.5	>3.4				
	TP6	2.9	>2.9	0.6	1.0		>2.9			
	TP7	2.4	>2.4		>2.4					
	WS1	4.0	>4.0		1.0		>4.0			
	WS2	4.0	>4.0		0.8		>4.0			
	WS5	2.4	>2.4		1.6	2.1	>2.4			
	WS10	4.0	>4.0		2.2	>4.0	3.0			
	RT1	14.0	>6.0		>6.0	-	-			
	SA1	6.1	?3.0	1.3			?3.0		5.0	>6.1
	SA2	12.2	7.4	7.4						>12.2
	SA3	19.7	15.0	17.3	15.0					>19.7
	TP11	4.2	>4.2		>4.2					
	TP12	3.9	>3.9	1.3	>3.9					
	TP20	3.8	3.1		3.1		1.1		>3.8	
	TP21	3.7	2.6		2.6				>3.7	
	TP22	4.0	>4.0	0.7	>4.0					
	TP23	3.7	>3.7		>3.7					
	TP24	3.2	0.8	0.8					1.8	>3.2
	TP25	3.2	1.2		1.2				>3.2	
	TP26	3.8	>3.8	0.8	1.2		>3.8			
	TP27	4.4	1.1	0.5	0.7		1.1		>4.4	
	TP28	2.1	0.6	0.6					>2.1	
	TP29	3.2	2.3			2.3			>3.2	
	TP30	4.2	>4.2		>4.2					
	TP31	4.2	>4.2		>4.2					
	BH1	9.8	8.9		8.9				9.6	>9.8
	BH2	18.7	16.6		16.6				>18.7	
	BH5	10.2	8.8			6.9	8.8			>10.2
	PH1	30.0	1.3			1.3				>30
	PH2	30.0	5.5			5.5				>30

Area D - Central industrial units

Area	Hole	Final depth	Depth of Made Ground	Maximum depth recorded						
				Granular Made Ground	Ash & Clinker	Granular Made Ground	Cohesive Made Ground	Alluvium	Weathered Coal Measures	Coal Measures
D	TP8	2.9	>2.9		>2.9					
	TP9	2.9	1.6	0.8	1.0	1.6			>2.9	
	TP10	2.7	1.4	1.1	1.4				>2.7	
	WS6	3.7	2.5		1.0		2.5		>3.7	
	WS1	3.1	0.5				0.5		>3.1	
	WS2	3.3	1.2		0.5	1.2			3.1	>3.3
	WS3	3.1	2.0		2.0				>3.1	
	WS4	2.5	0.2						>2.5	
	WS5*	5.3	>5.3		2.8		>5.3			
	WS6	1.6	>1.6		>1.6					
	TP13	2.8	1.8				1.8		>2.8	
	TP14*	2.1	>2.1			>2.1				
	TP15	3.6	0.8		1.2	0.8			>3.6	
	PH3	18.0	1.7			1.7				>18

* Likely within backfilled quarry

RGS data recorded in blue

Encia data recorded in red

AIG data recorded in brown

Annex II

Summary Table of Ground Conditions

SUMMARY OF GROUND CONDITIONS

Site Area	Hole ID	Final depth (mbgl)	Depth to Base of (mbgl)														depth to rockhead (mbgl)
			Made Ground											Natural Soils			
			Total made ground	Concrete	Hard-stand	Hard-core	Sub-Base	Burnt Shale	Cohesive Made Ground	Granular Made Ground	Ash & Clinker	Brickfill	Filter Sand	Alluvium	Cohesive Residual Soil	Granular Residual Soil	
A	BH501	17.2	10.7	-	-	0.2	-	-	7.2	10.7	5.8	-	5.2	-	-	-	-
A	TP436	3.3	1.3	-	-	-	-	-	1.3	-	-	0.8	-	-	3.0	-	3.0
A	TP437	3.7	>3.7	2.5	-	-	-	-	1.2 then >3.7	-	2.4	1.1 then 3.5	-	-	-	-	-
A	TP438	4.5	>4.5	-	-	-	-	-	-	-	>4.5	1.5	-	-		-	-
A	TP439	4.4	3.8	-	-	-	-	-	-	-	-	1.8 then 2.4	2.3 then 3.8	-	>4.4	-	-
A	TP440	4.0	2.5	1.4	-	-	-	-	-	1.3	2.5	-	-	-	2.9	-	2.9
A	TP441	4.1	3.8	-	-	-	-	-	3.8	1.8	2.2	-	-	-	>4.1	-	-
A	TP442	3.2	1.4	-	-	-	-	-	-	1.4	-	0.9	-	-	3.0	-	3.0
A	TP443	1.4	>1.5	-	-	-	-	-	0.6	>1.4	-	-	-	-	-	-	-
A	TP443A	2.4	>2.4	-	-	-	-	-	0.3		-	>2.4	-	-	-	-	-
A	TP444	3.4	2.5	-	-	-	-	-	1.2	2.5	-	-	-	-	>3.4	-	-
A	TP501	3.8	3.8	-	-	-	-	-	3.3	3.8	-	-	-	-	-	-	-
A	TP502	4.5	4.5	-	-	0.3	-	-	-	2.4	-	1.6	4.5	-	-	-	-
A	TP503	4.2	4.2	-	-	0.4	-	1.0	4.2	-	-	2.9	1.8	-	-	-	-
A	TP504	3.4	3.4	1.5	-	0.1	-	0.8	-	3.4	-	1.4	-	-	-	-	-
A	TP505	5.2	5.2	-	-	-	-	0.3	-	5.2	-	-	-	-	-	-	-
A	TP506	2.8	1.6	-	-	-	-	-	-	1.6	-	-	-	-	2.5	-	-
A	TP507	2.0	2.0	1.4	0.1	-	-	-	2.0	1.7	-	-	-	-	-	-	-
A	TP508	3.2	3.2	-	-	-	-	1.6	3.2	1.2	-	-	2.2	-	-	-	-
A	TP509	3.3	2.9	-	-	-	-	-	-	2.9	-	-	-	-	3.3	-	-
A	TP510	1.9	1.9	-	-	-	-	0.3	-	1.9	-	-	-	-	-	-	-
A	TP511	1.9	1.6	-	-	-	-	-	-	-	-	1.6	-	-	-	-	-
A	TP512	2.4	1.7	-	-	-	-	-	-	1.7	-		-	-	-	-	-
A	TP513	5.0	4.4	-	-	-	-	-	4.4	2.7	-	-	-	-	5.0	-	-
A	TP514	4.5	3.5	-	-	-	-	0.8	3.5	2.0	-	2.2	-	-	4.5	-	-
B	BH507	4.4	3.6	-	-	-	-	-	1.2	3.6	-	-	-	-	-	-	3.6
B	BH508	4.4	1.8	0.1	-	-	0.7	-	1.8	-	-	-	-	3.0	-	-	3.0
B	BH509	4.5	0.8	0.1	-	-	0.3	-	0.8	-	-	-	-	3.2	-	3.8	3.8
B	TP417	2.1	>2.1	0.3	-	-	-	-	0.5	>2.1	1.2	-	-	-	-	-	-
B	TP418	3.3	2.0	0.3	-	-	-	-	-	-	-	>2.0	-	>3.3	-	-	-
B	TP419	3.7	2.4	0.4	-	-	-	-	-	0.6	2.4	0.2	-	3.5	>3.7	-	-
B	TP420	1.8	0.8	0.3	-	-	-	-	0.8	-	-	0.5	-	-	-	1.2	1.2
B	TP421	3.7	1.8	0.4	-	-	-	-	-	-	-	1.8	-	3.4	>3.7	-	-
B	TP422	1.2	>1.2	0.1	-	-	-	-	-	>1.2	-	-	-	-	-	-	-
B	TP424	2.8	0.9	0.2	-	-	-	-	0.9	-	-	0.4	-	-	2.6	-	2.6
B	TP425	2.9	1.1	0.1	-	-	-	-	-	0.2	1.1	-	-	-	2.5	-	2.5
B	TP427	3.5	1.3	-	-	-	-	-	0.3		1.3	-	-	3.3	-	-	3.3
B	TT428 N	2.5	>2.5	-	-	-	-	-	1.2	>2.5	-	-	-	-	-	-	-
B	TT428 S	2.8	0.4	-	-	-	-	-	0.3		0.4	-	-	2.8	-	-	-
B	TP429	3.2	>3.2	-	-	-	-	-	0.3 then 2.8	>3.2	1.7	-	-	-		-	-
B	TP524	3.5	>3.5	-	-	-	-	-	2.7	>3.5	-	-	-	-	-	-	-
B	TP525	3.4	>3.4	-	-	-	-	-	>3.4	-	-	1.8	-	-	-	-	-
B	TP526	0.4	>0.4	0.4	-	0.1	-	-	-	0.3	-	-	-	-	-	-	-
B	TP527	0.4	>0.4	0.4	-	0.4	-	-	-	-	-	-	-	-	-	-	-
B	TP528	2.0	0.9	-	-	-	-	-	-	0.1	0.9	-	-	2.0	-	-	-
C	BH502	17.1	9.7	-	-	0.2	-	-		9.7	9.5	-	-	-	-	-	-
C	BH503	15.4	9.0	-	-	-	-	-	9.0	-	2.0	-	-	-	-	-	-
C	BH504	12.0	12.0	-	-	0.1	-	-		-	12.0	-	-	-	-	-	-
C	BH505	9.5	8.8	-	-	-	-	-	8.8	-	2.8	-	-	-	-	-	-

Site Area	Hole ID	Final depth (mbgl)	Depth to Base of (mbgl)														depth to rockhead (mbgl)
			Made Ground											Natural Soils			
			Total made ground	Concrete	Hard-stand	Hard-core	Sub-Base	Burnt Shale	Cohesive Made Ground	Granular Made Ground	Ash & Clinker	Brickfill	Filter Sand	Alluvium	Cohesive Residual Soil	Granular Residual Soil	
C	TP402	4.2	>4.2	-	-	-	-	-	-	1.2	>4.2	-	-	-	-	-	-
C	TP403	2.1	1.0	-	-	-	-	-	-	1.0	-	-	-	-	1.9	-	1.9
C	TP404	2.1	0.8	-	-	-	-	-	-	-	0.8	-	-	-	1.8	-	1.8
C	TP405	3.0	1.4	-	-	-	-	-	-	-	1.4	-	-	-	>3.0	-	-
C	TP406	1.9	1.3	0.9	-	-	-	-	-	0.7	1.3	-	-	-	-	1.6	1.6
C	TP407	2.2	>2.2	-	-	-	-	-	-	-	-	>2.2	-	-	-	-	-
C	TP408	4.4	>4.4	-	-	-	-	-	-	0.2	>4.4	-	-	-	-	-	-
C	TP409	3.8	>3.8	-	-	-	-	-	-	-	>3.8	-	-	-	-	-	-
C	TP410	3.6	>3.6	-	-	-	-	-	-	0.4	>3.6	-	-	-	-	-	-
C	TP414	3.6	0.9	-	-	0.0	-	-	-	-	0.9	-	-	-	1.5	2.5	2.5
C	TP447	2.8	1.2	-	-	-	-	-	1.2	1.0	-	-	-	-	2.2	>2.8	-
C	TP448	3.3	>3.3	-	-	-	-	-	1.1	-	>3.3	-	-	-	-	-	-
C	TP449	2.9	1.2	-	-	-	-	-	0.6	0.4	1.2	-	-	-	2.0	>2.9	-
C	TP516	4.0	4.0	-	-	0.1	-	-	-	4.0	3.2	0.4	-	-	-	-	-
C	TP523	3.8	3.8	-	-	-	-	-	-	1.3	3.8	-	-	-	-	-	-
C	TT401	3.0	1.6	-	-	-	-	-	-	-	1.6	-	-	-	>3.0	-	-
C	TT401 E	5.1	>5.1	-	-	-	-	-	-	-	>5.1	-	-	-	-	-	-
C	TT411	1.6	1.0	-	-	-	-	-	-	-	1.0	-	-	-	>1.6	-	-
C	TT411 W	2.7	>2.7	-	-	-	-	-	-	-	>2.7	-	-	-	-	-	-
D	BH506	9.0	9.0	-	-	-	-	-	9.0	4.3	-	-	-	-	-	-	-
D	TP423	2.8	1.0	0.2	-	-	-	-	-	-	1.0	-	-	1.4	-	2.5	2.5
D	TP426	1.3	>1.3	>1.3	0.1	-	-	-	-	-	-	1.1	-	-	-	-	-
D	TP412	2.1	1.7	-	-	-	-	-	-	-	1.7	-	-	-	-	-	1.7
D	TP413	3.6	>3.6	-	-	-	-	-	-	-	>3.6	-	-	-	-	-	-
D	TP415	3.6	>3.6	-	0.1	-	-	-	-	-	>3.6	-	-	-	-	-	-
D	TP416	3.4	>3.4	-	-	-	-	-	-	-	>3.4	-	-	-	-	-	-
D	TP430	3.2	2.9	-	-	0.3	-	-	2.0	2.9	1.5	-	-	-	>3.2	-	-
D	TP432	2.6	>2.6	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-
D	TP433	3.4	1.5	-	-	-	-	-	-	0.3	-	>2.6	-	-	2.8	>3.4	-
D	TP434	3.0	1.4	-	-	-	-	-	-	-	-	1.4	-	-	2.8	-	2.8
D	TP435	3.1	0.7	-	-	-	-	-	-	-	0.7	-	-	-	1.7	2.9	2.9
D	TP445	4.9	>4.9	-	-	-	-	-	>4.9	-	>4.6	-	-	-	-	-	-
D	TP446	3.1	1.5	-	-	-	-	-	-	-	-	1.5	-	-	2.9	-	2.9
D	TP515	3.7	3.7	-	-	-	-	-	1.0	0.2	>3.7	-	-	-	-	-	-
D	TP517	3.4	0.6	-	-	-	-	-	0.6	-	-	-	-	-	3.2	-	3.2
D	TP518	3.9	2.3	-	-	-	-	-	-	2.3	-	-	-	-	>3.9	-	-
D	TP519	2.4	0.7	-	0.1	-	-	-	-	0.15	0.7	-	-	-	2.0	-	2.0
D	TP520	2.9	1.8	-	0.3	-	-	-	-	0.7	1.8	-	-	-	2.6	-	2.6
D	TP521	2.0	1.0	-	0.1	-	-	-	-	-	-	1.0	-	-	1.8	-	1.8
D	TP522	3.6	0.9	-	0.1	-	-	-	-	-	0.9	-	-	-	>3.6	-	-
D	TT431	3.6	3.4	-	-	-	-	-	-	0.3	3.4	-	-	-	>3.6	-	-

Text in red highlights pits that encountered significant thicknesses of made ground. Made Ground Topsoil was encountered in TPs 512, 517 & 518 to 0.3m, 0.3m & 0.1m respectively

Annex III

Summary Tables of Ground Contamination

SUMMARY OF DEGREE OF SOILS CONTAMINATION (INORGANICS)

Site Area	Expl Hole	Depth (m)	Material	Concentrations in mg/kg unless otherwise stated. Results are quoted to 1 decimal place if <10, and whole numbers if >10. Trigger Level Concentrations are shown in **BLUE** and assume a **residential with gardens** end-use.														
				pH	As ∞	B~	Cd ∞	Cr x	Cu♣$	Pb ∞	Hg*	Ni	Se	V (S4UL)	Zn$	CN	Total S	Asbestos
					37	5	26	3000	200	200	169	127	350	410	200	-	-	
A	TP437	0.1	Ash & Clinker	8.0	**77**	1.6	1.3	120	160	**530**	0.1	50	0.9	53	110	0.5	1.0	N.D.
A	TP512	1.0	Cement Sheet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**Chrysotile**
A	TP436	0.9	Cohesive Made Ground	6.8	**93**	1.5	0.7	13	31	77	0.1	30	0.6	25	65	0.5	0.3	N.D.
A	TP444	0.1	Cohesive Made Ground	7.9	**110**	0.5	0.2	22	56	**340**	0.6	37	1.2	37	94	1.2	0.4	N.D.
A	TP501	1.8	Cohesive Made Ground	5.0	7.2	**8.1**	0.1	22	24	24	0.1	34	0.2	21	72	-	-	-
A	TP508	2.3	Cohesive Made Ground	4.0	16	3.6	0.1	29	52	18	0.1	6.8	0.2	24	21	-	-	-
A	TP513	4.0	Cohesive Made Ground	4.0	21	1.7	0.1	13	9.9	46	0.1	4.6	0.3	19	22	-	-	-
A	TP514	0.3	Cohesive Made Ground	7.6	**320**	0.9	0.3	29	140	**980**	1.6	27	1.6	40	150	-	-	-
A	TP514	2.8	Cohesive Made Ground	9.1	**200**	3.8	0.1	7.3	21	150	0.4	5.7	3.6	14	19	-	-	-
A	TP503	1.5	Filter Sand	5.1	**69**	0.8	0.1	14	26	**370**	0.3	16	1.3	28	39	-	-	N.D.
A	TP436	0.1	Granular Made Ground	8.0	**920**	1.0	11	24	**390**	**730**	0.2	64	3.5	47	**320**	0.5	0.5	**Amosite**
A	TP437	0.4	Granular Made Ground	7.6	**70**	1.5	0.3	70	110	**1500**	0.1	65	1.3	58	77	0.5	1.3	N.D.
A	TP438	0.1	Granular Made Ground	-	-	-	-	-	-	-	-	-	-	-	-	2.0	0.3	-
A	TP439	0.1	Granular Made Ground	7.7	**47**	1.2	0.6	110	110	**560**	0.2	50	1.1	52	**250**	0.8	0.6	N.D.
A	TP439	2.0	Granular Made Ground	-	-	-	-	-	-	-	-	-	-	-	-	0.6	1.4	-
A	TP440	0.1	Granular Made Ground	9.4	**180**	0.6	0.8	28	76	**640**	0.7	38	1.1	38	130	1.3	0.6	N.D.
A	TP441	0.1	Granular Made Ground	7.5	**270**	0.7	0.7	37	100	**560**	1.0	45	1.6	66	150	1.9	1.4	N.D.
A	TP442	0.1	Granular Made Ground	7.9	**46**	1.8	0.4	25	58	140	0.2	31	0.4	44	68	1.5	0.4	N.D.
A	TP442	1.0	Granular Made Ground	-	-	-	-	-	-	-	-	-	-	-	-	0.5	3.5	-
A	TP443	0.8	Granular Made Ground	7.3	**72**	0.7	0.6	47	82	**840**	0.3	47	1.0	95	91	0.8	0.9	N.D.
A	TP501	1.2	Granular Made Ground	7.2	23	2.1	0.8	11	26	130	0.4	24	0.3	15	160	-	-	N.D.
A	TP502	2.8	Granular Made Ground	4.0	**200**	2.6	0.1	9.1	43	**2800**	0.4	14	1.2	28	35	-	-	N.D.
A	TP504	0.6	Granular Made Ground	7.6	**410**	0.8	0.1	29	87	**560**	1.1	32	1.1	39	120	-	-	N.D.
A	TP505	0.8	Granular Made Ground	7.9	**230**	1.2	0.2	84	160	**890**	1.6	39	1.0	62	120	-	-	N.D.
A	TP505	4.8	Granular Made Ground	7.1	**140**	0.5	0.1	22	100	**770**	0.5	24	1.1	67	39	-	-	N.D.
A	TP506	1.5	Granular Made Ground	6.1	30	1.6	0.1	8	20	**270**	0.1	6.1	0.5	13	16	-	-	N.D.
A	TP507	1.0	Granular Made Ground	8.5	**180**	0.7	0.1	67	370	**1400**	1.3	33	0.8	50	**290**	-	-	N.D.
A	TP508	1.4	Granular Made Ground	8.1	**63**	0.8	0.3	53	100	**550**	0.5	32	0.6	49	130	-	-	N.D.
A	TP510	0.9	Granular Made Ground	7.9	**230**	0.6	0.1	45	130	**1100**	1.2	43	1.1	47	180	-	-	N.D.
A	TP512	0.9	Granular Made Ground	8.4	**61**	1.8	0.5	150	160	**630**	0.4	69	0.7	53	200	-	-	N.D.
A	TP512	2.3	Granular Made Ground	7.8	**56**	1.0	0.1	37	49	**220**	0.4	21	0.9	26	61	-	-	N.D.
A	TP514	0.9	Granular Made Ground	7.7	18	0.7	0.1	15	60	**290**	0.1	24	0.2	28	50	-	-	N.D.
A	TP512	0.2	Made Ground Topsoil	8.3	**83**	1.6	1.2	97	**240**	**720**	0.9	64	1.0	49	**870**	-	-	N.D.
A	TP517	0.2	Made Ground Topsoil	8.4	35	0.9	0.9	54	**310**	**700**	1.0	66	0.5	58	**700**	-	-	N.D.
B	TP417	1.0	Ash & Clinker	7.9	**100**	0.6	0.2	24	73	45	0.1	55	0.5	61	68	-	-	N.D.
B	TP419	1.1	Ash & Clinker	11.5	29	0.4	5.1	29	80	130	0.3	34	0.2	42	**330**	-	-	N.D.
B	TP423	0.3	Ash & Clinker	8.0	**59**	0.6	0.3	85	90	150	0.7	39	0.2	220	110	-	-	N.D.
B	TP425	0.3	Ash & Clinker	8.4	33	0.4	0.1	13.	140	73	0.2	28	0.2	23	39	-	-	N.D.
B	TP427	0.5	Ash & Clinker	6.4	31	0.5	0.2	32	180	110	0.2	44	0.2	36	110	0.5	0.2	N.D.
B	TP429	0.5	Ash & Clinker	7.5	**97**	0.6	0.4	70	**660**	**380**	1.4	88	0.2	72	**270**	0.7	0.2	N.D.
B	TP525	0.7	Brickfill	10.3	16	0.4	0.1	32	33	81	0.1	42	0.2	-	80	-	-	N.D.
B	TT428 S	1.8	Cohesive Alluvium	-	-	-	-	-	-	-	-	-	-	-	-	0.5	0.7	-
B	TP420	0.6	Cohesive Made Ground	9.0	9.9	0.4	1.0	31	48	44	0.1	57	0.2	24	150	-	-	N.D.
B	TP424	0.5	Cohesive Made Ground	5.5	6.0	0.4	0.1	25.0	24	21	0.1	35	0.2	25	60	-	-	N.D.
B	TP427	0.1	Cohesive Made Ground	6.8	9.7	0.4	0.2	22	18	21	0.1	24	0.2	22	76	0.5	0.1	N.D.
B	TP428 S	0.1	Cohesive Made Ground	7.7	**40**	0.4	0.7	65	**280**	**770**	0.4	50	0.3	100	150	0.5	0.2	N.D.
B	TP429	0.1	Cohesive Made Ground	8.0	**140**	0.5	0.4	53	18	**770**	1.4	57	0.7	54	**220**	0.9	0.2	N.D.
B	TP524	2.3	Cohesive Made Ground	8.8	**110**	2.6	0.5	75	170	**8100**	0.9	32	1.8	-	**290**	-	-	N.D.
B	TP525	2.0	Cohesive Made Ground	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N.D.
B	TP525	3.0	Cohesive Made Ground	8.8	**41**	0.4	0.3	27	79	160	0.4	25	0.2	-	130	-	-	N.D.
B	TP407	0.6	Granular Made Ground	9.1	29	0.9	0.6	45	120	**990**	0.4	38	0.2	33	**280**	-	-	N.D.
B	TP418	0.4	Granular Made Ground	9.1	31	0.4	0.1	26	87	140	0.2	33	0.2	45	87	-	-	N.D.
B	TP419	0.5	Granular Made Ground	7.9	11	0.4	0.1	24	27	49	0.1	17	0.2	23	38	-	-	N.D.
B	TP421	0.5	Granular Made Ground	8.9	**70**	0.6	0.6	31	200	**210**	0.2	70	0.3	33	180	-	-	N.D.
B	TP429	3.0	Granular Made Ground	-	-	-	-	-	-	-	-	-	-	-	-	1.7	0.1	-
B	TT428N	1.4	Granular Made Ground	7.6	**180**	0.8	4.4	56	**240**	**4100**	0.9	**160**	1.5	42	**1700**	0.5	1.8	N.D.
B	TP428 S	0.4	Relict Topsoil	7.8	**93**	0.8	0.4	64	**390**	**680**	0.7	80	0.9	70	170	4.7	0.2	N.D.
B	TP401	0.1	Sub-base	10	25	0.7	0.5	49	**640**	**320**	0.2	58	0.2	31	**710**	-	-	N.D.
C	TP401	0.4	Ash & Clinker	8.1	**91**	1.5	0.5	83	**330**	**290**	0.3	93	0.6	60	**340**	-	-	N.D.
C	TP408	0.4	Ash & Clinker	8.4	**66**	2.9	2.8	40	150	**1200**	0.6	60	0.3	41	**330**	-	-	N.D.
C	TP409	0.2	Ash & Clinker	6.7	**450**	1.0	0.2	39	**310**	**940**	1.7	58	5.4	66	150	-	-	N.D.
C	TP411	0.1	Ash & Clinker	8.2	**51**	1.1	0.7	150	**220**	**630**	0.5	52	0.4	41	**290**	-	-	N.D.
C	TP413	0.2	Ash & Clinker	7.9	**200**	1.7	0.1	170	**8000**	**810**	1.7	**350**	0.2	54	**1500**	-	-	N.D.
C	TP415	1.2	Ash & Clinker	8.4	**58**	1.1	1.4	43.	15	**220**	1.9	69	1.5	38	**490**	-	-	N.D.
C	TP416	0.2	Ash & Clinker	7.1	**51**	0.5	0.8	55	190	**650**	0.3	68	0.2	61	**390**	-	-	N.D.
C	TP517	0.5	Cohesive Made Ground	4.0	18	1.2	0.1	3.8	16	50	0.8	8.7	2.9	15	13	-	-	-
C	TP402	0.4	Granular Made Ground	8.8	36	1.0	4.9	28	160	**390**	0.4	37	0.2	40	**370**	-	-	**Chrysotile**
C	TP403	0.3	Granular Made Ground	8.1	35	3.5	0.5	29	50	**340**	0.3	26	0.2	29	180	-	-	N.D.
C	TP406	0.2	Granular Made Ground	8.4	20	0.8	1.0	74	**1600**	**400**	0.5	53	0.2	21	**550**	-	-	N.D.
C	TP410	0.1	Granular Made Ground	7.9	18	0.4	0.2	11	52	38	0.1	20	0.2	19	26	-	-	N.D.
C	TP516	0.8	Granular Made Ground	8.2	35	0.7	1.1	45	**210**	**240**	0.3	69	0.3	54	140	-	-	N.D.
C	TP518	2.0	Granular Made Ground	7.9	**40**	0.7	0.1	16	65	180	1.2	25	0.2	37	51	-	-	N.D.
D	TP412	0.1	Ash & Clinker	8.9	27	1.6	0.9	71	79	120	0.1	54	0.2	41	140	-	-	N.D.
D	TP412	1.0	Ash & Clinker	6.7	**290**	1.0	0.6	54	190	**330**	0.1	98	0.4	190	98	-	-	N.D.
D	TP414	0.2	Ash & Clinker	7.5	**38**	0.7	3.1	73	**460**	**680**	0.2	76	0.2	41	**410**	-	-	N.D.
D	TP431	0.5	Ash & Clinker	4.5	**700**	0.7	0.1	27	93	**380**	0.8	19	1.5	57	46	-	-	N.D.
D	TP435	0.10	Ash & Clinker	9.3	18	0.6	0.9	130	72	18	1.0	4	0.5	40	**300**	-	-	N.D.
D	TP446	0.30	Ash & Clinker	6.0	**52**	0.7	0.3	25	43	86	0.1	16	0.6	35	49	-	-	N.D.
D	TP515	0.4	Ash & Clinker	6.0	**370**	0.6	0.1	55	74	**570**	0.9	25	1.1	27	60	-	-	N.D.
D	TP515	1.8	Ash & Clinker	4.4	**75**	4.4	0.1	35	78	**360**	0.34	23	0.6	48	120	-	-	N.D.
D	TP522	0.50	Ash & Clinker	8.0	**67**	1.2	0.7	36	110	**700**	0.4	45	0.7	-	**350**	-	-	N.D.

Site Area	Expl Hole	Depth (m)	Material	Concentrations in mg/kg unless otherwise stated. Results are quoted to 1 decimal place if <10, and whole numbers if >10. Trigger Level Concentrations are shown in BLUE and assume a **residential with gardens** end-use.														Asbestos
				pH	As ∞	B~	Cd ∞	Cr x	Cu♣$	Pb ∞	Hg*	Ni	Se	V (S4UL)	Zn$	CN	Total S	
					37	5	26	3000	200	200	169	127	350	410	200	-	-	
D	TP430	0.5	Granular Made Ground	9.2	31	3.8	0.6	98	100	**610**	0.4	55	0.2	40	**260**	-	-	N.D.
D	TP432	0.6	Granular Made Ground	8.3	**47**	0.6	0.3	25	71	**250**	0.3	33	0.2	41	120	-	-	N.D.
D	TP433	0.2	Granular Made Ground	7.6	22	0.9	0.2	22	**130**	**88**	0.2	21	0.2	28	83	-	-	N.D.
D	TP434	0.10	Granular Made Ground	9.1	17	1.0	0.4	15	52	120	0.2	33	0.3	26	140	-	-	N.D.
D	TP520	0.40	Granular Made Ground	8.2	**170**	0.4	0.3	74	**210**	**290**	2.1	57	0.6	-	**250**	-	-	N.D.
D	TP524	0.50	Granular Made Ground	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**Chrysotile**
D	TP432	0.2	Sub-base	6.4	35	0.4	0.2	11	9.8	38	0.1	13.0	0.2	17	29	-	-	N.D.

Key		Source of guidance trigger level	
36	Parameter tested for and found to be in excess of Tier 1 value.	With the exception of those annotated with one of the symbols below (∞, $, ~), all Soil Screening Values in brackets above have been derived using CLEA v1.06.	
179	Parameter tested for and found to be > 5 x Tier 1 value.		
12	Parameter tested for but not found to be in excess of Tier 1 value.	∞	Category 4 Screening Level – SP1010, December 2013 (CL:AIRE/Defra).
-	Parameter not tested for.	$	MAFF. Code of Practice for Agricultural Practice for the Protection of Soil, 1998.
♣	Tier 1 Value is pH dependent.	*	Assumes mercury present as an inorganic compound (cf elemental metal or within organic compound). See Science Report SC050021/Mercury SGV.
x	Assumes Cr is CrIII. If demonstrated Cr is CrVI Tier 1 would be 21mg/kg.	ND	No fibres detected (asbestos screen)
~	Engineering judgement (Lithos). Boron is a phytotoxic, although most phytotoxic compounds can pose a risk to human health if sufficient concentrations are present. However, plants represent the most sensitive receptor, and a Tier 1 value which is protective of flora is therefore also protective of human health.		

SUMMARY OF DEGREE OF SOILS CONTAMINATION (ORGANICS)

Site Area	Expl Hole	Depth (m)	Material	Concentrations in mg/kg. Results are quoted to 1 decimal place if <10, and whole numbers if >10. Trigger Level Concentrations are shown in BLUE and assume a **residential with gardens and 600mm** cover end use						PAH		TPH - C6 to C40		
				% TOC	Benzene ∞	Toluene	Ethyl Benzene	Xylenes	Phenols	B(a)P ∞	Napht-halene	GRO~ C_6 to C_{10}	DRO◊ C_{10} to C_{21}	LRO C_{21} to C_{40}
					0.9	3,000	932	327	2,400	25	9	34	156	5000
A	TP437	0.1	Ash & Clinker	12	-	-	-	-	-	0.5	0.6	1.0	26	170
A	TP437	1.4	Ash & Clinker	-	-	-	-	-	5.0	-	-	-	-	-
A	TP438	1.8	Ash & Clinker	-	1.0	1.0	1.0	1.0	5.0	7.0	4	-	-	-
A	TP438	2.8	Ash & Clinker	-	1.0	1.0	1.0	1.0	8.3	7.1	**33**	-	-	-
A	TP438	3.6	Ash & Clinker	-	1.0	1.0	1.0	1.0	5.0	13	**29**	-	-	-
A	TP439	2.8	Ash & Clinker	-	1.0	1.0	1.0	1.0	5.0	4.1	5.5	-	-	-
A	TP440	2.0	Ash & Clinker	16	1.0	1.0	1.0	1.0	5.0	9.0	2.3	-	-	-
A	TP441	1.9	Ash & Clinker	19	-	-	-	-	5.0	-	-	-	-	-
A	TP505	2.1	Bitumen Sealant	0.6	-	-	-	-	74	**350**	**1700**	**6350**	**171000**	**150000**
A	TP436	0.9	Cohesive Made Ground	0.3	-	-	-	-	5.0	-	-	1.0	1.0	1.0
A	TP437	3.6	Cohesive Made Ground	-	-	-	-	-	5.0	-	-	-	-	-
A	TP441	3.0	Cohesive Made Ground	1.1	-	-	-	-	5.0	-	-	-	-	-
A	TP444	0.1	Cohesive Made Ground	4.8	1.0	1.0	1.0	1.0	5.0	2.6	0.5	-	-	-
A	TP501	1.8	Cohesive Made Ground	0.7	-	-	-	-	0.5	0.5	0.5	2.0	46.2	410
A	TP508	2.3	Cohesive Made Ground	0.5	-	-	-	-	0.5	0.5	0.5	2.0	44	84
A	TP513	2.9	Cohesive Made Ground	2.0	1.0	1.0	1.0	1.0	0.5	0.5	0.5	-	-	-
A	TP513	4.0	Cohesive Made Ground	0.3	-	-	-	-	0.5	0.5	0.5	2.0	47.5	72
A	TP514	0.3	Cohesive Made Ground	4.4	-	-	-	-	0.5	7.8	1.1	2.0	77.9	120
A	TP514	2.8	Cohesive Made Ground	1.6	-	-	-	-	0.5	1.1	0.8	2.0	**234**	290
A	TP436	1.4	Cohesive Residual Soil	0.6	-	-	-	-	5.0	-	-	-	-	-
A	TP439	3.9	Cohesive Residual Soil	0.6	1.0	1.0	1.0	1.0	5.0	0.5	0.5	-	-	-
A	TP440	2.7	Cohesive Residual Soil	1.7	1.0	1.0	1.0	1.0	5.0	0.5	0.5	-	-	-
A	TP441	3.9	Cohesive Residual Soil	1.8	-	-	-	-	5.0	0.5	0.8	-	-	-
A	TP442	1.5	Cohesive Residual Soil	0.6	1.0	1.0	1.0	1.0	5.0	0.5	0.6	-	-	-
A	TP509	3.0	Cohesive Residual Soil	0.2	1.0	1.0	1.0	1.0	0.5	0.5	0.5	-	-	-
A	TP514	3.3	Cohesive Residual Soil	1.1	1.0	1.0	1.0	1.0	0.5	0.5	0.5	3.0	3.0	2.0
A	TP514	4.4	Cohesive Residual Soil	0.9	1.0	1.0	1.0	1.0	0.5	0.5	0.5	3.0	3.0	2.0
A	TP503	1.5	Filter Sand	7.7	-	-	-	-	0.5	4.9	3.0	2.0	3.0	1.0
A	BH501	7.6	Granular Made Ground	6.2	**3.5**	2.7	4.5	14	0.5	0.5	0.5	-	-	-
A	TP436	0.1	Granular Made Ground	4.7	-	-	-	-	5.0	2.2	0.5	1.0	1.0	1.0
A	TP437	0.4	Granular Made Ground	25	-	-	-	-	5.0	-	-	1.0	9.3	37
A	TP438	0.1	Granular Made Ground	-	1.0	1.0	1.0	1.0	5.0	5.9	4.7	-	-	-
A	TP439	0.1	Granular Made Ground	12	1.0	1.0	1.0	1.0	5.0	0.8	0.5	1.0	57	160
A	TP439	2.0	Granular Made Ground	-	1.0	1.0	1.0	1.0	5.0	3.8	0.7	-	-	-
A	TP440	0.1	Granular Made Ground	5.5	1.0	1.0	1.0	1.0	5.0	5.3	0.7	-	-	-
A	TP441	0.1	Granular Made Ground	6.2	-	-	-	-	5.0	0.5	0.5	1.0	21	54
A	TP442	0.1	Granular Made Ground	10	1.0	1.0	1.0	1.0	5.0	6.6	0.5	-	-	-
A	TP442	1.0	Granular Made Ground	5.8	1.0	1.0	1.0	1.0	5.0	3.6	1.6	-	-	-
A	TP443	0.8	Granular Made Ground	23	-	-	-	-	5.0	-	-	1.0	50	340
A	TP444	1.5	Granular Made Ground	12	1.0	1.0	1.0	1.0	5.0	0.5	0.5	-	-	-
A	TP444	2.4	Granular Made Ground	0.8	1.0	1.0	1.0	1.0	5.0	0.5	0.5	-	-	-
A	TP501	1.2	Granular Made Ground	7.1	-	-	-	-	0.5	0.8	0.9	**234**	**12110**	**27000**
A	TP501	3.6	Granular Made Ground	4.3	**2.1**	3.0	6.0	8.8	0.5	23	4.1	-	-	-
A	TP502	2.8	Granular Made Ground	9.8	-	-	-	-	0.5	0.7	0.5	2.0	39.5	54
A	TP504	0.6	Granular Made Ground	5.6	-	-	-	-	0.5	1.8	0.5	2.0	3.0	1.0
A	TP504	1.2	Granular Made Ground	4.3	1.0	1.0	1.0	1.0	0.5	10	2.2	-	-	-
A	TP505	0.8	Granular Made Ground	6.1	-	-	-	-	0.5	23	4.3	2.0	151	320
A	TP505	3.8	Granular Made Ground	7.2	1.0	1.0	1.0	1.0	0.5	0.5	0.5	-	-	-
A	TP508	1.4	Granular Made Ground	2.4	-	-	-	-	0.5	2.1	0.5	2.0	3.0	1.0
A	TP509	0.5	Granular Made Ground	7.8	1.0	1.0	1.0	1.0	0.5	3.1	3.8	-	-	-
A	TP510	0.9	Granular Made Ground	5.0	-	-	-	-	0.5	4.1	0.5	2.0	3.0	1.0
A	TP512	0.9	Granular Made Ground	18	1.0	1.0	1.0	1.0	0.5	15	1.1	-	-	-
A	TP512	2.3	Granular Made Ground	36	-	-	-	-	0.5	**67**	**15**	5.7	**1072**	2200
A	TP514	0.7	Granular Made Ground	0.7	1.0	1.0	1.0	1.0	0.5	0.6	0.5	-	-	-
A	TP514	0.9	Granular Made Ground	11	1.0	1.0	1.0	1.0	0.5	3.7	0.5	-	-	-
A	TP512	0.2	Made Ground Topsoil	8.7	-	-	-	-	0.5	2.7	0.5	2.0	3.0	1.0
B	TP417	1.0	Ash & Clinker	12	-	-	-	-	-	-	-	1.0	1.0	1.0
B	TP419	1.1	Ash & Clinker	5.6	-	-	-	-	-	0.5	0.5	1.0	1.0	1.0
B	TP423	0.3	Ash & Clinker	7.2	-	-	-	-	5.0	0.7	0.5	1.0	7.1	24
B	TP425	0.3	Ash & Clinker	12	1.0	1.0	1.0	1.0	5.0	3.1	3.1	-	-	-
B	TP425	0.9	Ash & Clinker	6.8	1.0	1.0	1.0	1.0	5.0	0.5	0.5	-	-	-
B	TP427	0.5	Ash & Clinker	2.7	-	-	-	-	5.0	3.1	0.5	1.0	150	660
B	TP429	0.5	Ash & Clinker	9.0	1.0	1.0	1.0	1.0	5.0	2.8	0.5	-	-	-
B	TP525	0.7	Brickfill	5.8	-	-	-	-	0.5	7.8	1.4	3.7	3.7	70
B	TT428 S	1.8	Cohesive Alluvium	0.5	1.0	1.0	1.0	1.0	5.0	0.5	0.5	-	-	-
B	TP420	0.6	Cohesive Made Ground	1.0	1.0	1.0	1.0	1.0	5.0	0.5	0.5	-	-	-
B	TP424	0.5	Cohesive Made Ground	0.9	-	-	-	-	5.0	0.5	0.5	1.0	1.0	1.0
B	TP427	0.1	Cohesive Made Ground	0.9	-	-	-	-	5.0	-	-	1.0	1.0	1.0
B	TP428 S	0.1	Cohesive Made Ground	5.2	1.0	1.0	1.0	1.0	5.0	2.1	0.5	-	-	-
B	TP429	0.1	Cohesive Made Ground	5.9	1.0	1.0	1.0	1.0	5.0	10	1.9	-	-	-
B	TP524	2.3	Cohesive Made Ground	0.5	-	-	-	-	0.5	0.5	0.5	2.0	2.0	11
B	TP525	2.0	Cohesive Made Ground	7.0	-	-	-	-	0.5	14	0.5	2.0	2.0	3300
B	TP525	3.0	Cohesive Made Ground	9.9	-	-	-	-	0.5	3.0	0.5	2.0	2.0	850
B	TP425	1.3	Cohesive Residual Soil	14	1.0	1.0	1.0	1.0	5.0	0.5	0.5	-	-	-
A	TP518	2.7	Cohesive Residual Soil	0.5	-	-	-	-	0.5	0.5	0.5	2.0	3.0	1.0
B	TP407	0.6	Granular Made Ground	4.8	-	-	-	-	-	-	-	1.0	15	99

Site Area	Expl Hole	Depth (m)	Material	Concentrations in mg/kg. Results are quoted to 1 decimal place if <10, and whole numbers if >10. Trigger Level Concentrations are shown in **BLUE** and assume a **residential with gardens and 600mm** cover end use										
										PAH		TPH - C6 to C40		
				% TOC	Benzene ∞	Toluene	Ethyl Benzene	Xylenes	Phenols	B(a)P ∞	Napht-halene	GRO~ C_6 to C_{10}	DRO◊ C_{10} to C_{21}	LRO C_{21} to C_{40}
					0.9	3,000	932	327	2,400	25	9	34	156	5000
B	TP418	0.4	Granular Made Ground	4.8	-	-	-	-	-	0.5	0.5	1.0	1.0	1.0
B	TP419	0.5	Granular Made Ground	1.7	-	-	-	-	5.0	0.5	0.5	1.0	1.0	1.0
B	TP421	0.5	Granular Made Ground	4.9	-	-	-	-	5.0	-	-	1.0	92	540
B	TP429	3.0	Granular Made Ground	4.3	1.0	1.0	1.0	1.0	5.0	0.5	0.5	-	-	-
B	TT428N	1.4	Granular Made Ground	7.9	1.0	1.0	1.0	1.0	5.0	8.6	0.7	-	-	-
B	TP420	0.9	Granular Residual Soil	0.7	1.0	1.0	1.0	1.0	5.0	0.5	0.5	-	-	-
B	TP428 S	0.4	Relict Topsoil	7.7	1.0	2.0	3.0	4.0	5.0	1.0	0.5	-	-	-
B	TP401	0.1	Sub-base	2.2	-	-	-	-	-	0.5	0.5	1.0	30	120
C	TP401	0.4	Ash & Clinker	20	-	-	-	-	-	1.7	0.5	1.0	80	270
C	TP408	0.4	Ash & Clinker	11	-	-	-	-	-	-	-	1.0	**270**	530
C	TP409	0.2	Ash & Clinker	13	-	-	-	-	-	0.5	0.5	1.0	55	95
C	TP411	0.1	Ash & Clinker	6.5	-	-	-	-	-	-	-	1.0	50	230
C	TP413	0.2	Ash & Clinker	12	-	-	-	-	-	-	-	1.0	39	360
C	TP415	1.2	Ash & Clinker	16	-	-	-	-	-	0.5	0.5	1.0	7.5	9.3
C	TP416	0.2	Ash & Clinker	8.5	-	-	-	-	-	-	-	1.0	3.2	1.0
C	TP517	0.5	Cohesive Made Ground	6.0	-	-	-	-	0.5	3.3	0.9	2.0	74	330
C	TP402	0.4	Granular Made Ground	4.2	1.0	1.0	1.0	1.0	-	0.8	0.5	-	-	-
C	TP403	0.3	Granular Made Ground	5.0	1.0	1.0	1.0	1.0	-	0.9	0.5	-	-	-
C	TP406	0.2	Granular Made Ground	2.1	-	-	-	-	-	7.0	1.1	1.0	18	180
C	TP410	0.1	Granular Made Ground	2.6	-	-	-	-	-	1.5	0.5	1.0	1.0	1.0
C	TP516	0.8	Granular Made Ground	23	-	-	-	-	0.5	0.5	0.5	2.0	3.0	1.0
C	TP518	2.0	Granular Made Ground	7.9	-	-	-	-	0.5	3.8	2.3	2.0	3.0	1.0
C	TP415	0.05	Macadam	5.4	-	-	-	-	-	1.0	0.5	-	-	-
D	TP412	0.1	Ash & Clinker	8.6	-	-	-	-	-	0.5	0.5	1.0	**260**	2600
D	TP412	1.0	Ash & Clinker	12	-	-	-	-	-	1.2	0.5	1.0	1.0+	1.0
D	TP414	0.2	Ash & Clinker	18	-	-	-	-	-	0.9	0.5	1.0	110	240
D	TP430	1.1	Ash & Clinker	8.0	1.0	1.0	1.0	1.0	-	0.5	0.5	-	-	-
D	TP431	0.5	Ash & Clinker	10	-	-	-	-	-	18	2.3	1.0	**590**	1500
D	TP435	0.1	Ash & Clinker	3.2	-	-	-	-	-	-	-	1.0	9.6	42
D	TP446	0.3	Ash & Clinker	4.9	-	-	-	-	5.0	8.4	5.2	1.0	45	49
D	TP515	0.4	Ash & Clinker	12	-	-	-	-	0.5	4.3	0.5	2.0	56	66
D	TP522	0.5	Ash & Clinker	4.8	-	-	-	-	0.5	0.5	0.5	2.0	2.0	11
D	TP430	3.0	Cohesive Residual Soil	0.9	1.0	1.0	1.0	1.0	-	0.5	0.5	-	-	-
D	TP446	1.6	Cohesive Residual Soil	0.8	1.0	1.0	1.0	1.0	5.0	0.5	0.5	-	-	-
D	TP430	0.5	Granular Made Ground	3.0	1.0	1.0	1.0	1.0	-	0.5	0.5	-	-	-
D	TP430	2.4	Granular Made Ground	52	1.0	1.0	1.0	1.0	-	0.5	0.5	-	-	-
D	TP432	0.6	Granular Made Ground	8.5	-	-	-	-	-	0.5	0.5	1.0	20	28
D	TP433	0.2	Granular Made Ground	3.6	-	-	-	-	-	-	-	1.0	61	2300
D	TP434	0.1	Granular Made Ground	2.4	-	-	-	-	-	-	-	1.0	86	200
D	TP520	0.4	Granular Made Ground	7.3	-	-	-	-	0.5	0.5	0.5	2.0	2.0	2.0
D	TP524	0.5	Granular Made Ground	5.2	-	-	-	-	0.5	2.7	0.5	2.0	2.0	2.0
D	TP432	0.2	Sub-base	2.2	-	-	-	-	-	0.5	0.5	1.0	1.0	1.0

Key		Source of guidance trigger level	
60	Parameter tested for and in excess of Tier 1 concentration.	∞	Category 4 Screening Level – SP1010, December 2013 (CL:AIRE/Defra).
0.3	Parameter tested for but not in excess of Tier 1 concentration.	~	Assumes all GRO is aromatic fraction C7 to C8.
-	Contaminant not tested for.	◊	Assumes all DRO is aliphatic fraction C10 to C12.
All Soil Screening Values in brackets above have been derived using CLEA v1.06. Values assume contaminants located in a sandy loam, with 6% soil organic matter (SOM).			

SUMMARY OF DEGREE OF CONTAMINATION (SURFACE WATERS – INORGANICS)

Sampling Area	Depth	Material	Concentrations in mg/kg unless otherwise stated. Results are quoted to 1 decimal place if <10, and whole numbers if >10. Trigger Level Concentrations are shown in BLUE and assume a **residential with gardens** end-use.									
			pH	As ~	B ~	Cd ~	Cr ~	Cu ~	Pb ~	Hg ~	Ni ~	Se*	Zn ~
				50	1000	5	5	5	50	1	50	10	30
Upstream	n/a	Surface Water	8.0	0.9	44	0.1	0.6	2.9	0.7	0.1	2.8	0.3	14
Downstream	n/a	Surface Water	7.6	0.7	29	0.1	0.2	2.1	0.3	0.1	1.9	0.3	8.6

Key		Source of guidance trigger level	
60	Parameter tested for and in excess of Tier 1 concentration.	~	Directive (2000/60/EC) establishing a framework for Community action in the field of water policy (Water Framework Directive)
0.3	Parameter tested for but not in excess of Tier 1 concentration.	~	Water Supply (Water Quality) Regulations 1989, as amended in 2000

SUMMARY OF DEGREE OF CONTAMINATION (SURFACE WATERS – ORGANIC)

Sampling Area	Depth	Material	Concentrations in mg/kg unless otherwise stated. Results are quoted to 1 decimal place if <10, and whole numbers if >10. Trigger Level Concentrations are shown in BLUE and assume a **residential with gardens** end-use.						
			Benzene	Toulene	Ethylbenzene	Xylenes	Phenols	Benzo(a)Pyrene	Naphthalene
			30	50	20	30	0.1	0.05	2.4
Upstream	n/a	Surface Water	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Downstream	n/a	Surface Water	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Key		Source of guidance trigger level	
60	Parameter tested for and in excess of Tier 1 concentration.	x	Environment Agency Advice
0.3	Parameter tested for but not in excess of Tier 1 concentration.	~	Water Supply (Water Quality) Regulations 1989, as amended in 2000
~	Directive (2000/60/EC) establishing a framework for Community action in the field of water policy (Water Framework Directive)		

Site Area	Expl Hole	Depth (m)	Material	Concentrations in mg/kg. Results are quoted to 1 decimal place if <10, and whole numbers if >10. Trigger Level Concentrations are shown in BLUE and assume a residential with gardens and no cover or 300mm cover end use with 6% SOM.					
				GRO				DRO	LRO
				Benzene	Toluene	Ethyl Benzene	Xylenes	Naphthalene	Benzo(a)pyrene
				0.9	600	350	246	8.0	5
A	TP440	2.0	Ash & Clinker	<1.0	1.0	1.0	1.0	2.3	**9.0**
A	TP444	0.1	Cohesive Made ground	<1.0	1.0	1.0	1.0	0.5	2.6
A	TP442	1.5	Cohesive Residual Soil	<1.0	1.0	1.0	1.0	0.5	0.5
A	TP440	2.6	Cohesive Residual Soil	<1.0	1.0	1.0	1.0	0.5	0.5
A	TP440	0.1	Granular Made Ground	<1.0	1.0	1.0	1.0	0.7	**5.3**
A	TP442	0.1	Granular Made Ground	<1.0	1.0	1.0	1.0	0.5	**6.6**
A	TP442	1.0	Granular Made Ground	<1.0	1.0	1.0	1.0	1.6	3.6
A	TP444	1.5	Granular Made Ground	<1.0	1.0	1.0	1.0	0.5	0.5
A	TP444	2.4	Granular Made Ground	<1.0	1.0	1.0	1.0	0.5	0.5
B	TP425	0.3	Ash & Clinker	<1.0	1.0	1.0	1.0	3.1	3.1
B	TP429	0.5	Ash & Clinker	<1.0	1.0	1.0	1.0	0.5	2.8
B	TP425	0.9	Ash & Clinker	<1.0	1.0	1.0	1.0	0.5	0.5
B	TP430	1.1	Ash & Clinker	<1.0	1.0	1.0	1.0	0.5	0.5
B	TT4428 S	1.8	Cohesive Alluvium	<1.0	1.0	1.0	1.0	0.5	0.5
B	TT4428 S	0.1	Cohesive Made ground	<1.0	1.0	1.0	1.0	0.5	2.1
B	TP429	0.1	Cohesive Made ground	<1.0	1.0	1.0	1.0	1.9	**10**
B	TP420	0.6	Cohesive Made ground	<1.0	1.0	1.0	1.0	0.5	0.5
B	TP425	1.3	Cohesive Residual Soil	<1.0	1.0	1.0	1.0	0.5	0.5
B	TP430	3.0	Cohesive Residual Soil	<1.0	1.0	1.0	1.0	0.5	0.5
B	TP430	0.5	Granular Made Ground	<1.0	1.0	1.0	1.0	0.5	0.5
B	TT428 N	1.4	Granular Made Ground	<1.0	1.0	1.0	1.0	0.7	**8.6**
B	TP430	2.4	Granular Made Ground	<1.0	1.0	1.0	1.0	0.5	0.5
B	TP429	3.0	Granular Made Ground	<1	<1	<1	<1	<0.5	<0.5
B	TP420	0.9	Granular Residual Soil	<1	<1	<1	<1	<0.5	<0.5
B	TT428 S	0.4	Relict Topsoil	<1	<1	<1	<1	<0.5	1
C	TP403	0.3	Granular Made Ground	<1	<1	<1	<1	<0.5	0.9
C	TP402	0.4	Granular Made Ground	<1	<1	<1	<1	<0.5	0.8
A	TP514	3.3	Cohesive Residual Soil	<1	<1	<1	<1	<0.5	<0.5
A	TP514	4.4	Cohesive Residual Soil	<1	<1	<1	<1	<0.5	<0.5
A	TP501	1.2	Granular Made Ground	-	-	-	-	0.85	0.77
A	TP512	2.3	Granular Made Ground	-	-	-	-	**15**	**67**

Site Area	Expl Hole	Depth (m)	Material	Concentrations in mg/kg. Results are quoted to 1 decimal place if <10, and whole numbers if >10. Trigger Level Concentrations are shown in BLUE and assume a **residential with gardens and 600mm cover** end use.														Hazard Index
				Aliphatic							Aromatic							
				C5-C6	C6-C8	C8-C10	C10-C12	C12-C16	C16-C21	C21-C35	C5-C7	C7-C8	C8-C10	C10-C12	C12-C16	C16-C21	C21-C35	
				41	125	31	156	757	1.E+06	1.E+06	123	34	50	287	1.5E+03	1.E+06	1.E+06	
A	TP440	2.0	Ash & Clinker	1.0	1.0	1.0	1.0	3.2	5.0	28	1.0	1.0	1.0	1.2	8;1	54	180	0.1
A	TP444	0.1	Cohesive Made ground	1.0	1.0	1.0	1.0	1.0	1.6	18	1.0	1.0	1.0	1.3	2;1	14	78	0.1
A	TP442	1.5	Cohesive Residual Soil	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.1
A	TP440	2.6	Cohesive Residual Soil	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.1
A	TP440	0.1	Granular Made Ground	1.0	1.0	1.0	1.0	2.1	5.1	30	1.0	1.0	1.0	1.1	4;3	37	239	0.1
A	TP442	0.1	Granular Made Ground	1.0	1.0	1.0	1.0	2.4	5.5	29	1.0	1.0	1.0	1.6	10	69	67	0.1
A	TP442	1.0	Granular Made Ground	1.0	1.0	1.0	1.0	2.6	6.5	28	1.0	1.0	1.0	1.3	6.8	35	160	0.1
A	TP444	1.5	Granular Made Ground	1.0	1.0	7.1	12	15	1.0	920	1.0	1.0	1.0	1.0	11	550	700	0.4
A	TP444	2.4	Granular Made Ground	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.1
B	TP425	0.3	Ash & Clinker	1.0	1.0	4.9	8.9	8.7	9.1	47	1.0	1.0	8.9	62	150	370	696	0.8
B	TP429	0.5	Ash & Clinker	1.0	1.0	1.0	1.0	1.8	2.8	15	1.0	1.0	1.0	1.0	1.0	2.5	63	0.1
B	TP425	0.9	Ash & Clinker	1.0	1.0	1.0	1.0	2	4.5	22	1.0	1.0	1.0	1.0	1.2	18	40	0.1
B	TP430	1.1	Ash & Clinker	1.0	1.0	1.0	1.0	10	4.7	2.4	1.0	1.0	1.0	1.0	16	130	280	0.2
B	TT4428 S	1.8	Cohesive Alluvium	1.0	1.0	1.0	1.0	9.2	7.6	44	1.0	1.0	1.0	1.0	1.5	15	82	0.1
B	TT4428 S	0.1	Cohesive Made ground	1.0	1.0	1.0	1.0	1.0	6.5	48	1.0	1.0	1.0	1.0	1.0	14	110	0.1
B	TP429	0.1	Cohesive Made ground	1.0	1.0	1.0	1.0	9.9	11	78	1.0	1.0	1.0	1.3	11	92	433	0.2
B	TP420	0.6	Cohesive Made ground	1.0	1.0	1.0	1.0	210	250	110	1.0	1.0	1.0	1.0	22	37	34	0.4
B	TP425	1.3	Cohesive Residual Soil	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.1
B	TP430	3.0	Cohesive Residual Soil	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.1
B	TP430	0.5	Granular Made Ground	1.0	1.0	1.0	1.0	24	8.6	130	1.0	1.0	1.0	1.0	29	210	89	0.2
B	TT428 N	1.4	Granular Made Ground	1.0	1.0	1.0	1.0	8.1	31	170	1.0	1.0	1.0	1.0	1.9	11	60	0.1
B	TP430	2.4	Granular Made Ground	1.0	1.0	1.0	1.0	3.5	1.0	13	1.0	1.0	1.0	1.0	10	150	220	0.1
B	TP429	3.0	Granular Made Ground	1.0	1.0	7.4	16	24	170	2200	1.0	1.0	1.0	1.0	21	17	745	0.5
B	TP420	0.9	Granular Residual Soil	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.1
B	TT428 S	0.4	Relict Topsoil	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.1

Site Area	Expl Hole	Depth (m)	Material	Concentrations in mg/kg. Results are quoted to 1 decimal place if <10, and whole numbers if >10. Trigger Level Concentrations are shown in BLUE and assume a **residential with gardens and 600mm cover** end use.														Hazard Index
				Aliphatic							**Aromatic**							
				C5-C6	C6-C8	C8-C10	C10-C12	C12-C16	C16-C21	C21-C35	C5-C7	C7-C8	C8-C10	C10-C12	C12-C16	C16-C21	C21-C35	
				41	125	31	156	757	1.E+06	1.E+06	123	34	50	287	1.5E+03	1.E+06	1.E+06	
C	TP403	0.3	Granular Made Ground	1.0	1.0	1.0	1.0	3.6	40	920	1.0	1.0	1.0	1.0	1.0	20	190	0.1
C	TP402	0.4	Granular Made Ground	1.0	1.0	1.0	1.0	1.8	4.4	14	1.0	1.0	1.0	1.0	1.0	4.5	64	0.1
A	TP514	3.3	Cohesive Residual Soil	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0
A	TP514	4.4	Cohesive Residual Soil	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0
A	TP501	1.2	Granular Made Ground	1.0	1.0	**67**	98	340	1200	4800	1.0	1.0	**250**	160	520	1500	5300	**9**
A	TP512	2.3	Granular Made Ground	1.0	1.0	**59**	23	25	57	400	1.0	1.0	**180**	130	390	2300	9400	**6**

Appendix A

General Notes

01 - Environmental setting
Generic notes – geoenvironmental Investigations

General

Third party information obtained from the British Geological Survey (BGS), the Coal Authority, the Local Authority etc is presented in the "Search Responses" Appendix of this Geoenvironmental Report.

Geology, mining & quarrying

In order to establish the geological setting of a site, Lithos refer to BGS maps for the area, and the relevant geological memoir. Further information is sourced by reference to current and historical OS plans.

In July 2011, the Coal Authority (CA) formalised their requirements in relation to planning applications and introduced some new terminology. The CA, using its extensive records has prepared plans for all coalfield Local Planning Authorities, which effectively refines the defined coalfield areas into High Risk and Low Risk areas. **High Risk** areas are likely to be affected by a range of legacy issues that pose a risk to surface stability, including: mine entries; shallow coal workings; workable coal seam outcrops; mines gas; and previous surface mining sites. **Low Risk** areas comprise the remainder of the defined coalfield, and are areas where no known defined risks have been recorded; although there may still be unrecorded issues. Where a site lies within either a High or Low Risk area, a mining report is obtained from the CA.

Landfills

Reference is made to publicly available Government held digital data via **QGIS** (an Open Source Geographic Information System), data from Landmark or Groundsure, and sometimes the Environment Agency and the Local Authority with respect to known areas of landfilling within 250m of the proposed development site.

Historical OS plans are also inspected for evidence of backfilled quarries, railway cuttings, colliery spoil tips etc.

Radon

Radon is a colourless, odourless gas, which is radioactive. It is formed in strata that contain uranium and radium (most notably granite), and can move though fissures eventually discharging to atmosphere, or the spaces under and within buildings. Where radon occurs in high concentrations, it can pose a risk to health.

In order to assess potential risks associated with radon gas, Lithos refer to BRE Report BR211[1], and the Public Health England website. Advice on the limitation of exposure of the population to radon in buildings was originally published in 1990 by the National Radiological Protection Board (NRPB), which joined the Health Protection Agency (HPA) in 2005; the HPA updated NRPB advice in July 2010[2]. The HPA became part of Public Health England in 2013.

The HPA recommended that the NRPB radon Action Level for homes be retained, and a new Target Level for radon in homes be introduced. The values of the Action Level and Target Level, expressed as the annual average radon concentration in the home, are 200 Bqm^{-3} and 100 Bqm^{-3} respectively. The Target Level was to provide an objective for remedial action in existing homes and preventive action in new homes.

The term 'radon Affected Area' is defined as those parts of the country with >1% of homes estimated to be above the Action Levels. The NRPB first indicated which parts of the country should be regarded as radon Affected Areas in 1990. A more detailed mapping method was developed by the HPA in conjunction with the British Geological Survey in 2007[3]. The level of protection needed is site-specific and can be determined by reference to this mapping on the Public Health England website, which indicates the highest radon potential within each 1km grid square. Each 1km grid square is classified on the basis of the percentage of existing homes within that grid square estimated to have radon concentrations above the Action Level. There are 6 'bands': <1%; 1 to 3%; 3 to 5%; 5 to 10%; 10 to 30%; and >30%.

The NRPB advised that action should be taken to reduce radon concentrations in existing homes if the radon concentration exceeded the Action Level of 200 Bqm^{-3} in room air averaged over a year; ten times the average UK domestic radon concentration. NRPB advice informed changes in the requirements for radon protection in new buildings.

- **Basic** preventive measures are required in new buildings, extensions, conversions and refurbishments if the probability of exceeding the Action Level is **>3%** in England and Wales, and >1% in Scotland and Northern Ireland.
- Provision for further preventive (**Full**) measures is required in new buildings if the probability of exceeding the Action Level is **>10%**.

At present Building Regulations Approved Document C advocates basic measures for the probability banding 3% to 10%, and full measures if >10%. However, Public Health England would like to see all new build include basic measures.

Action & Target Levels should also be applied to non-domestic buildings with public occupancy exceeding 2,000 hrs/yr and to all schools.

Hydrogeology

Reference is made to publicly available Government held digital data via QGIS, and Landmark or Groundsure with respect to:

- Groundwater quality
- Recorded pollution incidents
- Licensed groundwater abstractions

From April 2010 the EA's Groundwater Protection Policy uses aquifer designations that are consistent with the Water Framework Directive. These designations reflect the importance of aquifers in terms of groundwater as a resource (drinking water supply), but also their role in supporting surface water flows and wetland ecosystems. The aquifer designation data is based on geological mapping provided by the British Geological Survey. The maps are split into two different types of aquifer designation:

- Superficial (Drift) - permeable unconsolidated (loose) deposits. For example, sands and gravels
- Bedrock - solid permeable formations e.g. sandstone, chalk and limestone

The maps display the following aquifer designations:

Principal aquifers: These are layers of rock or superficial deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer.

Secondary aquifers: These include a wide range of rock layers or superficial deposits with an equally wide range of water permeability and storage. Secondary aquifers are subdivided into three types:

- **Secondary A** - permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers
- **Secondary B** - predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers
- Secondary undifferentiated - In most cases, this is because the rock type in question has previously been designated as both a minor and non-aquifer in different locations due to the variable characteristics.

[1] BRE Report BR211, 2015: "Radon: guidance on protective measures for new buildings.

[2] Limitation of Human Exposure to Radon, Documents of the Health Protection Agency - Radiation, Chemical and Environmental Hazards, RCE-15. July 2010.

[3] Miles JCH, Appleton JD, Rees DM, Green BMR, Adlam KAM and Myers AH (2007). Indicative Atlas of Radon in England and Wales. Chilton, HPA-RPD-033.