

The background image for the cover is a photograph of a cross-section of a soil bank. The top layer is dark brown soil with some green grass. Below this is a layer of light-colored, possibly silty or sandy soil. At the bottom is a layer of large, flat, greyish-brown rocks or clays. The text "Geoenvironmental Appraisal" is overlaid in white on the left side of the image.

Geoenvironmental Appraisal

Land at Carlton Road, Barnsley

For Keepmoat Homes Yorkshire & Barnsley
Metropolitan Borough Council

Report no: 2551/1A

Date: February 2018



SUMMARY OF GEOENVIRONMENTAL ISSUES

Job No.	2551	Site area/ha	3.2ha
Client:	Keepmoat Homes Yorkshire & Barnsley Metropolitan Borough Council	NGR:	SE 358 084
Site:	Carlton Road, Barnsley	Nearest postcode:	S71 2AY

The site is located off St Helen's Boulevard, approximately 2.5km north-east of Barnsley town centre, and currently comprises an open grassed field, a demolished former school and open arable land.

Lithos were commissioned by Keepmoat & BMBC to provide a geoenvironmental appraisal of the site, which it is understood is to be redeveloped with housing. Lithos' investigation included a review of the site's history and environmental setting and a ground investigation comprising 24 trial pits, 17 dynamic sample boreholes and 6 road cores in St. Helen's Boulevard.

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

Issue	Remarks
Made ground	The thickest made ground is typically restricted to the north east of the site (associated with earthworks to create level development platforms & play areas), and predominantly comprises reworked natural clays. More variable made ground, comprising a mixture of made ground topsoil, demolition rubble, burnt red shale, sub-base and granular made ground is typically restricted to the area around former school buildings in the north.
Natural ground	The site is underlain by cohesive residual soil (stiff gravelly clay), with bedrock (sandstone, mudstone or siltstone) typically within 2.0m to 2.5m of the surface.
Contamination	No significant contamination has been identified.
Mining & quarrying	The site is in a Coal Authority Low Risk area. No issues have been identified at the site.
Hazardous gas	There are two landfills within 250m, as well as deep made ground on the site. A programme of 9 monitoring visits over 6 months is underway. The site is in an area where 3-5% of homes are estimated to be above the radon action level.
Preparatory works	Site clearance and topsoil strip. Made Ground (within the exception of Re-worked Clay) should be blinded by 300mm clean topsoil within gardens/landscaped areas.
Foundations	The vast majority of proposed dwellings will be founded on strip foundations at a minimum depth of 900mm, over-deepened where necessary due to tree influence and/or significant thicknesses of made ground. Based on the current layout, Plots 103 & 104 are likely to require trench-fill foundations of greater than 2.5m depth which will require engineering-design.
Groundwater & excavations	No significant inflows of groundwater were encountered during this investigation. Shallow excavations should remain stable during the construction phase in the short term.
Flooding & drainage	The site is located in Flood Zone 1. Soakaways will not provide a suitable means for surface water disposal at the site.
Highways	Natural soils should provide a CBR of 2.5%. Deep made ground will need replacing with suitable aggregate or re-engineering to a specification to be agreed with the adopting authority.

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03	Geotechnical testing
04	Contamination laboratory analysis & interpretation
05	Hazardous gas
06	Soakaways

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Drawing	Revision	Title
2551/1	-	Site location plan
2551/2	-	Proposed site layout
2551/3	-	Site features
2551/4	-	Site photographs
2551/5	-	Preliminary conceptual site model
2551/6	B	Exploratory hole locations
2551/7	-	Revised conceptual site model
2551/8	-	Made Ground Thicknesses

Appendix C - Commission

Appendix D - Historical OS plans

Appendix E - Search responses

From	Date	Content
Landmark	11 th May 2017	Environmental search data
Coal Authority	11 th May 2017	Mining report

Appendix F to G - Exploratory records

Appendix F	TP01 to TP16, TP101 to 107
Appendix G	WS01 to WS04, WS101 to WS114

Appendix H - Chemical test results

Appendix I - Geotechnical test results

Appendix J - Gas monitoring results

Appendix K - Soakaway Test 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.

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 only included on the accompanying 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. All 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

CARLTON ROAD, BARNSELEY

1 INTRODUCTION

1.1 The commission and brief

- 1.1.1 Lithos Consulting Limited were commissioned by Keepmoat Homes Yorkshire & Barnsley Metropolitan Borough Council to carry out a geoenvironmental appraisal of land at St Helen's Boulevard, Carlton.
- 1.1.2 This document is a revision of the Geoenvironmental Appraisal (Report 2551/1) issued by Lithos in July 2017; Report 2551/1 is now superseded. This document now includes the findings of additional investigation undertaken in the southern parcel of the site, with the only significant revisions to 2551/1 having been made from Section 6 onwards. Drawing 2551/6 has also been updated.
- 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 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 24 trial pits, 17 dynamic sample boreholes and 6 road cores
 - 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 phase of investigation were to identify salient geoenvironmental issues affecting the site to support the submission of a planning application, and also to enable Keepmoat & BMBC 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 111 no. 2 storey domestic dwellings, associated gardens, POS and adoptable roads and sewers. A site layout has been provided by Chris Gothard Architecture (Drawing reference SK01, dated May 2016) which is reproduced as Drawing 2551/2 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
 - Soakaways
- 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 2551/1 presented in Appendix B to this report. Site details are summarised in the Table below.

Detail	Remarks
Location	2.5 km north-east of Barnsley town centre
NGR	SE 358 084
Approximate area	3.2ha (7.9 acres)
Known services	Underground electric, water and gas Overhead telecom

2.2 Site features

- 2.2.1 Lithos completed a walkover survey of the site on the 1st June 2017.
- 2.2.2 The site can be divided into 3 main areas:
- a grassed field in the north of the site;
 - the former school area and playing fields; and
 - arable farmland in the south of the site.
- 2.2.3 The grassed field in the north of the site comprises a rectangular parcel of well-kept grass, sloping very gently to the east. A 3m by 3m electricity sub-station of brick construction exists in the far south-west of this area. The far east of this field is bounded by a road which runs north-south off St Helens Boulevard towards the former school area.
- 2.2.4 The former school area is separated from land to the north by a steel palisade fence. At the time of site visit, all former buildings had been demolished, and the entire area was grassed over, with minor amounts of scrub vegetation and weeds. The entirety of this area is bounded by mature trees.
- 2.2.5 The former school area is essentially a 'plateau', bounded to the north-east by a slope of about 1 in 4 down to the east. There are also steep slopes on the western boundary and southern boundary of the former school & playing fields, leading up to the adjacent land (c.1m higher), indicating that the site has been subject to some cut and fill earthworks.

- 2.2.6 The south of the site comprises two sub-areas of larger arable fields and a patch of overgrown weeds and scrub vegetation. The two larger arable fields are divided by a hardcore-surfaced track, and both slope down gently to the east.
- 2.2.7 Existing salient features, at the time of the walkover are presented on Drawing 2551/3 in Appendix B to this report and summarised in the Table below.

Feature	Remarks
Current Access	Off St Helen's Boulevard
Topography	Relatively flat with localised steep slopes in the far east, west & south of the former school & playing fields area
Approximate areas	1,100m ² tarmac hardstand 12,000m ² farmland 18,600m ² grass 300m ² hardcore surfacing
Nature of boundaries	North – St Helen's Boulevard East – palisade fence in former school area, no physical boundary in field area. South – no physical boundary West – Carlton Road in the far north, palisade fencing in former school area, hedgerows bound the arable fields
Surrounding land uses	North – Springwell Community School East – woodland and arable fields South – arable fields West – housing

- 2.2.8 A selection of site photographs is included on Drawing 2551/4.

3 SITE HISTORY

- 3.1 Site centred extracts from Ordnance Survey (OS) plans dating back to 1855 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
1855	Site comprises parts of several open fields, bounded to the north-west by St Helens Lane	Open fields
1895	No significant changes	Spring shown 200m north of the site
1931	'Urinal' shown in far north-west	No significant changes
1932	Footpath crosses the site running east-west	Housing shown immediately west of the site
1970	School & playing fields shown on site, including some slopes in the east and west of the site. Electricity sub-station shown in far north-west of the site in area of former 'urinal'	School shown immediately north of the site
2017	School no longer shown	No significant changes

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 responses received from Landmark and the Coal Authority 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 87) 1:10,000 BGS map (Sheet SE30NE) BGS Memoir/Technical Report	Drift – No drift is shown at the site, however approximately 1/3 of the site in the north-east is shown to be underlain by made ground. Solid – The majority of the site is underlain by undifferentiated Pennine Middle Coal Measures (mudstone, siltstone, sandstone). The far north-west of the site is underlain by Oaks Rock sandstone, and the far south-east of the site is underlain by an unnamed sandstone unit. The Haughton Marine Band runs across the site. Strata dip – not shown. Faults – nearest fault is the St Helen's Fault, approximately 100m north-west of the site, trending north-east south-west and downthrowing south-east.
Mining	Coal Authority	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). Shallowest Coal Seam – Newhill Coal (0.61m to 1.37m thick) at around 15m to 20m depth, outcropping approximately 300m south-west.
Radon	Public Health England	The site lies in an area where 3%-5% of homes are estimated to be above the action level. Therefore, basic radon measures will be required.
Hydrogeology	Environment Agency	Groundwater Source Protection Zone? No. Aquifer – Secondary A (Solid). Groundwater abstractions? None within 1000m of the site. Soil leaching potential – High (U).
Hydrology	Environment Agency Envirocheck Report	Nearest watercourse(s) – Unnamed watercourse 110m north-east of the site flowing north-east. Pollution incidents? None within 450m of the site. Abstractions? None within 1000m of the site. Discharge consents? None within 500m of the site.
Flood risk	Environment Agency	The site lies in Flood Zone 1, where the risk of flooding from rivers or the sea is classified as low. 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).

4.2 Coal

- 4.2.1 This site lies within a 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 A Coal Authority mining report has been obtained and is presented in Appendix E. In essence it states:
- *The property is in a surface area that could be affected by underground mining in 8 seams of coal at 70m to 400m depth, last worked in 1965. Any movement in the ground due to coal mining should have stopped.*
 - *The property is not within a surface area that could be affected by present underground mining.*
 - *The property is not in an area likely to be affected from any planned future underground coal mining.*
 - *There are no mine entries on, or within 20m of the site. However, a mine entry is present around 40m south of the site.*
- 4.2.3 Based on examination of the BGS map (SE 30 NE), the Newhill Coal is expected to underlie the site at around 15m to 20m depth, with a maximum recorded thickness within the region of 1.4m. There are no further significant seams within 40m depth of the Newhill Coal.
- 4.2.4 In addition, the geological memoir for the Barnsley area has been examined (Memoir 87). Referring to the Newhill coal, it states: *'is variable in thickness often containing several dirt partings which may be as much as 18in thick....It has been worked a little at crop....The coal does not appear to have been of sufficient value to justify mining at depth.'*
- 4.2.5 In addition, the Technical Report for the Wakefield South Area (WA/96/10) states that the Newhill has been worked, but solely by opencast methods. Although this report does not cover the area of the proposed development site, it does support the view given in the Barnsley memoir that underground mining within the Newhill Coal seam does not appear to have been worked underground.
- 4.2.6 In addition, a South Yorkshire Mining Advisory Service report relating to the site has been made available, which concludes that risks associated with mining legacy are considered 'low to negligible'.
- 4.2.7 Given the above, and the information given within the Coal Authority report, risks of underground mining within the Newhill seam appear very low, and an intrusive mining investigation is not considered necessary.

4.3 Landfills

- 4.3.1 Known or suspected areas of landfill in the vicinity of the proposed development site are summarised below:

Location	NGR (proximity to site)	Remarks	Source of data
Rotherham Road	SE 357 083 (65m south-west)	Waste includes Inert and Commercial. Date of filling- 1985 to 1986. No monitoring results or depth details available. Current land use: playing fields.	EA Landmark Report
Monk Bretton Recreation Ground	SE 360 082 (180m south-east)	Waste includes Inert, Industrial and Commercial wastes Date of filling- 1981 to 1983 No monitoring results or depth details available. Current land use: woodland.	EA Landmark Report

5 GROUND INVESTIGATION DESIGN

5.1 Anticipated ground conditions & potential issues

5.1.1 Based on the data reviewed in Section 4 (Environmental Setting), anticipated ground conditions are expected to comprise:

Anticipated condition	Remarks
Made ground	Made ground is anticipated to underlie the entire of the former school site, likely to be associated creation of a development platform. Made ground is not expected in the arable farmland (south).
Natural soils	Natural soils are likely to comprise residual soils (completely weathered bedrock), probably firm to stiff clays or clayey gravel.
Bedrock	Interbedded mudstone, sandstone and siltstone bedrock should be anticipated across the majority of the site. Oaks Rock Sandstone underlies the north-west of the site, and an unnamed sandstone underlies the far south-west of the site.
Groundwater	Perched/ isolated pockets of groundwater are likely to occur within made ground soils. True groundwater is likely to be at depth within bedrock, and therefore unlikely to be encountered.

5.1.2 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. Former oil-fired heating systems (if present) 2. On-site made ground	1. Organic contamination (spillage/leakage) 2. Inorganic, organic and hazardous gas contamination is all possible from on-site made ground.
Potential off-site contamination sources	1. Landfills to the south	1. Generation & migration of hazardous gas
Potential geotechnical hazards	1. Relict buried obstructions 2. Deep made ground 3. Localised steep slopes	1. Former foundations, floor slabs, service ducts etc associated with former buildings. 2. May preclude shallow foundations 3. Layout will have to accommodate accordingly
Other potential constraints	1. None identified	

5.2 Preliminary conceptual site model

5.2.1 A preliminary conceptual site model, presented as Drawing 2551/5 in Appendix B, has been prepared after consideration of all the data presented in Sections 2 to 5.1 inclusive of this report.

5.2.2 An assessment of potential contaminants associated with the former uses has been undertaken with reference to CLR8. As a consequence of this assessment, anticipated potential contaminants, within soil and/or groundwater include:

- Inorganics – heavy metals and asbestos may be present in made ground soils.
- Organics – PAHs may be present in made ground soils due to coal fragments, tarmac fragments, ash etc. TPH contamination may be present if the site was historically heated by an oil-fired system or similar.
- Hazardous gas – the site may be affected by hazardous gas as there are two landfills within 250m of the site, and made ground (of uncertain nature and thickness) is believed to underlie much of the north-east.

5.3 Ground investigation design & strategy

5.3.1 The preliminary conceptual site model was used as a basis for design of an appropriate ground investigation, the scope of which is summarised below.

Exploratory holes	Purpose
Around 20 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 eg biodegradable matter, foundations etc - Suitability of the ground for founding structures and highways
5 trial pits	To determine whether soakaways could be utilised for storm water drainage
8 dynamic sample boreholes	To allow installation of gas monitoring wells

5.3.2 Proposed exploratory hole locations were selected to provide a representative view of the strata beneath the site. A nominal 30m grid spacing was proposed in the former school area, and a 40m grid spacing proposed in the arable farmland. Additional exploratory locations might be scheduled by the site engineer in light of the ground conditions actually encountered.

5.3.3 The number of representative samples taken will be reflective of the geological complexity actually encountered.

6 FIELDWORK

6.1 Objectives

6.1.1 The original investigation strategy is outlined in Section 5.3 above. The south of the site has now been subject to an intrusive ground investigation and so the remaining sections of this report refer to ground conditions encountered across the whole site.

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

Exploratory holes	Purpose
WSs101 to 109	To enable better understanding of the depth and distribution of made ground.

6.2 Scope of works

6.2.1 Field work was undertaken in two phases; Phase 1 of the fieldwork was supervised by Lithos on the 1st and 6th of June 2017 and Phase 2 on the 4th/5th and 17th of January 2018. The exploratory holes are listed below:

Technique	Phase	Exploratory holes	Final depth(s)	Remarks
Trial pitting (machine dug)	1	TPs 01 to 12	1.4m to 3.3m	Hand vane tests in cohesive soils
		TPs 101 to 103	1.7m to 2.5m	Soakaway tests undertaken
	2	TPs 13 to 16	2.2m to 3.0m	Hand vane tests in cohesive soils
		TPs 104 to 107	2.5m to 3.0m	Soakaway tests undertaken
Dynamic sample boreholes	1	WSs 01 to 05	1.6m to 3.1m	Monitoring wells installed
		WSs 101 to 109	0.9m to 2.8m	SPTs typically performed at 1.0m and 2.0m
	2	WSs 111 to 114	2.0m to 3.0m	Monitoring wells installed
Road Cores	2	BHs 01 to 06	0.9m	Road cores photographed

- 6.2.2 Notes describing ground investigation techniques, in-situ testing and sampling are included in Appendix A to this report.
- 6.2.3 Exploratory hole logs are presented in Appendices F & G 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
- 6.2.4 Exploratory hole locations are shown on Drawing 2551/6 Rev B presented in Appendix B. It should be noted that WS110 was not advanced.

7 GROUND CONDITIONS

7.1 General

- 7.1.1 A complete record of strata encountered beneath the proposed development site is given on the various exploratory hole records, presented in Appendices F and G.
- 7.1.2 The site can be split into two main areas based on ground conditions. These areas are shown on Drawing 2551/6B and are summarised below:
- Area A – Former school in north (c. 2.01ha)
 - Area B – Arable farmland in the south (c. 1.31ha)
- 7.1.3 In addition, road cores were undertaken within the footprint of St Helen's Boulevard, immediately north of Area A.
- 7.1.4 Typical ground conditions encountered at the site are described below in Sections 7.2 (road cores, 7.3 (made ground) and 7.5 (natural ground), with a summary provided in the Table on pages 11 & 12.

7.2 Road Cores

- 7.2.1 Six road cores were taken along St. Helen's Boulevard in the north of the site in order to determine the properties of the road materials. All six boreholes were advanced to natural ground and were relatively similar in properties and thicknesses. A summary of the strata encountered is given below:
- **Surface Course:** black macadam comprising approximately 60% to 70% aggregate of angular to sub-angular fine to medium gravel, 50mm to 100mm thick.
 - **Base Course:** Black macadam comprising 70% to 80% aggregate of angular to sub-angular fine to coarse chalk gravel, encountered in 4 of the cores, between 50mm and 100mm thick.
 - **Sub-Base:** Varied between a black angular to sub-angular fine to coarse gravel of sandstone and white-yellow sandy angular to sub-angular fine to coarse gravel of chalk and limestone. Encountered in the majority of cores to between 0.3m and 0.65m depth.
 - **Granular Made Ground:** Encountered in BHs 05 and 06 only, to depths of 0.5m and 0.6m respectively comprising gravel of brick, tarmac, burnt shale and chalk.

7.3 Made ground

- 7.3.1 Made ground at the site is confined to Area A (former school) and is distributed in a relatively simple pattern, with reworked clays thickening towards the north-east of the site, representing historic earthworks (to create level development platforms & play areas), and other made ground types generally being restricted to the area around the former school buildings.
- 7.3.2 The bulk of the made ground can be categorised as one of 7 broad types:
- **Made Ground Topsoil:** A topsoil with much anthropogenic material (predominantly gravel of brick and concrete, with some glass) was encountered in the north in TPs 03 to 06, 08 and WS03.
 - **Demolition Rubble:** A gravel of brick, concrete, wood and rare clinker was encountered in TP07 to a depth of 0.8m.
 - **Burnt Red Shale:** A red sandy angular gravel was encountered in WSs 03 and 106 in the north-east of the site. This material was in layers 100mm to 200mm thick.
 - **Reworked Clay:** A firm to stiff (locally soft) slightly gravelly clay underlies the north-east of the site. Gravels are typically of natural origin, with occasional brick. This material was thickest in the north-east of the site (maximum thickness of 2.9m, TP06) and likely represents historical earthworks.
 - **Relict Topsoil:** A grey sandy clay was locally encountered beneath Reworked Clay. This material was encountered at a minimum depth of 1.3m to a maximum depth of 2.4m, and was a maximum of 300mm thick. This material probably represents original ground levels, pre-earthworks.
 - **Sub-Base:** A 300mm thick layer of yellow sandy fine to coarse gravel of limestone was encountered in TP03.
 - **Granular Made Ground:** A clayey, cobbly gravel of brick, concrete and glass was encountered in TP05 to 0.8m depth.
- 7.3.3 Review of the exploratory logs suggest made ground thicknesses beneath Area A vary between 0m and 2.9m; average 1.5m. The thickest made ground (TP06) was encountered in the north-east, where ground has apparently been filled to create a development plateau for the former school. The approximate distribution of made ground is shown on Drawing 2551/8.

7.4 Obstructions

- 7.4.1 It is apparent from a review of historical OS Plans (see Section 3) that buildings have been present on about 5% of the site area.
- 7.4.2 To date, no significant obstructions have been encountered within the vicinity of the former school buildings, however some obstructions may still be present.
- 7.4.3 Reference should be made to the demolition Specification and/or Completion Report to confirm that the recently completed works included for removal of relict foundations.

7.5 Natural ground

7.5.1 Natural ground was encountered in all exploratory holes, and typically comprised:

- **Topsoil:** a dark brown to grey sandy clayey topsoil was encountered across the majority of the site to a typical depth of about 300mm.
- **Cohesive Residual Soil:** a light brown to orange slightly sandy clay of stiff consistency was encountered across the majority of the site. This in turn was typically underlain by a black gravelly clay, also of stiff consistency. This black clay had much gravel of carbonaceous mudstone and rare coal, locally absent in TP12 and WS 105 and 107.
- **Granular Residual Soil:** A grey or orange sandy/clayey, gravel of sandstone/mudstone was encountered more sporadically than cohesive residual soils, in TPs 01, 02, 12, 14, 16, 103, 104, 106 & 107, WSs 05 and 105.
- **Bedrock:** Pennine Middle Coal Measures bedrock was encountered in the majority of locations at depths of between 1.4m and 3.1m (average 1.8m) and typically comprised very thinly bedded sandstone in Area A, with mudstone bedrock more common in Area B.

7.6 Visual & olfactory evidence of organic contamination

7.6.1 No visual or olfactory evidence of organic contamination was recorded in any exploratory holes.

7.7 Groundwater

7.7.1 No significant inflows of groundwater were encountered during the investigation.

7.7.2 Groundwater levels within the boreholes in Area A have been monitored on 8 occasions to date, between June and December 2017; results are summarised below:

Hole ID	Response zone (depth range & strata)	Groundwater body	Range of standing water levels
			m bgl
WS01	0.7m – 1.8m (Residual Soils and bedrock)	N/A	Dry to 1.71
WS02	0.5m – 1.6m (Residual Soils)		Dry to 1.63
WS03	0.9m – 2.3m (Reworked clay and relict topsoil)		Dry to 1.53
WS04	0.4m – 0.9m (Reworked clay)		None detected
WS05	0.9m – 2.0m (Residual soils)		Dry to 1.99

7.8 Stability

7.8.1 Stability of excavations within natural ground soils and made ground was generally good, although locally some spalling occurred when excavating through the Re-worked Clay.

Summary of Ground Conditions

Hole ID	Final depth (m)	Depth to Base of Made Ground (m)	Depth to Base of (m)											Bedrock	
			Made Ground						Natural Soils						
			Made Ground Topsoil	Demolition Rubble	Burnt Red Shale	Reworked Clay	Sub-Base/ Granular Made Ground	Relict Topsoil	Topsoil	Cohesive Residual Soil	Granular Residual Soil	Weathered Bedrock	Unnamed Sandstone	Depth to Rockhead (m)	Bedrock Type
TP01	1.4							0.3	1.0	1.4			1.4	Sandstone	
TP02	1.5							0.3	1.4	1.9			1.9	Sandstone	
TP03	1.7	0.6	0.3				0.6		1.6				1.6	Sandstone	
TP04	1.9	0.4	0.4						1.7				1.7	Sandstone	
TP05	2.7	2.3	0.3			2.0	0.8	2.3		>2.7				-	
TP06	3.3	2.9	0.4			2.9				>3.3				-	
TP07	1.6	0.8		0.8					1.5				1.5	Siltstone	
TP08	2.3	1.6	0.4			1.3		1.6		>2.3				-	
TP09	2.1							0.3	1.8				1.8	Sandstone	
TP10	1.8							0.3	1.6				1.6	Mudstone	
TP11	2.1							0.6	2.0				2.0	Sandstone	
TP12	1.4							0.3		1.2			1.2	Mudstone	
TP13	3.2							0.3	2.4				2.4	Mudstone	
TP14	3.0							0.3	1.9		2.4		2.4	Mudstone	
TP15	3.0							0.3	2.0	2.0			2.0	Mudstone	
TP16	2.2							0.3	1.6		>2.2	2.0		-	
TP101	2.1							0.4	1.9				1.9	Sandstone	
TP102	2.5	1.6				1.3		1.6	0.3	>2.5				-	
TP103	1.7							0.3	0.6	1.5			1.5	Sandstone	
TP104	2.5							0.2	1.5		2.2		2.2	Mudstone	
TP105	2.8							0.3	2.5				2.5	Mudstone	
TP106	2.5							0.3	1.6		2.0		2.0	Mudstone	
TP107	3.0							0.3	1.1	2.8		1.5	2.8	Mudstone	

Hole ID	Final depth (m)	Depth to Base of Made Ground (m)	Depth to Base of (m)											Bedrock	
			Made Ground						Natural Soils						
			Made Ground Topsoil	Demolition Rubble	Burnt Red Shale	Reworked Clay	Sub-Base/ Granular Made Ground	Relict Topsoil	Topsoil	Cohesive Residual Soil	Granular Residual Soil	Weathered Bedrock	Unnamed Sandstone	Depth to Rockhead (m)	Bedrock Type
WS01	1.8								0.3	1.7				1.7	Sandstone
WS02	1.6								0.3	1.6				1.6	Sandstone
WS03	3.1	2.4	0.3		0.4	2.1		2.4		3.1				3.1	Sandstone
WS04	1.7	0.9				0.9			0.3	1.6				1.6	Sandstone
WS05	2.0								0.3	1.6	2.0			2.0	Sandstone
WS101	1.5								0.2	1.4				1.4	Sandstone
WS102	1.0								0.3	0.9				0.9	Sandstone
WS103	1.7	0.9				0.9			0.4	1.6				1.6	Sandstone
WS104	2.5	1.8				1.8			0.3	2.3				2.3	Sandstone
WS105	2.5	2.2				2.2			0.2		2.4			2.4	Sandstone
WS106	2.8	2.1	0.2		0.4	2.1				2.7				2.7	Sandstone
WS107	0.9	>0.9				>0.9			0.2						-
WS108	1.8	1.4				1.4			0.2	1.6				1.6	Sandstone
WS109	1.8	1.2				1.2			0.2	1.7				1.7	Sandstone
WS111	2.2								0.2	1.6				1.6	Sandstone
WS112	3.0								0.3	2.7				2.7	Mudstone
WS113	2.0								0.3	1.5				1.5	Mudstone
WS114	2.0								0.4	>2.0					-

8 SOAKAWAY TEST RESULTS

8.1 UK Guidance

- 8.1.1 General notes about soakaways, including their location, design, and Lithos' test methodology are presented in Appendix A.
- 8.1.2 UK guidance does not explicitly state that soakaways cannot be constructed in made ground, but such construction is not generally considered good practice. There may be a risk of settlement caused by wash out of fine soil particles if soakaway waters are allowed to infiltrate into made ground.
- 8.1.3 CIRIA C753:2015¹ recommends that soakaways should not be constructed 'in ground where the water table reaches a level within 1m below the base of the soakaway at any time of the year'.

8.2 Field tests

- 8.2.1 Seven soakaway tests were carried out in general accordance with BRE Digest 365² "Soakaway Design". The locations of the soakaways are shown on Drawing 2551/6 presented in Appendix B to this report.
- 8.2.2 Where the water level did not fall to 25% effective depth within 4 hours, the test was not considered suitable for calculation of an infiltration rate; this was the case for all tests performed. Copies of the test results are included within Appendix K.

8.3 Discussion & conclusions

- 8.3.1 Soakaways are generally only considered likely to provide a suitable drainage solution for the discharge of surface water run-off where vast majority of tests yield reasonable infiltration rates, which is clearly not the case on this site.
- 8.3.2 Consequently, soakaways will not provide a suitable drainage solution for the discharge of surface water run-off at the site and therefore there may be a need for surface water balancing.

¹ CIRIA C753. The SUDS Manual (2015).

² BRE Digest 365. Soakaway Design (1991).

9 CONTAMINATION (ANALYSIS)

9.1 General

- 9.1.1 The site has been formerly used as a school.
- 9.1.2 The site's former usage may have given rise to some ground contamination, and significant thicknesses of made ground were encountered in many of the exploratory locations, albeit generally comprising re-worked natural soils.
- 9.1.3 An assessment of potential contaminants associated with the former uses has been undertaken; see Section 5.2.
- 9.1.4 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.
- 9.1.5 Where available, Category 4 Screening Levels (C4SL) have also been referenced.
- 9.1.6 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.

Type of sample	No. of samples	Determinands
Made ground	16	pH, water soluble boron, and total metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc) & Asbestos ID TOC, Speciated Polycyclic Aromatic Hydrocarbons (PAH)
	11	Banded Total Petroleum Hydrocarbons (TPH)
	10	Water soluble sulphate
	2	Calorific Value (CV)
Topsoil	11	pH, water soluble boron, and total metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc) & Asbestos ID TOC, Speciated Polycyclic Aromatic Hydrocarbons (PAH)

9.3 Soil contamination results

- 9.3.1 The soil contamination test results are summarised in the Tables on pages 16 to 19.
- 9.3.2 Laboratory test certificates as received from the laboratory are presented in Appendix H to this report.

Inorganic determinands

- 9.3.3 Of the 27 samples of made ground and topsoil analysed for inorganic parameters, 26 can be classified as uncontaminated and one could be classified as contaminated.
- 9.3.4 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).
- 9.3.5 The contaminant of concern is zinc, with a value of 670 mg/kg recorded in TP05 in Made Ground Topsoil.

- 9.3.6 Zinc is a phytotoxic metal; phytotoxicity describes the inhibitive and toxic effect high concentrations of some substances can have on plant growth.
- 9.3.7 Most substances are harmful to human health at lower concentrations than would be detrimental to plant growth. However, there are three notable exceptions - boron, copper and zinc. Plants are the more sensitive receptor to these elements i.e. detrimental effects are seen in plants at concentrations which do not present a risk to human health. Consequently, for zinc, consideration and protection of flora would also be protective of human health.
- 9.3.8 Allowable concentrations of heavy metals in arable soils are set out in Defra's Code of Good Agricultural Practice 2009. The value for zinc is 200mg/kg, and is based on a continued annual application of heavy metal rich fertiliser (sludge); as such it is not representative of activity in a standard UK garden.
- 9.3.9 Lithos have also derived a value for zinc in relation to risks to human health, using the CLEA model, assuming a residential end use with consumption of home grown produce in a sandy loam soil with 6% SOM. The reported value is 2,170mg/kg, ten times greater than the potential phytotoxic concentration.
- 9.3.10 Furthermore, the log for TP05 indicates the presence of anthropogenic materials within the topsoil (brick, concrete and glass). The concentration of zinc within this sample does not fit within the typical range of results for this stratum (or indeed in any of the made ground). It is quite likely that it is associated with a fragment of foreign matter, and is therefore of limited significance.
- 9.3.11 On balance, given the context of a residential development and the relatively low concentrations recorded, zinc is not considered significant and no special remedial measures are considered necessary.

Calorific value

- 9.3.12 The calorific value of two samples of Burnt Red Shale both yielded CVs of <1.0 MJ/kg. Materials whose CVs exceed 10MJ/kg are almost certainly combustible, while those with values below 2MJ/kg are unlikely to burn. As such, this material is not considered potentially combustible.

Asbestos

- 9.3.13 No asbestos fibres were identified in any of the 27 samples screened.

Summary of degree of soils contamination - Inorganics

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	Zn\$	CV	Asbestos
				37	5	26	3000	200	200	169	127	350	200	2	
TP03	0.1	Made Ground Topsoil	9.9	9.3	0.7	1.2	33	50	170	0.15	16	< 0.5	170		N.D.
TP04	0.2	Made Ground Topsoil	11.1	9	0.9	0.4	65	45	66	0.11	18	1.3	83		N.D.
TP05	0.1	Made Ground Topsoil	10.5	12	0.3	0.4	22	36	23	0.11	20	< 0.5	670		N.D.
TP06	0.2	Made Ground Topsoil	7.8	13	0.7	0.6	24	33	45	0.12	18	0.9	86		N.D.
TP08	0.2	Made Ground Topsoil	9.5	9.7	< 0.2	0.3	20	31	36	0.08	12	0.6	71		N.D.
TP107	0.1	Made Ground Topsoil	7.6	17	1	0.2	15	22	46	0.13	9.8	<0.5	49		N.D.
TP01	0.1	Topsoil	6.8	18	0.4	0.3	25	29	45	< 0.05	22	1	88		N.D.
TP09	0.1	Topsoil	6.4	16	0.3	0.2	19	26	45	0.13	16	0.7	67		N.D.
TP10	0.1	Topsoil	6.3	17	< 0.2	0.3	25	31	54	0.12	22	1	85		N.D.
TP101	0.1	Topsoil	6.4	15	0.3	0.3	23	30	48	0.08	20	< 0.5	87		N.D.
TP102	0.1	Topsoil	6.8	15	0.2	0.3	21	32	33	0.08	27	0.9	75		N.D.
TP11	0.1	Topsoil	6.9	15	< 0.2	0.3	27	27	42	0.11	21	1	110		N.D.
TP104	0.1	Topsoil	6.6	20	1.3	0.3	13	32	54	0.08	9.6	< 0.5	54		N.D.
TP105	0.1	Topsoil	7.4	16	0.9	0.2	10	21	45	0.16	8.6	< 0.5	41		N.D.
TP106	0.1	Topsoil	7.3	15	1.2	0.2	11	24	43	0.14	7.5	< 0.5	35		N.D.
TP15	0.1	Topsoil	7.4	12	1	0.2	9.1	19	33	0.09	6.6	< 0.5	33		N.D.
TP16	0.1	Topsoil	7.3	18	1	0.2	14	35	51	0.11	12	0.9	55		N.D.
TP05	2.1	Relict Topsoil	6.9	20	1	0.2	25	38	16	0.13	40	< 0.5	89		N.D.
TP102	1.5	Relict Topsoil	7.1	20	0.8	0.2	25	31	45	0.09	20	1	78		N.D.
WS03	0.35	Burnt Red Shale	7.8	6.8	1.2	< 0.1	17	18	16	< 0.05	19	< 0.5	27	<1.0	N.D.

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	Zn\$	CV	Asbestos
				37	5	26	3000	200	200	169	127	350	200	2	
WS106	0.35	Burnt Red Shale	7.6	8.5	1	0.2	20	29	23	< 0.05	24	< 0.5	56	<1.0	N.D.
TP03	0.4	Sub-Base	8.7	1.9	< 0.2	0.5	4.3	7.1	7.2	< 0.05	1.9	< 0.5	45		N.D.
TP07	0.3	Demolition Rubble	10.2	8	0.6	0.3	24	33	140	0.08	14	< 0.5	110		N.D.
TP05	0.4	Granular Made Ground	8.8	11	0.5	0.9	38	120	160	0.1	20	0.8	92		N.D.
TP05	1.0	Reworked Clay	5.4	7.5	0.9	< 0.1	24	30	22	0.07	23	< 0.5	52		N.D.
TP06	0.6	Reworked Clay	6.0	13	0.2	< 0.1	21	27	27	0.09	25	< 0.5	62		N.D.
TP08	0.6	Reworked Clay	6.6	4.7	< 0.2	0.1	25	27	17	0.08	30	< 0.5	64		N.D.

Key		Source of Guidance Trigger Level	
36	Parameter tested for and found to be in excess of Tier 1 concentration	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. Values assume contaminants located in a sandy loam, with 6% soil organic matter (SOM).	
179	Parameter tested for and found to be > 5 x Tier 1 concentration		
12	Parameter tested for but not found to be in excess of Tier 1 concentration	∞	Category 4 Screening Level – SP1010, December 2013 (CL:AIRE\Defra)
	Parameter not tested for	\$	Ministry of Agriculture, Fisheries & Food. Code of Practice for Agricultural Practice for the Protection of Soil. 1998
♣	Tier 1 Value is pH dependent	~	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.
x	Assumes Cr is CrIII. If demonstrated Cr is CrVI screen would be 21mg/kg		
*	Assumes mercury present as an inorganic compound (cf elemental metal or within organic compound). See Science Report SC050021/Mercury SGV.	N.D.	Not detected, applicable to asbestos I.D. screen only

Summary of degree of soils contamination - Organics

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) end use					
			% TOC	PAH		TPH - C6 to C40		
				B(a)P ∞	Naphthalene	GRO~ C ₆ to C ₁₀	DRO∅ C ₁₀ to C ₂₁	LRO C ₂₁ to C ₄₀
				5	8	30	151	1000
TP03	0.1	Made Ground Topsoil	3.9	0.9	0.05			
TP04	0.2	Made Ground Topsoil	1.9	1.0	0.07	< 0.1	41	255
TP05	0.1	Made Ground Topsoil	1.9	0.54	0.03	< 0.1	140	370
TP06	0.2	Made Ground Topsoil	4.6	0.8	0.04			
TP08	0.2	Made Ground Topsoil	1.5	1.1	0.06	< 0.1	28	233
TP03	0.4	Sub-Base	< 0.1	< 0.03	< 0.03	< 0.1	<10	<10
TP01	0.1	Topsoil	2.1	< 0.03	< 0.03			
TP09	0.1	Topsoil	2.7	0.06	< 0.03			
TP10	0.1	Topsoil	2.9	< 0.03	< 0.03			
TP101	0.1	Topsoil	3.6	< 0.03	< 0.03			
TP102	0.1	Topsoil	2.0	< 0.03	< 0.03			
TP11	0.1	Topsoil	2.1	< 0.03	< 0.03			
TP104	0.1	Topsoil	6.8	0.13	<0.03			
TP105	0.1	Topsoil	3.2	<0.03	<0.03			
TP106	0.1	Topsoil	3.0	<0.03	<0.03			
TP107	0.1	Topsoil	2.6	0.04	<0.03			
TP15	0.1	Topsoil	3.2	<0.03	<0.03			
TP16	0.1	Topsoil	3.5	<0.03	<0.03			

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) end use					
			% TOC	PAH		TPH - C ₆ to C ₄₀		
				B(a)P ∞	Naphthalene	GRO~ C ₆ to C ₁₀	DRO◇ C ₁₀ to C ₂₁	LRO C ₂₁ to C ₄₀
				5	8	30	151	1000
TP05	2.1	Relict Topsoil	1.1	< 0.03	< 0.03	< 0.1	<10	<10
TP102	1.5	Relict Topsoil	3.9	< 0.03	< 0.03	< 0.1	<10	43
TP05	1.0	Reworked Clay	1.0	< 0.03	< 0.03	< 0.1	<10	<10
TP06	0.6	Reworked Clay	1.3	< 0.03	< 0.03			
TP08	0.6	Reworked Clay	1.0	< 0.03	< 0.03	< 0.1	<10	<10
WS03	0.35	Burnt Red Shale	0.1	0.18	< 0.03			
WS106	0.35	Burnt Red Shale	0.4	0.08	< 0.03	< 0.1	<10	<10
TP07	0.3	Demolition Rubble	1.9	0.51	< 0.03	< 0.1	99	439
TP05	0.4	Granular Made Ground	1.8	0.09	< 0.03	< 0.1	66	168

Key		Source of Guidance Trigger Level	
0.3	Parameter tested for but not in excess of Tier 1 concentration	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). Assumes no soil cover , see Generic Notes 04 in Appendix A.	
60	Parameter tested for and 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
		∞	Category 4 Screening Level – SP1010, December 2013 (CL:AIRE\Defra)

Organic determinands

- 9.3.14 Area A is classed as brownfield and underlain by made ground, however no visual/olfactory evidence of significant contamination was noted, and the majority of the made ground appears to be re-worked natural soils. Area B is essentially greenfield, therefore, for organic compounds, the Tier 1 Screening Values used in this report assume no clean soil cover placed in gardens and landscaped areas (Lithos Scenario A).
- 9.3.15 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.
- 9.3.16 Sample results have been classified by comparison with these Tier 1 Soil Screening Values. 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.
- 9.3.17 In order to check the validity of 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 with revised screening value necessary?
Demolition Rubble	3.9	No
Topsoil	3.1	
Burnt Red Shale	1.8	Yes, but no significant organic contamination was recorded in this soil type. All determinands well below "6%" screening value; most below limit of detection.
Granular Made Ground	1.9	
Made Ground Topsoil	2.8	
Relict Topsoil	1.0	
Reworked Clay	1.0	
Sub-Base	2.7	

Hydrocarbons (TPH & PAH)

- 9.3.18 Given the previous uses of the site and absence of visual/olfactory evidence of any hydrocarbon contamination, only a simple banded TPH (cf full speciation) was initially scheduled on 11 samples.
- 9.3.19 Assessment of TPH would normally be undertaken in accordance with a 3-step approach, (outlined in Generic Note 04 in Appendix A) on fully speciated TPH results. However, although only banded TPH analysis was scheduled here, none of the fractions exceed their respective Tier 1 criteria, even if it is conservatively assumed all of each fraction is either aliphatic or aromatic.
- 9.3.20 Consequently, no significant petroleum hydrocarbon concentrations have been identified, and there is no risk to human health from these hydrocarbons.

Polycyclic Aromatic Hydrocarbons (PAH)

- 9.3.21 There are numerous PAH compounds. The USEPA identified 16 PAHs that are considered to represent the most problematic in terms of toxicology, fate and behaviour. The UK have also focused on these 16 and these are included in the laboratory report where speciated PAH analysis has been scheduled.
- 9.3.22 Speciated PAH analysis has been undertaken in order to determine concentrations of the key "marker" compounds: benzo(a)pyrene (considered the most toxic of the PAHs); and naphthalene (the most mobile and volatile of the PAHs).

- 9.3.23 Speciated analysis has confirmed the absence of significant concentrations of both benzo(a)pyrene and naphthalene in the soils beneath this site.

10 CONTAMINATION (QUALITATIVE RISK ASSESSMENT)

10.1 Summary of significant contamination

- 10.1.1 Topsoil, typically 300mm thick is present beyond the area of former school buildings. Testing suggests this material is chemically suitable for re-use.
- 10.1.2 Given the nature of the topsoil present on this site it would be expected to be suitable to support plant growth. However, no testing in accordance with BS3882:2015 Specification for Topsoil (N-P-K, clay content etc) has been undertaken to date.
- 10.1.3 Made Ground Topsoil, whilst chemically suitable for re-use, contains significant amounts of unsuitable material (brick, concrete, glass) and is therefore not considered suitable for re-use as near-surface material in garden areas.

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 2551/7 in Appendix B.

10.3 Potential remediation options

- 10.3.1 No significant remediation works are anticipated. However, where made ground (with the exception of Re-worked Clay) remains within the footprint of proposed gardens/soft landscaped areas, a 300mm thickness of 'clean' topsoil should be placed in order to 'blind' any undesirable materials (eg, glass, brick, concrete) from future end-users.
- 10.3.2 It is also recommended that Made Ground Topsoil be 'blinded' by at least 300mm of 'clean' topsoil where present in garden/landscaped areas.
- 10.3.3 Engineering supervision is recommended when stripping the Topsoil in order to enable segregation of the Made Ground Topsoil (within footprint of former school buildings) from the 'clean' Topsoil to ensure that the two material types are stockpiled separately and are not 'mixed'.

10.4 Waste classification

- 10.4.1 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.
- 10.4.2 It should be noted that the classification and assessment of waste soils under the Environment Agency's Technical Guidance WM3³, is a complex process.

³ Technical Guidance WM3 – Guidance on the classification and assessment of waste. Environment Agency 2015

- 10.4.3 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 (eg WAC) is required.
- 10.4.4 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.
- 10.4.5 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.
- 10.4.6 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%).
- 10.4.7 Contractors exporting waste from the site should be asked to review the site investigation data and make their own assessment. Alternatively, Lithos could undertake this assessment once exported waste streams have been identified.

10.5 Summary of potential pollutant linkages & mitigation

- 10.5.1 In terms of the proposed redevelopment plausible pollutant linkages, and feasible remediation options, can be summarised as follows:

Receptors	Pathways	Contaminants	Remediation options
Human health (Future residents) ◇	N/A	Anthropogenic materials (brick, glass, concrete) within the made ground (except re-worked clay). Undesirable at surface in gardens but no elevated contaminants.	'Blinding' with at least 300mm of clean topsoil in gardens/landscaped areas
Buildings	Migration & accumulation of explosive gas	Methane / carbon dioxide migration from landfills and potential for gas in made ground.	To be assessed on completion of monitoring and gas risk assessment
	Contact with "aggressive" soil and/or groundwater	Sulphate in the made ground.	Design sulphate class DS-1 or DS2, ACEC classification of AC-3z for sub-surface concrete

◇ 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.

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	Very Low: made ground essentially inert, with little degradable matter
	Buildings	Explosion		
Off-site landfills (Rotherham Road & Monk Bretton Recreation Ground)	Human health	Asphyxiation & explosion	Lateral migration, ingress & accumulation	Low: natural strata to at least 2m depth are generally of low permeability
	Buildings	Explosion		

11.1.2 Given the above gas monitoring wells have been installed in 9 boreholes across the site. Monitoring wells within Area A were installed in June 2017, whilst those in Area B were installed in January 2018. Details of the installations are given on the Dynamic Sample borehole logs presented in Appendix G 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, 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 in Area A have been monitored on 8 occasions for groundwater levels and soils-gases, and the results are presented in Appendix J. 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)

11.3 Monitoring results

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

Well	Response zone	Range of methane concentrations (% v/v)	Range of carbon dioxide concentrations (% v/v)	Range of steady flow rates (litre/hour)
WS01	0.7m – 1.8m (Residual Soils & bedrock)	0.0	0.8 - 2.2	0.0
WS02	0.5m – 1.6m (Residual Soils)	0.0	0.9 - 1.9	0.0
WS03	0.9m – 2.3m (Reworked clay & relict topsoil)	0.0	1.5 - 4.0	0.0
WS04	0.4m – 0.9m (Reworked clay)	0.0	2.0 - 5.1	0.0
WS05	0.9m – 2.0m (Residual soils)	0.0	0.5 - 0.8	0.0

- 11.3.2 Monitoring within the northern parcel is almost complete, and a gas risk assessment for this area will be issued in March 2018. Monitoring within the south of the site (arable farmland) should be completed by October 2018.

11.4 Radon

- 11.4.1 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. At present Approved Document C advocates basic measures for the probability banding 3% to 10% (full measures if >10%).
- 11.4.2 The site is in an area where 3-5% of homes are estimated to be above the radon action level, therefore basic protection measures will be required.

12 GEOTECHNICAL TESTING

12.1 General

- 12.1.1 A total of 25 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 I to this report.

12.2 Atterberg limits

- 12.2.1 The plasticity indices of 9 samples of cohesive soil have been determined; results are summarised below.

Soil type	Moisture content range (average)	Range of Plasticity Indices* (average)	Shrinkability
Cohesive Residual Soil	18 - 32 (24)	Non-Plastic - 52 (30)	Medium

* 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 A single sample recorded a result of High Shrinkability (52). This is significantly higher than the other values and is likely an erroneous result. The remaining results were all within the range of 21 to 33 (medium shrinkability).
- 12.2.3 For the purposes of foundation design, it is recommended that all cohesive soils be regarded as being of medium shrinkability.

12.3 Soluble sulphate and pH

- 12.3.1 In accordance with BRE Special Digest 1:2005, this site has been classified as brownfield with a mobile groundwater regime.
- 12.3.2 It is envisaged foundations will extend to depths of about 1m to 3m 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).
- 12.3.3 The concentrations of sulphate in the aqueous natural soil extracts of 11 samples were determined. In addition, 10 samples of made ground were tested as part of the contamination suite. The pH value of each sample has also been determined.

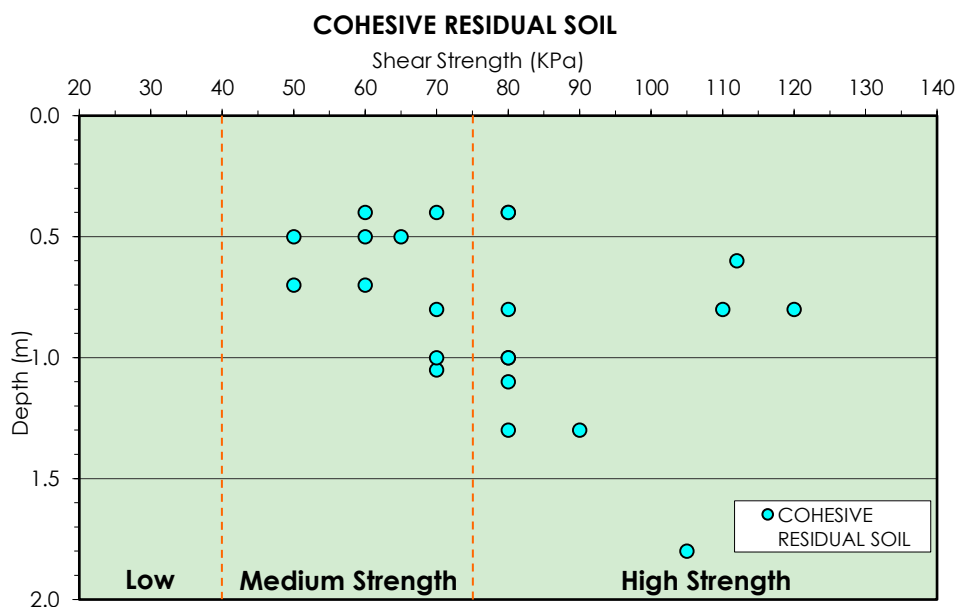
- 12.3.4 The highest water-soluble sulphate concentration and the lowest pH value for each soil type analysed are shown in the table below.

Soil type	Lowest pH values	Highest soluble sulphate concentration (mg/l)
Cohesive Residual Soil	5.4	1,000
Granular Residual Soil	5.8	82
Bedrock	6.4	36
Made Ground	5.4	380

- 12.3.5 Only 2 of 11 samples of natural soils/rock and only 1 of 8 samples of Made Ground tested yielded pHs of <5.5 (both 5.4). Therefore, in accordance with BRE Special Digest 1:2005, concentrations of chloride and nitrate are considered insignificant.
- 12.3.6 In accordance with Tables C1 and C2 of SD1, sub-surface concrete in contact with natural ground should be Design Sulphate Class DS-2, with an ACEC Classification of AC-3z, this could be revised to DS-1, AC-3z through made ground strata.

12.4 Hand shear vane testing

- 12.4.1 Hand shear vane testing was undertaken within trial pits in-situ to around 1.2m depth and from larger blocks of excavated clay below that depth. Where possible, testing was also carried out on 'cores' of clay recovered during dynamic sampling.
- 12.4.2 It should be noted that the clay was sometimes too friable/stiff to allow use of the hand vane.
- 12.4.3 The results are summarised within the plot below and broadly illustrate a linear increase in undrained shear strength (S_u) with depth within the glacial clay deposits. Below approximately 0.5m depth S_u is typically greater than 60kPa, the lowest reading recorded was 50kPa (medium strength).
- 12.4.4 The plot below provides a summary of undrained shear strengths.



13 GEOTECHNICAL ISSUES

13.1 Conceptual site model

- 13.1.1 The majority of the site is underlain by 1m to 2m of residual soil (stiff clay) with bedrock typically encountered from 2.0m to 2.5m.
- 13.1.2 Made ground encountered is essentially restricted to an area of approximately 7,200m² as shown on Drawing 2551/8 in Appendix B to this report. The thickest made ground encountered typically comprised reworked natural clays, which looks to have been placed to create the level development platforms/play areas. Other made ground types were restricted to within the footprint of former school buildings.

13.2 Mining & quarrying

- 13.2.1 This site is located within a Coal Mining Development Low Risk Area.
- 13.2.2 The site is predominantly underlain by undifferentiated Pennine Middle Coal Measures bedrock, with the far north-west of the site underlain by Oaks Rock sandstone. The shallowest coal seam is the Newhill Coal, which BGS maps suggest is 0.67m to 1.37m thick at around 15m to 20m depth.
- 13.2.3 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.
- 13.2.4 There are no known quarries on, or within 50m of the site.

13.3 Site regrade and/or ground improvement

- 13.3.1 The majority of the site is relatively flat. However, in Area A appears to have been subject to historical earthworks. The edge of the filled area slopes down to the east, with the steepest slopes on the site (c. 1 in 4 gradient) in the north-eastern corner; localised steep slopes are also present along the south and west of the former school & playing fields area.
- 13.3.2 Foundations of plots located adjacent to the steeply sloping land in the north-east should be taken to below a line drawn up at 45° from the base of the slope. In addition, it is recommended that, where foundations for plots lie within 5m of the crest of a slope, they should be extended to the underlying bedrock (i.e. not cast within the overlying residual soil).
- 13.3.3 The current layout suggests that some minor regrade may be required in order to create a level development platform within the vicinity of Plots 92 to 101, 104 & 105.
- 13.3.4 Any digital terrain modelling undertaken or commissioned by Keepmoat should consider implications for the foundation recommendations outlined below.
- 13.3.5 Natural ground underlying this site is often clayey, therefore consideration should be given to the implication of undertaking earthworks in poor/wet weather when the ground surface is likely to become difficult to cross with heavy machinery.
- 13.3.6 Wherever possible, Lithos recommend that excavated soils are retained on site. However, if this is not possible the comments in Section 10.4 should apply.

13.4 Foundation recommendations

General

- 13.4.1 Foundation recommendations assume that development will be of 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.
- 13.4.2 We have assumed that final development levels will not differ significantly from ground levels existing at the time of investigation. Any digital terrain modelling undertaken, or commissioned by, Keepmoat should consider implications for the foundation recommendations outlined below.
- 13.4.3 Made ground is not considered a suitable foundation material and foundations should therefore be taken through these materials into underlying natural strata of adequate bearing capacity.
- 13.4.4 Sub-surface concrete in contact with the made and natural ground should be Design Sulphate Class DS-2, with the site allocated an ACEC Classification of AC-3z.

Strip/trench fill footings

- 13.4.5 It is considered that shallow strip or deepened trench fill footings will be the most suitable foundation solution for the majority of two or three storey houses constructed at the site. Footings will be founded in stiff clay or competent rock. This solution is viable where the made ground is less than about 2.5m thick.
- 13.4.6 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.
- 13.4.7 Foundations will be required to be placed below a line drawn up at 45° from the base of any service, slope, or similar excavation.
- 13.4.8 Overdeepened foundations should be stepped in accordance with NHBC Standards, Chapter 4.4.
- 13.4.9 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).
- 13.4.10 Keepmoat & BMBC Keepmoat or their groundworker should seek further advice from Lithos if unexpected ground conditions are encountered in foundation or sewer excavations, including any conflict between soft ground associated with a backfilled trial pit excavation and the line of a proposed footing.
- 13.4.11 Clay classification tests suggest that natural cohesive soils at the site should be regarded as being of medium shrinkability. A minimum founding depth of 900mm is therefore recommended for all soils on the site where strip footings are proposed.
- 13.4.12 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.
- 13.4.13 Foundations should be deepened near trees in accordance with NHBC Standards Chapter 4.2. It is estimated that up to 40% of the site may be affected by trees.
- 13.4.14 It would therefore be prudent to prepare a detailed foundation schedule and seek approval from NHBC in order to determine likely foundation abnormalities.

- 13.4.15 A safe bearing capacity of at least 150kPa can be assumed if the following are true
- A maximum foundation line load of 90kN/m run
 - A foundation length of 10m
 - A foundation breadth of 0.6m
 - A foundation thickness of 225mm
 - A foundation depth of 0.9m
 - An undrained shear strength of 75kPa for the cohesive residual soil (typical minimum recorded on site)
- 13.4.16 Assuming the foundation geometry detailed above, minimal settlements would be anticipated. This is considered likely to be acceptable, however, further advice should be sought from the Structural Engineer responsible for foundation design.
- 13.4.17 Locally, clay was absent and foundations will encounter Granular Residual Soils at founding depth. Where this is the case, assuming a minimum founding depth of 0.6m, a safe bearing capacity of at least 150kPa can be assumed.
- 13.4.18 Foundations deepened due to tree influence, made ground and/or the presence of slopes are likely to encounter bedrock. The bedrock is generally considered to have a safe bearing capacity of at least 250kPa and minimal settlements would be anticipated.
- 13.4.19 Where rock is encountered, foundations should be placed entirely on rock and not partially on rock and partially on soil. Foundations within bedrock need only be penetrated by the proposed foundation thickness.
- 13.4.20 Very localised deep made ground (>2.5m) exists within the vicinity of proposed plots 103 and 104. Consequently, depending on final development levels, it may be necessary for trenchfill foundations to be placed at depths of greater than 2.5m. 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)
- 13.4.21 Alternatively, a piled foundation solution could be utilised for plots 103 and 104, although shallow depths to bedrock may necessitate pre-boring and consequently, piling is likely to be uneconomical.

Summary of foundation recommendations

- 13.4.22 In summary, the vast majority of plots will be founded at a minimum depth of 0.9m on traditional strip foundations. Over-deepening will be required within the north-east of Area A due to the presence of made ground. Over-deepening will also be required within the zone of influence of trees.
- 13.4.23 Locally, (vicinity of Plots 103 & 104), engineer-designed trench fill foundations may be required due to deep made ground (up to 2.9m).
- 13.4.24 Lithos could prepare a detailed Foundation Schedule if provided with: an External Works Drawing (with proposed FFLs & infrastructure details); a topographic survey; and a tree survey.
- 13.4.25 The foundation solutions outlined above 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.

13.5 Floor slabs

- 13.5.1 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).
- 13.5.2 It is estimated that the thickness of made ground is likely to exceed 600mm beneath at least 25% of the plots.
- 13.5.3 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. Cast in-situ slabs are not acceptable where foundations are within the influence of trees.
- 13.5.4 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.
- 13.5.5 Beyond the influence of existing or proposed trees, it is considered that the natural ground is generally suitable for the use of ground bearing floors. However, ground bearing slabs should not be cast on topsoil or made ground. Where plots are elevated for design reasons, the depth of engineered stone below a ground bearing slab should not exceed 600mm, in accordance with NHBC guidance.
- 13.5.6 The natural ground beneath this site includes cohesive soils and is therefore subject to seasonal variation in moisture content. If ground slabs were constructed on desiccated soil, heave of the slab would occur on re-hydration of the ground. If any significantly desiccated soil is present, a suspended floor slab, with sub-floor void will be required.
- 13.5.7 It should be noted that NHBC have suffered a significant number of claims resulting from the use of ground bearing floor slabs. Consequently, if ground bearing slabs are proposed, care should be taken correct and careful construction. For example, if fill to the internal face of the foundation excavation is not properly compacted, subsequent settlement can result in cracking of the slab.

13.6 Designated concrete mixes

- 13.6.1 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.
- 13.6.2 Consequently, Keepmoat should seek advice from their appointed Structural Engineer.

13.7 Excavations

- 13.7.1 Groundwater should be controlled in accordance with CIRIA report 113 "Control of Groundwater for Temporary Works".
- 13.7.2 Based on the results of the investigation it is considered unlikely that major groundwater flows will be encountered in shallow excavations.
- 13.7.3 Excavations into natural ground and made ground should remain stable in the short term but if left open for any significant period of time may require shoring.
- 13.7.4 Bedrock was encountered in the majority exploratory holes, especially in the south. Based on the exploratory hole logs, excavation greater than around 2m is likely to prove difficult across most 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.

13.8 Drainage

- 13.8.1 Based on the results of the in-situ testing, soakaways will not 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.
- 13.8.2 Alternative SUDS options (see CIRIA C753:2015 for further details) include:
 - Swales – linear grassed features in which surface water can be stored or conveyed.
 - Pervious Pavements – provide a surface suitable for pedestrian and/or vehicular traffic, while allowing rainwater to infiltrate into subsurface storage, with subsequent infiltration or controlled discharge. Pavement could be porous (water able to infiltrate across entire surface material; e.g. reinforced grass), or permeable (water infiltrates via joints between concrete blocks).
 - Ponds – designed to have permanent pool of water, but with capacity to provide temporary storage controlled discharge.
- 13.8.3 Yorkshire Water have published a guide⁴ for developers and designers outlining their design requirements for surface water attenuation assets.
- 13.8.4 With respect to detention basins, which should normally be dry, water table levels should be taken from borehole monitoring wells over 4 consecutive seasons, for at least 3 points in the basin area. Ground conditions must be suitable to allow free drainage from the detention basin all year round by having regard to groundwater levels, and impermeable liners are not to be used.
- 13.8.5 The guide also discusses required access to flow control chambers, large diameter (i.e. >900mm) surface water storage pipes, and surface water storage tanks.

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

13.9 Highways

- 13.9.1 The natural soils present at shallow depth (anticipated formation) are predominantly cohesive. Based on visual inspection of the natural materials and the recorded plasticity indices at the site, published tables (Interim Advice Note 73/06 Revision 1 (2009), Chapter 5. Characterisation of Materials Design Guidance for Road Pavement Foundations - Draft HD25) indicate that the cohesive residual soils will provide a CBR value of at least 2.5%. This value should be verified prior to or during construction.
- 13.9.2 Whilst the CBRs estimated above should be achievable, significant deterioration during/after periods of significant rainfall is likely and/or site trafficking. Consequently, it would be prudent to consider flexibility in the groundworks programme to enable highway construction during prolonged dry/warm weather (typically between May and September) when formation will be least vulnerable to deterioration. Alternatively, a minimum 200mm thickness of suitable granular fill (ie a "blanket" of 6F2) could be placed along the line of proposed highways to protect formation during the construction phase.
- 13.9.3 Made ground is present across about 25% of the site area, and consultation with the adopting authority regarding the specification of the highways is strongly recommended.
- 13.9.4 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 & relict topsoil, wood, scrap metal, frozen material and oversize.
- 13.9.5 Some refinement of the above advice might be possible after highways design (with consideration of the proposed formation level of existing ground level), and via inspection (and usually CBR testing) of the proposed formation during site preparatory groundworks.
- 13.9.6 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.
- 13.9.7 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.

13.10 External works

- 13.10.1 Any digital terrain modelling undertaken or commissioned by Keepmoat should be made available to their Engineering Designer prior to issue of an External Works Drawing, most notably in the north-east of the site where the existing development platform slopes down.

14 REDEVELOPMENT ISSUES

14.1 General

- 14.1.1 This report has presented options with respect to foundation solutions, re-use of topsoil etc that are considered technically feasible and in line with current good practice. 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 If unanticipated ground is encountered during the site preparatory works, the Contractor should immediately seek further advice from the Engineer.

14.2 Control of excavation arisings

- 14.2.1 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.
- 14.2.2 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: Made Ground Topsoil; Topsoil; Re-worked Clay; Red Shale; Sub-Base; Demolition Rubble; excess clean, natural soil arisings; general construction waste etc.
- 14.2.3 Further characterisation of stockpiled materials is likely to be required if off-site disposal is proposed. See also comments in Section 10.4 regarding asbestos.
- 14.2.4 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, only if suitable (ie not compressible, rich in deleterious matter etc)
 - Isolated beneath the 300mm thick cover layer in garden or landscaped areas (not required for re-worked clay)
 - Exported from site to a suitably licensed landfill facility

14.3 Good practice guidance

- 14.3.1 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 Guidelines⁵:
 - PPG6 - Working at construction and demolition sites
 - PPG2 - Above ground oil storage tank
 - PPG7 – The safe operation of refuelling facilities.
 - PPG21 – Incident Response Planning

⁵ Whilst this has formally been withdrawn it can still be accessed via the EA archives and provides useful information on managing risks.

- 14.3.2 Site preparatory works associated with this project are likely to involve the re-use of both natural and made ground soils on site. Therefore, the Contractor should prepare a Materials Management Plan (MMP) in accordance with the CL:AIRE Code of Practice (v2, March 2011).
- 14.3.3 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.

14.4 New utilities

- 14.4.1 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.
- 14.4.2 Given the lack of contamination encountered and the site's history, the use of 'standard' polyethylene water supply pipes should be acceptable, although Keepmoat & BMBC should consult Yorkshire Water at the earliest opportunity to confirm this.

14.5 Health & safety issues - construction workers

- 14.5.1 Access into excavations etc. must be controlled and only undertaken in accordance with the Confined Spaces Regulations 1997. The atmosphere in shored trenches in excess of 1.2m should be monitored for oxygen and hazardous gas (methane & carbon dioxide), prior to personnel entering such excavations. Monitoring should continue whilst personnel are working in deep excavations.
- 14.5.2 Before site operations are started, the necessary COSHH statements and Health & Safety Plan should be drafted in accordance with the CDM regulations.

14.6 Potential development constraints

- 14.6.1 Some deterioration of the surface is likely to be caused by trafficking, especially after topsoil has been stripped and during/after periods of significant rainfall. Consequently, it would be prudent to consider placement of a minimum 200mm thickness of suitable granular fill (i.e. a "blanket" of 6F2) along the line of proposed highways and any temporary haul roads to protect formation during the construction phase.
- 14.6.2 The electric, water and gas utilities present a potential development constraint unless they can be relocated. Additional enquiries are required to ascertain the feasibility of such diversionary works and the particular easement required by each service undertaker if they remain in-situ.

15 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

15.1 General

- 15.1.1 The site comprises a single parcel of 3.2ha to the south of St Helen's Boulevard, Carlton, Barnsley. The north of the site was occupied by the (now demolished) Holy Cross Deanery Church of England Primary School, and the south of the site comprises an area of arable farmland.
- 15.1.2 It is understood that Keepmoat are considering developing the site with 111 no. 2-storey domestic dwellings, associated gardens, POS and adoptable roads and sewers.
- 15.1.3 The majority of ground encountered comprised topsoil over residual soil, with rockhead typically encountered within 2.0m to 2.5m of ground level. The north-east of the site is underlain by up to c. 3m of made ground, which is most commonly reworked natural clay. This is likely due historical earthworks that created level development platforms/play areas for the former school.

15.2 Mining

- 15.2.1 This site is located within a Coal Mining Development Low Risk Area.
- 15.2.2 The site is predominantly underlain by undifferentiated Pennine Middle Coal Measures bedrock, with the far north-west of the site underlain by Oaks Rock sandstone. The shallowest coal seam is the Newhill Coal, which BGS maps suggest is 0.67m to 1.37m thick at around 15m to 20m depth.
- 15.2.3 While 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.

15.3 Hazardous gas

- 15.3.1 There are two former landfills within 250m of the site and the site is underlain by made ground up to c. 3m thick.
- 15.3.2 The site is in an area where 3-5% of homes are estimated to be above the radon action level, therefore basic protection measures will be required.
- 15.3.3 Gas monitoring wells have been installed in 9 boreholes. Monitoring within the northern parcel is almost complete, and a gas risk assessment for this area will be issued in March 2018. Monitoring within the south of the site (arable farmland) should be completed by October 2018.

15.4 Contamination & remediation

- 15.4.1 Made ground at the site (limited to the north-east) has been found to be essentially 'clean'.
- 15.4.2 Where made ground (within the exception of re-worked clay) remains underneath gardens and soft-landscaped areas, a 300mm thick layer of clean topsoil and subsoil is recommended.

15.5 Foundations

- 15.5.1 The vast majority of proposed dwellings will be founded on strip foundations at a minimum depth of 900mm, over-deepened where necessary due to tree influence and/or significant thicknesses of made ground.
- 15.5.2 Based on the current layout, Plots 103 & 104 are likely to require trench-fill foundations of greater than 2.5m depth which will require engineering-design.

15.6 Flooding

- 15.6.1 The EA indicate that the site is not located within an indicative floodplain.

15.7 Drainage

- 15.7.1 Due to very slow infiltration rates, soakaways will not 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.

15.8 Highways

- 15.8.1 Based on visual inspection of the shallow natural materials and published guidance, the cohesive residual soil should provide a CBR value of at least 2.5%. This value should be verified prior to or during construction.
- 15.8.2 However, made ground is present across approximately 25% of the site to depths of around 3m, and consultation with the adopting authority, regarding the specification of the highways, is strongly recommended.
- 15.8.3 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.

Appendix A
General Notes

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

Lithos obtain data from Landmark or Groundsure, 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 through 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, 2015: "Radon: guidance on protective measures for new buildings", and the Public Health England website. The level of protection needed is site-specific and is determined by reference to 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 (average annual radon concentration of 200 Bq.m⁻³). There are 6 'bands': <1%; 1 to 3%; 3 to 5%; 5 to 10%; 10 to 30%; and >30%.

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.

Hydrogeology

Lithos obtain information from the Environment Agency (EA), 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 two 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 - usually assigned in cases where it has not been possible to attribute either category A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both a minor and non-aquifer in different locations due to the variable characteristics of the rock type

Unproductive strata: These are rock layers or superficial deposits with low permeability that have negligible significance for water supply or river base flow.

The EA maps only display the principal and secondary aquifers as coloured areas. All uncoloured areas on the bedrock designation map will be unproductive strata. However, for uncoloured areas on the superficial (drift) designation map it is not possible to distinguish between areas of unproductive strata and areas where no superficial deposits are present; to do this, it is necessary to consult the published geological survey maps.

For the purposes of the EA's Groundwater Protection Policy the following default position applies, unless there is site specific information to the contrary:

- If no superficial (drift) aquifers are shown, the bedrock designation is adopted
- In areas where the bedrock designation shows unproductive strata (the uncoloured areas) the superficial designation is adopted
- In all other areas, the more sensitive of the two designations is used (e.g. If secondary superficial overlies principal bedrock, an overall designation of principal is assumed)

The EA have also designated groundwater Source Protection Zones, which are based on proximity to a groundwater source (springs, wells and abstraction boreholes). The size of a Source Protection Zone is a function of the aquifer, volume of groundwater abstracted and the effective rainfall, and may vary from tens to several thousand hectares.

Hydrology

Lithos obtain information from the Environment Agency and Landmark or Groundsure with respect to:

- Surface water quality
- Recorded pollution incidents
- Licensed abstractions (groundwater & surface waters)
- Licensed discharge consents
- Site susceptibility to flooding

The EA have set water quality targets for all rivers. These targets are known as River Quality Objectives (RQOs). The water quality classification scheme used to set RQO planning targets is known as the River Ecosystem scheme. The scheme comprises five classes (RE1 to RE5) which reflect the chemical quality requirements of communities of plants and animals occurring in our rivers.

General Quality Assessment (GQA) grades reflect actual water quality. They are based on the most recent analytical testing undertaken by the EA. There are 6 GQA grades (denoted A to F) defined by the concentrations of biochemical oxygen demand, total ammonia and dissolved oxygen.

The susceptibility of a site to flooding is assessed by reference to a Flood Map on the Environment Agency's website. These maps show natural floodplains - areas potentially at risk of flooding if a river rises above its banks, or high tides and stormy seas cause flooding in coastal areas. There are two different kinds of area shown on the Flood Map:

1. Dark blue areas (Flood Zone 3) could be flooded by the sea by a flood that has a 0.5% (1 in 200) or greater chance of happening each year, or by a river by a flood that has a 1% (1 in 100) or greater chance of happening each year
2. Light blue areas (Flood Zone 2) show the additional extent of an extreme flood from rivers or the sea. These outlying areas are likely to be affected by a major flood, with up to a 0.1% (1 in 1000) chance of occurring each year

These two colours show the extent of the natural floodplain if there were no flood defences or certain other manmade structures and channel improvements. Where there is no blue shading (Flood Zone 1), there is less than a 0.1% (1 in 1000) chance of flooding occurring each year.

The maps also show all flood defences built in the last five years to protect against river floods with a 1% (1 in 100) chance of happening each year, or floods from the sea with a 0.5% (1 in 200) chance of happening each year, together with some, but not all, older defences and defences which protect against smaller floods.

The Agency's assessment of the likelihood of flooding from rivers and the sea at any location is based on the presence and effect of all flood defences, predicted flood levels, and ground levels.

It should also be noted that as the floodplain shown is the 1 in 100 year (or 1 in 200 year as appropriate), areas outside this may be flooded by more extreme floods (e.g. the 1 in 1000 year flood). Also, parts of the areas shown at risk of flooding will be flooded by lesser floods (e.g. the 1 in 5 year flood). In some places due to the shape of the river valley, the smaller floods will flood a very similar extent to larger floods but to a lesser depth.

If a site falls within a floodplain, it is recommended that a flood survey be undertaken by a specialist consultant who can advise on appropriate mitigating measures; i.e. raising slab levels, provision of storage etc. 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); and any new development in Flood Zones 2 and 3.

COMAH & explosive sites

Lithos obtain information from Landmark or Groundsure with respect to Control of Major Accident Hazards (COMAH) or explosive sites within 1km of the proposed development site. Lithos' report refers to any that are present, and recommends that the Client seeks further advice from the HSE.

Areas around COMAH sites (chemical plants etc) are zoned with respect to the implementation of emergency plans. The HSE are a statutory consultee to the local planning authority for all COMAH sites. The COMAH site may have to revise its emergency action plan if development occurs. This might be quite straightforward or could entail significant expenditure. Consequently, the COMAH site may object to a proposed development (although it is the Local Authority who have final say, and they are likely to place more weight on advice from the HSE).

Preliminary conceptual site model

The site's environmental setting (and proposed end use) is used by Lithos to assess the significance of any contamination encountered during the subsequent ground investigation.

Assessment of contaminated land is based on an evaluation of pollutant linkages (source-pathway-receptor). Contaminants within the near surface strata represent a potential source of pollution. The environment (most notably groundwater), site workers and end users are potential receptors.

Potential pollutant linkages are shown on a preliminary conceptual site model (pCSM). A CSM is essentially a cross-section through a site that reflects both the surface topography and underlying geology, and shows surface features of interest. The most significant sources of contamination are then superimposed onto this cross-section together with potential receptors (human health & controlled waters), and plausible pathways between the two. In addition to environmental issues, the CSM should also highlight geotechnical issues.

A pCSM is prepared after consideration of all available "desk study" data, and before design of the ground investigation. Data reviewed should include historical plans (with superimposition on a current-day plan), previous SI reports, geological maps etc. The pCSM, in conjunction with knowledge of site constraints (buildings, services, slopes etc) is used to design the ground investigation.

The revised CSM takes account of data obtained during the ground investigation, including the distribution of made ground, the nature and distribution of contamination etc.

General

Lithos Ground Investigations are undertaken in accordance with current UK guidance including:

- BS5930:2015 "Code of practice for site investigation"
- Eurocode 7: BS EN 1997-1:2004. Geotechnical design - Part 1: General rules
- Eurocode 7: BS EN 1997-2:2007. Geotechnical design - Part 2: Ground investigation and testing
- BS10175:2013 "Code of practice for the identification of potentially contaminated sites"
- "Technical Aspects of Site Investigation" – EA R&D Technical Report P5-065/TR (2000)
- "Development of appropriate soil sampling strategies for land contamination" – EA R&D Technical Report P5-066/TR (2001)
- Contaminated Land Reports 1 to 6, most notably CLR Report No. 4 "Sampling strategies for contaminated land"
- "Guidance on the protection of housing on contaminated land" – NHBC & EA R&D Publication 66 (2000)
- AGS: 1996 "Guide to the selection of Geotechnical Soil Laboratory Testing"

Exploratory hole locations

Exploratory hole locations are selected by Lithos, prior to commencement of fieldwork, to provide a representative view of the strata beneath the site and to target potential contaminant sources identified during the preliminary investigation (desk study). Additional exploratory locations are often determined by the site engineer in light of the ground conditions actually encountered; this enables better delineation of the depth and lateral extent of organic contamination, poor ground, relict structures etc.

Investigation techniques

Ground conditions can be investigated by a number of techniques; the procedures used are in general accordance with BS5930: 2015 and BS1377: 1990. Techniques most commonly used by Lithos include:

- Machine excavated trial pits, usually equipped with a backactor and a 0.6m wide bucket.
- Cable percussive (Shell & Auger) boreholes, typically using 150mm diameter tools and casing.
- Window or windowless sampling boreholes (dynamic sampling). Constraints associated with existing buildings, operations and underground service runs can render some sites partly or wholly inaccessible to a mechanical excavator. In such circumstances, window sampling is often the most appropriate technique. A window sampling drilling rig can be manoeuvred in areas of restricted access and results in minimal disturbance of the ground (a 150mm diameter tarmac/concrete core can be lifted and put to one side). However, it should be noted that window sampling allows only a limited inspection of the ground (especially made ground with a significant proportion of coarse material).
- Rotary percussive open-hole probeholes are typically drilled using a tri-cone rock roller or polycrystalline diamond compact (PDC) bit with air as the flushing medium. Probeholes are generally lined through made ground with temporary steel casing to prevent hole collapse.

Where installed, gas/groundwater monitoring wells typically comprise a lower slotted section, surrounded by a filter pack of 10 mm non-calcareous gravel and an upper plain section surrounded in part by a bentonite seal and in part by gravel or arisings. The top of the plain pipe is cut off below ground level and the monitoring well protected by a square, stopcock type manhole cover set in concrete, or the plain pipe is cut off just above ground level and the well protected by 100mm diameter steel borehole helmet set in concrete. Monitoring well details, including the location of the response zone and bentonite seal are presented on the relevant exploratory hole logs.

In-situ testing

Relative densities of granular materials given on the trial pit logs are based on visual inspection only, they do not relate to any specific bearing capacities.

The relative densities of granular materials encountered in cable percussive boreholes are based on Standard Penetration Test (SPT) results. SPTs are carried out boreholes, in accordance with BS 1377 1990, Part 9 Section 3.3. Where full penetration (600mm) is not possible, N values are calculated by linear extrapolation and are shown on the logs as $N^* = x$. The strength of cohesive deposits is determined using a hand shear vane.

Shear strength test results (hand vane readings) reported on trial pit logs are considered to be more reliable than those reported on window sample logs. Significant sample disturbance occurs during window sampling and consequently shear strength results on disturbed window samples are generally lower than results obtained during trial pitting, in-situ or in large excavated blocks.

Sampling

Typically Lithos collect at least three soil samples from each exploratory hole, although in practice a greater number are often taken. The collection of a sufficient number of samples provides a sound basis upon which to schedule laboratory analysis, ensuring:

- A sufficient number of samples from each (common) site material are tested
- Horizontal and vertical coverage of the site is adequate, thereby providing a robust data set for use in the conceptual ground model
- Any localised, significant, but non-pervasive conditions are considered

Made ground and natural soils encountered in the field during a ground investigation often contain a significant proportion of coarse grained material (e.g. brick etc). Soil samples obtained during most investigations are often only truly representative of the in-situ soil mass where there is an absence of particles coarser than medium gravel; i.e the entire soil mass would pass a 20mm sieve.

Representative bulk samples of the **soil mass** are retrieved from coarse soils for specific geotechnical tests (most notably grading and compaction); this typically requires the collection of at least 10kg of soil, and occasionally >50kg. However, in the context of assessing land contamination, it is generally accepted that samples should be representative of the **soil matrix** of the stratum from which they are taken. Consequently, truly representative samples of coarse soils for subsequent contaminant analysis are not obtained - only the finer fraction is placed in sample containers. Coarse constituents not sampled would typically comprise any 'particles' with an average diameter greater than about 20mm (i.e. coarse gravel, cobble and boulder).

At present, neither ISO/IEC 17025 nor MCERTS specify sample pre-treatment with respect to stone removal. Unsurprisingly therefore UKAS accredited testing laboratories do not adopt the same approach to stones¹ – some crush and test the "as received" soil, whilst others sieve out stones and analyse only the residual soil (the sieve size used varies depending on the laboratory).

¹ Mark Perrin. *Stoned – Sample Preparation for Soils Analysis*. Ground Engineering, April 2007.

In essence, samples taken from coarser soils for contaminant analysis are "screened" by the geoenvironmental engineer in the field, and often sieved again by the laboratory during sample preparation. Geoenvironmental engineers do not typically re-calculate soil mass contaminant concentrations by taking account of the unsampled coarse fraction. Likewise, laboratories that remove stones typically report contaminant concentrations based on the dry weight of soil passing the sieve. In the context of land contamination and human health risk assessment, this is considered reasonable, because it is the soil matrix which is of greatest concern. Stones are unlikely to:

- Provide a significant source for plant uptake (consumption of vegetables)
- Remain on vegetables after washing (consumption of vegetables)
- Be eaten (accidentally by an adult, or deliberately by a child)
- Be whipped-up by the wind for dust generation (inhalation)
- Stick to the skin for any length of time (dermal contact)
- Yield toxic vapour (inhalation)

Consequently, Lithos instruct labs to remove all stones >10mm, and to report the results as dry-weight based on the mass of matrix tested. However, the laboratory are given site-specific instruction where coarse stones are coated in say oil, or impregnated with mobile contaminants such as diesel. Where the stones are predominantly natural, or inert (e.g. brick, concrete etc), removal will clearly result in higher reported concentrations, than if the stones were crushed and added to the matrix.

Where the stones include a significant proportion of contaminant-rich material (e.g. slag, fragments of galvanised metal etc) an argument could be made for crushing and analysing. However, provided the stones are stable (i.e. unlikely to disintegrate or degrade) they should not pose a significant risk to human health for the reasons stated above.

Sometimes it is necessary to obtain samples that are not representative of the wider soil matrix, for example when investigating localised, significant, but non-pervasive conditions. Any such unrepresentative samples are annotated with the suffix '*' (eg 2D*, or 4G*). Lithos' site engineer describes both the unrepresentative sample, and the soil mass from which it was been taken.

Sample Containers (for contaminant analysis). Samples of soil for contaminant testing are placed into appropriate containers (see below). Soil samples for organic analysis are stored in cool boxes, at a temperature of approximately 4°C, until delivery to the selected laboratory.

Anticipated testing	Container(s)
Asbestos identification	500ml plastic tub
pH & metals, and non-volatile organics	500ml glass jar
Speciated TPH	500ml & 50ml glass jars
VOCs (incl. naphthalene and/or GRO)	50ml glass jar

Sample Containers (for geotechnical analysis). The majority of samples are only scheduled for PI and sulphate testing, for which 500g of sample is required (a full 0.5-litre plastic tub). However, bulk bags are taken where scheduling of compaction or grading tests is proposed.

Groundwater

Where encountered during fieldwork, groundwater is recorded on exploratory hole logs. If monitoring wells are installed, groundwater levels are also recorded on one or more occasions after completion of the fieldwork. Long-term monitoring of standpipes or piezometers is always recommended if water levels are likely to have a significant effect on earthworks or foundation design.

It should be borne in mind that the rapid excavation rates used during a ground investigation may not allow the establishment of equilibrium water levels. Water levels are likely to fluctuate with season/rainfall and could be substantially higher at wetter times of the year than those found during this investigation.

Description of strata

Soils encountered during a Lithos investigation are described (logged) in general accordance with BS 5930:2015. The descriptions and depth of strata encountered are presented on the exploratory hole logs and summarised in the Ground Conditions section within the main body of text. The materials encountered in the trial pits are logged, samples taken, and tests performed on the in-situ materials in the excavation faces, to depths of up to 1.2m; below this depth these operations are conducted at the surface on disturbed samples recovered from the excavation.

Key to exploratory hole logs

Keys to logs are presented in the Appendix containing the logs. There are two Keys – Symbols & Legends and Terms & Definitions.

General

Soil samples are delivered to the laboratory for testing along with a schedule of testing drawn up by Lithos. All tests are carried out in accordance with BS 1377:1990. The following laboratory testing is routinely carried out on a selection of samples:

- Atterberg limits & moisture contents
- Soluble sulphate & pH

Where soft, cohesive soils are encountered, one-dimensional consolidation tests are scheduled in order to assess settlement characteristics, and unconsolidated undrained triaxial compression tests to assess shear strength.

The additional tests are typically only scheduled where significant earthworks regrade is anticipated:

- Grading
- Compaction tests
- Particle density

Test results are presented as received in an Appendix to the Geoenvironmental Report.

Atterberg limits & moisture content

The Liquid and Plastic Limits of samples of natural in-situ clay are determined using the cone penetrometer method and the rolling thread test. These tests enable determination of an average Plasticity Index (PI) for each "type" of clay, although judgement is applied where variable results are reported.

PI can be related to shrinkability (low, medium or high) and then to minimum founding depth. Lithos typically only consider a soil to be shrinkable if the proportion finer than 63µm is >35%. PI results are compared against guidance given in the NHBC Standards, Chapter 4.2 (revised April 2003), which advocates the use of modified Plasticity Index (I_p), defined as:

$$I_p = I_p * (\% < 425\mu\text{m} / 100)$$

i.e. if PI is 30%, but the soil contains 80% < 425µm, then: $I_p = 30 * 80 / 100 = 24\%$.

It should be noted that in accordance with the requirements of BS 1377, the % passing the 425µm sieve is routinely reported by testing labs. Lithos apply engineering judgment where PI results are spread over a range of classifications. Consideration is given to:

- The average values for each particular soil type (ie differentiate between residual soil and alluvium)
- The number of results in each class and
- The actual values

Unless the judgment strongly indicates otherwise, Lithos typically adopts a conservative approach and recommends assumption of the higher classification.

Soluble sulphate and pH

Sulphates in soil and groundwater are the chemical agents most likely to attack sub-surface concrete, resulting in expansion and softening of the concrete to a mush. Another common cause of concrete deterioration is groundwater acidity.

The rate of chemical attack depends on the concentration of aggressive ions and their replenishment at the reaction surface. The rate of replenishment is related to the presence and mobility of groundwater.

Lithos refer to BRE Special Digest 1 (SD1) "Concrete in aggressive ground. Part 1: Assessing the aggressive chemical environment" (2005). SD 1 provides definitions of:

- The nature of the site (greenfield, brownfield or pyritic)
- The groundwater regime (static, mobile or highly mobile)
- The design sulphate class (DS class) and
- The aggressive chemical environment for concrete (ACEC class)

Lithos reports clearly state each of the above for the site being considered.

The concentrations of sulphate in aqueous soil/fill extracts are determined in the laboratory using the gravimetric method. The results are expressed in terms of SO₄ for direct comparison with BS 5328:1997. The pH value of each sample was determined by the electrometric method.

SD1 also discusses determination of "representative" sulphate concentration from a number of tests. Essentially if <10 samples of a given soil-type have been tested, the highest measured sulphate concentration should be taken. If >10 samples have been tested, the mean of the highest 20% of the sulphate test results can be taken. With respect to groundwater, the highest sulphate concentration should always be taken.

With respect to pH (soil & groundwater) the value used is the lowest value if <10 samples have been tested and the mean of the lowest 20% if >10 samples have been tested.

Oedometer (Consolidation) tests

Oedometer tests measure a soil's consolidation properties, and are performed by applying different loads to a soil sample and measuring the deformation response. Typically the sample is subject to 5 incremental pressures (4 loading & 1 unloading), and the convention is for each subsequent pressure to be double the previous pressure. BS1377 suggests the **initial** pressure should be:

- For stiff soils the effective overburden pressure*
- For firm soils "somewhat less" than the effective overburden pressure
- For soft soils "appreciably less" than the effective overburden pressure, usually 25 kPa or less
- For very soft soils very low, typically 5 kPa or 10 kPa

* Effective **overburden pressure** (kNm⁻²) = depth (m) x soil bulk unit weight (kNm⁻³)

Results from these tests are used to predict how a soil in the field will deform in response to a change in effective stress.

Triaxial tests

This test measures the mechanical properties of a soil by placing the sample between two parallel platens which apply stress in one (usually vertical) direction, with fluid used to apply a confining pressure in the perpendicular directions. During the test, the surrounding fluid is pressurized, and then stress on the platens is increased until the material in the cylinder fails.

From triaxial test data, it is possible to extract fundamental material parameters, including its angle of shearing resistance, apparent cohesion, and dilatancy angle. These parameters are then used in computer models to predict how the material will behave in a larger-scale engineering application.

Quick (single stage, Unconsolidated, Undrained tests) are most appropriate for foundation design. This is because load is applied relatively quickly, and shear strength of the clay will be lowest initially; after the applied load causes some consolidation of the ground (after drainage results in dissipation of short-term excess pore water pressure), the in-situ clays will become progressively stronger and hence the factor of safety will increase. Confining pressure is specified as equivalent to overburden pressure (kNm^{-2}).

Foundations on granular soils would use effective shear strength parameters (c' and ϕ') to assess safe bearing capacity, as the soil would fully drain quickly. These effective shear strength parameters could be determined from Consolidated Undrained (or sometimes the more expensive Consolidated Drained) triaxial tests, but often correlations to the SPT are used.

Unconsolidated Undrained triaxial tests are most appropriate for assessment of the stability of fill slopes on clays. Similar to foundations, the application of load gradually increases the strength of the clays and hence the critical case is the short term undrained condition.

Consolidated Undrained (or sometimes **Consolidated Drained**) triaxial tests are most appropriate for assessment of the stability of cut slopes in clays. This is because unloading of the ground leads to short term reduction in pore pressures that approximately balance the unloading, hence the soil strength is largely unchanged. Over time the reduced pore pressures suck water in, which leads in to the progressive increase in pore pressure and loss of strength. The fully drained state is critical, which must be modelled using effective strength parameters and a reasonable estimate of the long term water table conditions.

Slopes formed in granular soils would use effective shear strength parameters (c' and ϕ') to assess safe bearing capacity, as the soil would fully drain quickly. These effective shear strength parameters could be determined from Consolidated Undrained (or sometimes the more expensive Consolidated Drained) triaxial tests, but often correlations to the SPT are used.

Determination of analytical suite

An assessment of potential contaminants associated with the former usages of the site is undertaken with reference to CLR 8 "Potential contaminants for the assessment of land" and the relevant DETR Industry Profile(s).

Common contaminants

Common **Inorganic** Contaminants include:

- Metals, most notably cadmium, copper, chromium, mercury, lead, nickel, and zinc
- Semi-metals, most notably arsenic, selenium, and (water soluble) boron
- Non-metals, most notably sulphur
- Inorganic anions, most notably cyanides (free & complex), sulphates, sulphides, and nitrates

With respect to the terminology used by most analytical laboratories:

Total cyanide = Free cyanide + Complex cyanide

Total cyanide (CN) is determined by acid extraction; whereas free cyanide is the water soluble fraction. Complex cyanide is "bound" in compounds and is hard to breakdown. Laboratory determination of complex CN involves subjecting the sample to UV digestion for determination of both free and total CN.

Thiocyanate (SCN) is a different species combined with sulphur.

Elemental sulphur (S) and free sulphur are the same. Total sulphur is all forms, including that present in sulphates (SO₄), sulphides etc.

There are 2 forms of chromium (Cr), chromium VI and chromium III. Chromium VI is the more toxic of these. In soils, total chromium is determined by a strong aqua regia acid digestion. Chromium VI is an empirical method based on a water extract test.

Common **Organic** Contaminants include hydrocarbons, phenols, and polychlorinated biphenyls.

Petroleum is a mixture of hydrocarbons produced from the distillation of crude oil, and includes aliphatics (alkanes, alkenes and cycloalkanes), aromatics (benzene and derivatives) and hydrocarbon-like compounds containing minor amounts of oxygen, sulphur or nitrogen. Petroleum hydrocarbons can be grouped based on the carbon number range:

- GRO – Gasoline Range Organics (typically C₆ to C₁₀). Also referred to as PRO – Petroleum Range Organics
- DRO – Diesel Range Organics (typically C₁₀ to C₂₈)
- LRO – Lubricating Oil Range Organics (typically C₂₈ to C₄₀)
- MRO – Mineral Oil Range Organics (typically C₁₈ to C₄₄)

However, it should be borne in mind that the terms "GRO" and "DRO" analysis are purely descriptive terms, the exact definition of which varies. Total Petroleum Hydrocarbons (TPH) is also a poorly defined term; some testing laboratories regard TPH as hydrocarbons ranging from C₅-C₄₀, whereas others define TPH as C₁₀-C₃₀.

The composition of a TPH plume migrating through the ground can vary significantly; this is primarily dictated by the nature of the source (eg petrol, diesel, engine oil etc). Furthermore, different hydrocarbons are affected differently by weathering processes, and this can result in further variation in the chemical composition of the TPH.

Gasoline contains light aliphatic hydrocarbons (especially within the C₄ to C₅ range) that are volatile. The aromatic hydrocarbons in gasoline are primarily benzene, toluene, ethylbenzene and xylenes, referred to as BTEX. Small amounts of polycyclic aromatic hydrocarbons (PAHs) such as benzo(a)pyrene may also be present. Diesel and light fuel oils have higher molecular weights than gasoline. Consequently, they are less volatile and less water soluble. About 25 to 35% is composed of aromatic hydrocarbons. BTEX concentrations are generally low.

Heavy Fuel Oils are typically dark in colour and considerably more viscous than water. They contain 15 to 40% aromatic hydrocarbons. Polar nitrogen, sulphur and oxygen-containing compounds (NSO) compounds are also present. Lubricating Oils are relatively viscous and insoluble in groundwater. They may contain 10 to 30% aromatics, including the heavier PAHs. NSO compounds are also common.

Polycyclic Aromatic Hydrocarbons (PAHs) have more than two fused benzene rings as a structural characteristic. PAH compounds are present in both petrol and diesel, although in significantly lower concentrations than in coal tars. Certain PAH compounds are carcinogenic (benzo(a)pyrene) and/or mobile in the environment (naphthalene).

Volatile Organic Compounds (VOCs) are organic chemicals, and most are liquids that readily evaporate on exposure to air. Examples include benzene, toluene, xylene, chloroform etc. Semi-Volatile Organic Compounds (sVOCs) include phenol and benzo(a)pyrene, and have relatively low boiling points. Both groups of chemicals are readily absorbed through skin and some, such as benzene, are believed to be linked to tumour growth.

Phenols are compounds that have a hydroxyl group (-OH) attached to an aromatic ring (ie include a benzene ring and an -OH group). Most are colourless solids. A solution of phenol in water is known as carbolic acid, and is a powerful antiseptic. However, phenol vapour is toxic, and skin contact can result in burns.

Polychlorinated Biphenyls (PCBs) were used in pre-1974 transformers as dielectric fluids. PCB's are of increasing toxicity relative to the degree of chlorination. Acute symptoms of PCB poisoning are irritation of the respiratory tract leading to coughing and shortness of breath. Nausea, vomiting and abdominal pain are caused by ingestion of PCB's.

Dioxins and furans (polychlorinated dibenzodioxins and polychlorinated dibenzofurans) are some of the most toxic chemicals known; in the environment, they tend to bio-accumulate in the food chain. Dioxin is a general term that describes a group of hundreds of chemicals that are highly persistent in the environment. The most toxic compound is 2,3,7,8-tetrachlorodibenzo-p-dioxin or TCDD.

Dioxin is formed by burning chlorine-based chemical compounds with hydrocarbons. The major source of dioxin in the environment comes from waste-burning incinerators and also from backyard burn-barrels. Dioxin pollution is also affiliated with paper mills which use chlorine bleaching in their process and with the production of Polyvinyl Chloride (PVC) plastics and with the production of certain chlorinated chemicals (like many pesticides).

Methods of analysis (organic compounds)

TPH by GC-FID is an analytical technique which only detects hydrocarbons (aliphatic and aromatic) in the range C₁₀ to C₄₀ (volatiles, heavy tars, humic material and sulphur are not detected). The laboratory can provide a broad, 'banded' breakdown of the TPH results into gasoline range organics (GRO), diesel range organics (DRO) and heavier lubricating oil range organics (LRO), or fully speciated results with the reporting of hydrocarbon concentrations in 14 specific carbon bandings based upon behavioural characteristics, e.g. aliphatic C₆ to C₈, aromatic C₁₀ to C₁₂ etc.

Speciated VOC (by GC-MS) analysis quantifies the concentrations of 30 USA-EPA priority compounds. These include chlorinated alkanes and alkenes (in the molecular weight range chloroethane to tetrachloroethane); trimethylbenzenes; dichlorobenzenes; and the 4 BTEX compounds (benzene, ethyl-benzene, toluene & xylene).

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Speciated sVOC by (GC-MS) analysis quantifies the concentrations of a variety of organic compounds, including the 16 USA-EPA priority PAHs, phenols, 7 USA EPA priority PCB congeners, herbicides & pesticides.

Note: PAHs are hydrocarbons and consequently (where present) will be picked-up when scheduling TPH by GC-FID.

Note: Risk assessment models require physiochemical properties (solubilities, toxicities etc) of compounds in order to model their behaviour in the environment. These physiochemical properties cannot be derived from a single "TPH", "GRO" or "DRO" value. However, the carbon banded fractions can be used in risk assessment models.

Current UK guidance

The UK approach to contaminated land is set out in Contaminated Land Report No. 11 (2004) "Model Procedures for the Management of Land Contamination". The approach is based upon risk assessment, where risk is defined as the combination of the probability of occurrence of a defined hazard and the magnitude of the consequences of the occurrence.

In the context of land contamination, there are three essential elements to any risk: (1) a contaminant source; (2) a receptor (eg controlled water or people); and (3) a pathway linking (1) and (2). Risk can only exist where all three elements combine to create a pollutant linkage. Risk assessment requires the formulation of a conceptual model which supports the identification and assessment of pollutant linkages.

Lithos adopt a tiered approach to risk assessment, consistent with UK guidance and best practice. The initial step of such a risk assessment (or Tier 1) is the comparison of site data with appropriate UK guidance levels, Lithos risk-derived screening values, or remedial targets. It should be noted that exceedance of Tier 1 does not necessarily mean that remedial action will be required.

Soil screening values used by Lithos

In March 2002 DEFRA and the Environment Agency published a series of technical papers (R&D Publications CLR 7, 8, 9 and 10) outlining the UK approach to the assessment of risk to human health from land contamination. In 2008 CLR 7, 9 and 10 and all corresponding SGV and Tox reports were withdrawn and superseded by new guidance including:

- Guidance on Comparing Soil Contamination Data with a Critical Concentration - CL:AIRE and CIEH, May 2008
- Evaluation of models for predicting plant uptake of chemicals from soil - Science Report – SC050021/SR
- Human health toxicological assessment of contaminants in soil - Science Report: SC050021/SR2
- Updated technical background to the CLEA model - Science Report: SC050021/SR3
- CLEA Software Handbook (Version 1.071), Science report: SC050021/SR4
- Compilation of data for priority organic pollutants for derivation of Soil Guideline Values - Science Report: SC050021/SR7

The approach set out in these documents represents current scientific knowledge and thinking; and includes the Contaminated Land Exposure Model (CLEAv1.06). The Environment Agency are in the process of using this updated approach to regenerate a selection of Soil Guideline Values (SGVs).

CLEA SGVs were derived for standard land use scenarios predominantly in the context of Part IIA, using a conceptual site model (CSM) defined in SR3. Lithos have incorporated amendments to the CSM used to derive SGVs, that more accurately reflect redevelopment within the planning regime; consequently, Lithos have not adopted any published SGV as a screening value.

The CLEA conceptual site model assumes a source located in a sandy loam, with 6% soil organic matter (SOM) - equivalent to 3.5% total organic carbon (TOC). However, where the average TOC value for a particular soil type is significantly lower than the 3.5%, evaluation of Lithos Screening Values should be undertaken and a site specific risk assessment will usually be required. Other CLEA default characteristics adopted by Lithos are:

Sandy Loam characteristics (source)	Default values adopted
Total porosity (fraction)	0.53
Water filled porosity (fraction)	0.33
Air filled porosity (fraction)	0.2

Lithos have derived Screening Values for four different CSMs (scenarios); these are:

- A - Residential with gardens, but no cover (or only up to 300mm)
- B - Residential with gardens and 600mm 'clean' cover
- C - Residential apartments with landscaping (i.e. no home grown produce)
- D - Commercial/industrial with landscaping
- E - Importation of soil cover

The **exposure** pathways considered for each scenario are detailed in the table below.

Scenario	Land use	Pathways	Justification
A	Residential with garden, but no cover (or only up to 300mm)	• Direct ingestion of soil • Dermal contact • Consumption of vegetables & soil attached to vegetables • Inhalation of indoor vapours and dust • Inhalation of outdoor vapours and dust	Minimal cover – insufficient to break any pathways therefore all exposure pathways are relevant.
B	Residential with garden minimum 600mm cover	• Inhalation of indoor vapours • Inhalation of outdoor vapours	The 600mm cover removes the risk from all pathways other than inhalation.
C	Residential apartments with landscaped areas and minimum 300mm cover	• Direct ingestion of soil • Dermal contact • Inhalation of indoor vapours and dust • Inhalation of outdoor vapours and dust	All pathways applicable due to possible exposure from landscaped areas. However consumption of home grown produce not included as unlikely to be grown in landscaped areas. Where vegetables are to be grown site specific QRA may be required.
D	Commercial/ industrial with landscaped areas no cover	• Direct ingestion of soil • Dermal contact • Inhalation of indoor vapours and dust • Inhalation of outdoor vapours and dust	All pathways applicable due to possible exposure from landscaped areas. Assumed the commercial development consists of offices to provide a conservative assessment.
E	Importation of soil for cover in garden and landscaped areas	• Direct ingestion of soil • Dermal contact • Consumption of vegetables & soil attached to vegetables • Inhalation of outdoor vapours and dust	Material used as cover to break existing pathways therefore all direct and indirect pathways relevant; however cover is not placed below plots therefore indoor inhalation is not relevant.

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Lithos have assumed the source of contamination is directly below the building foundations; i.e. a depth of source of 0.15m as opposed to the CLEA default of 0.65m. This assumption provides for a more conservative approach than the UK default. This adjustment has been included to account for sites where made ground is re-engineered to enable new buildings to be established on raft foundations. In such situations contamination may lie directly beneath the foundation.

The Soil Screening Values referred to in this document are **not** intended to be used when considering potential risks associated with:

- Existing land uses in the context of Part IIA of the Environment Protection Act 1990;
- End uses such as allotments, sports fields, children's playgrounds, care homes, hospitals etc; and
- Controlled waters.

In December 2013 Defra published the results of research project SP1010 – Development of Category 4 Screening Levels (C4SLs) for Assessment of Land Affected by Contamination. The objective of this project was provide technical guidance in support of Defra's revised Statutory Guidance for Part 2A of the Environmental Protection Act 1990 (Part 2A). The revised Statutory Guidance, published in April 2012, introduced a new four-category system for classifying land under Part 2A where Category 1 includes land where the level of risk is clearly unacceptable, and Category 4 includes land where the level of risk posed is acceptably low. Project SP1010 aimed to deliver:

- A methodology for deriving C4SLs for four generic land-uses comprising residential, commercial, allotments and public open space; and
- Demonstration of the methodology, via derivation of C4SLs for 6 substances – arsenic, cadmium, chromium IV, lead, benzene & benzo(a)pyrene.

The methodology for deriving both the previous Soil Guideline Values and the new Category 4 Screening Levels is based on the Environment Agency's Contaminated Land Exposure Assessment (CLEA) methodology. Development of C4SLs has been achieved by modifying the toxicological and/or exposure parameters used within CLEA (while maintaining current exposure parameters).

The Part 2A Statutory Guidance was developed on the basis that C4SLs could be used under the planning regime. However, policy responsibility for the National Planning Policy Framework falls to the Department for Communities and Local Government. Defra anticipate that, where they exist, C4SLs will be used as generic screening criteria, and Lithos consider C4SLs to be suitable for use as Tier 1 Screening Values. Lithos have discussed this matter with both NHBC and YAHPAC (collection of Yorkshire & Humberside local authorities) and received confirmation that they are satisfied with this approach.

With respect to **inorganic** determinands, Lithos derived Tier 1 values for the five Scenarios A to E are presented below:

Inorganic contaminant	Tier 1 assessment criteria (mg/kg) for Scenarios A to D							Comments/notes
	SGV*	C4SL*	A	B	C	D	E	
As	32	37	37	Use (A) in SI Report for initial "screen". If >5 x A, then consider increase of cover to 1,000mm	40	640	37	C4SL adopted
Cd	10	26	26		149	410	26	C4SL adopted
Cr			3,000		3,000	30,000	3,000	Assumes Cr is CrIII
Pb	450	200	200		310	2,330	200	C4SL adopted
Ni	130		127		127	1,700	127	Assessment of health risk only
Se	350		350		595	13,000	434	
Hg	170		169		238	3,640	199	Assumes in an inorganic compound
B			5		5	5	5	
Cu			80-200		80-200	80-200	80-200	Based on phytotoxic risks as plants are the more sensitive receptor (Cu is pH dependant)
Zn			200		200	200	200	

With respect to **organic** determinands, Lithos derived Tier 1 values for the five Scenarios A to E are presented below:

Organic contaminant (all sourced via CLEA)	Tier 1 assessment criteria (mg/kg) for Scenarios A to D							Comments/notes
	SGV*	C4SL*	A	B	C	D	E	
Benzene	0.33	0.87	0.9	0.9	3.3	98	N/A	C4SL adopted
Toluene	610		600	3,000	2,700	5,000	N/A	Calculated value over 10,000
Ethyl Benzene	350		350	932	843	5,000	N/A	
Xylenes	240		246	327	321	5,000	N/A	
Phenol	420		412	2,400	519	5,000	N/A	
PCBs			2	8	2	38	N/A	Based on toxicity of EC7
Benzo(a)pyrene		5	5	25	5.3	76	5	C4SL adopted. Where source is not a coal tar
Naphthalene			8	9	9	1,000	12	
Gasoline Range Organics			30	34	34	5,000	45	See 3-step assessment of TPH below
Diesel Range Organics			151	156	154	5,000	219	
Lubricating Range Org			1,000	5,000	2,000	5,000	1,000	

* For a residential end use

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 amount of toxicological data available and has been used by various authoritative bodies to assess the carcinogenic risk of PAHs in food. A surrogate marker approach can be used to estimate the toxicity of a mixture of PAHs in soil using toxicity data for individual indicator compounds within that mixture. Exposure to the surrogate marker is assumed to represent exposure to all PAHs in that matrix. The surrogate marker approach relies on a number of assumptions:

- Surrogate marker (bap) must be present in all soil samples
- Profile of the different pah relative to bap should be similar in all samples
- PAH profile in the soil samples should be similar to that used in the pivotal toxicity study¹

¹ SP1010 Appendix E, Provisional C4SLs for benzo(a)pyrene as a surrogate marker for PAHs, CL:AIRE 2013

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To assess the PAH profile in a soil sample, the ratio of the seven genotoxic PAHs (benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[g,h,i]perylene, chrysene, dibenz[a,h]anthracene and indeno[1,2,3-c,d]pyrene), relative to BaP, should be calculated. The ratio relative to BaP should lie within an order of magnitude above and below the mean ratio to BaP.

Naphthalene should also be considered separately against its generic screen. Whilst classed as a PAH, naphthalene is more volatile and mobile in the environment than most other PAHs. As such the significance of naphthalene cannot be considered within the surrogate marker approach.

Similarly, **TPH** cannot be assessed as a single "total" value, and reference has been made to the Environment Agency's document P5-080/TR3, "The UK approach for evaluating human health risks from petroleum hydrocarbons in soils". This document supports the assumptions and recommendations made by the US Total Petroleum Hydrocarbons Criteria Working Group (TPHCWG). The TPHCWG have broken down "TPH" into representative constituent fractions or "EC Bandings". The TPHCWG have derived a series of physiochemical and toxicological parameters for each of the bandings.

The significance of speciated TPH results can be assessed by following the 3 steps outlined in the tables below.

Step	Result	Action
1. Consider indicator compounds: Are BTEX, naphthalene, benzo(a)pyrene above their respective Tier 1 values?	Yes	Remediation or dQRA required
	No	Proceed to Step 2
2. Consider individual TPH fractions: are they above respective screening values?	Yes	Remediation or dQRA required
	No	Proceed to Step 3
3. Assess Cumulative effects: Is the calculated Hazard Index for each source >1	Yes	Remediation or dQRA required
	No	TPH compounds pose no significant risk

Step 1 - Assessing indicator compounds

TPH fraction Indicator compound	End use specific screening value (mg/kg)			
	A: Residential no cover	B: Residential with 600mm cover	C: Residential no gardens	D: Commercial \ industrial
Benzene	0.9	0.9	3.3	98
Toluene	600	3,000	2,700	5,000
Ethyl Benzene	350	932	843	5,000
Xylenes	246	327	321	5,000
Naphthalene	8	9	9	1,000
Benzo(a)pyrene	5	25	5.3	76

Step 2 - Assessing individual TPH fractions

TPH fraction		End use specific screening value (mg/kg)			
		A: Residential no cover	B: Residential with 600mm cover	C: Residential with no gardens	D: Commercial/ industrial
Aliphatic 5-6	GRO	41	41	42	5,000 [^] per fraction
Aliphatic 6-8	GRO	125	125	125	
Aliphatic 8-10	GRO	31	31	32	
Aliphatic 10-12	DRO	151	156	154	
Aliphatic 12-16	DRO	500 [^]	500 [^]	500 [^]	
Aliphatic 16-21	DRO	1,000 [^]	5,000 [#]	1,000 [^]	
Aliphatic 21-35	LRO	1,000 [^]	5,000 [#]	1,000 [^]	
Aromatic 5-7	GRO	100	123	122	
Aromatic 7-8	GRO	30	34	34	
Aromatic 8-10	GRO	47	50	50	
Aromatic 10-12	DRO	215	287	266	
Aromatic 12-16	DRO	689	1,000 [*]	1,000 [*]	
Aromatic 16-21	DRO	1,000 [^]	5,000 [#]	1,000 [^]	
Aromatic 21-35	LRO	1,000 [^]	5,000 [#]	1,000 [^]	

* Calculated Screening Value exceeded soil saturation limit and could indicate free product, therefore calculated soil saturation limit adopted as a target

[^] Calculated Screening Value close to soil saturation limit, screening value selected by Lithos considering visual and olfactory impacts.

[#] Five times the screening value for Scenario A.

Step 3 - Assessing Cumulative Effects

$$HI = \sum_{F_i=1}^{16} HQ F_i = \frac{\text{Measured concentration } F_i \text{ (mg kg}^{-1}\text{)}}{SGV F_i \text{ (mg kg}^{-1}\text{)}}$$

where HI = Hazard Index
 HQ = Hazard Quotient
 F_i = Fraction _i
 SGV = Soil Guideline Value