PROPOSED COMMERCIAL DEVELOPMENT
MABEY HOUSE, NEW HOUSE PARK, CHEPSTOW

ALUK (UK)

PHASE TWO GEO-ENVIRONMENTAL AND
GEOTECHNICAL ASSESSMENT

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GEOTECHNICAL ASSESSMENT

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SUMMARY

ALUK is considering the purchase of the subject site for redevelopment as a commercial site. ESP have undertaken a geo-environmental and geotechnical assessment, comprising a desk study, intrusive investigation, laboratory testing and assessment of data. This report includes the Preliminary Risk Assessment and Generic Quantitative Risk Assessment (for human health and controlled waters) elements of CLR11. The key potential land quality issues identified by the assessment are summarised below:

	Potential Hazard	Anticipated Risk	Discussion
Site Setting	**Current Site Status.** (Section 2.1)	-	The site is currently occupied by a manufacturing building and office with areas of hardstanding.
	Identified Ground Conditions.	-	Made Ground overlying weathered Mercia Mudstone bedrock.
	Groundwater Conditions.	-	The site is underlain by a Secondary B Aquifer
	Historical Land Use.	-	No significantly contaminative former use has been identified prior to the construction of the existing building some time in 2002.
Geo-environmental	**Potential Contamination Sources**	Low	No significant potential sources of contamination identified.
	Chronic Risks to Human Health	Low	Made Ground identified across the site, with 1no. marginal elevation of PAH's identified in TP3 0.55m).
	Risks to Controlled Waters	Low	The site is underlain by a Secondary B Aquifer, low levels of contamination identified and site is largely hardstanding – limiting migration of contamination.
	Hazardous Ground Gas	Low	No evidence of potential gas sources identified in the ground investigation. Basic radon protective measures required.
Geotechnical	**Abandoned Mine Workings and/or Old Mine Entries**	Negligible	Site not underlain by Coal Measures Rock.
	Weak/Compressible Ground, requiring non-traditional foundations	Low	Risk from weak ground considered low based on the findings to date.
	Shrinkage or Swelling	Moderate/ Low	Investigation identified moderate potential for volume change within the Mercia Mudstone bedrock.
	Sulphate Attack on Buried Concrete	Low	Laboratory testing has indicated low levels of sulphate.
	Soakaway Feasibility	-	Not considered as part of these works.
	Other Hazards	-	A deep excavation (up to 10m below surface level) is proposed at the site. Groundwater has been recorded at 2.0m below surface level during the summer period after a spell of warm and dry weather. Water levels likely to be shallower in winter months and this should be considered when designing the development and temporary works. The significant earthworks proposed for a 10m construction/maintenance pit will require substantial temporary works to ensure the stability of the excavation throughout the development. The temporary works will require careful design (taking into account shallow groundwater) and include consideration of all potential contamination implications given the depth (below the water table) of the proposed pit
Others	**Flooding**	Low	N/A
	Invasive Plants	-	None identified
	Further Investigation Required? (Section 9.0)	-	See Section 8.0

Note: The above is intended to provide a brief summary of the conclusions of the assessment. It does not provide a definitive assessment and must not be referenced as a separate document. Refer to the main body of the report for details.

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PHASE TWO GEO-ENVIRONMENTAL AND GEOTECHNICAL ASSESSMENT

ENCLOSURES

1.0 INTRODUCTION AND OBJECTIVES

1.1 Background

ALUK (hereafter known as the Client) are proposing to purchase the subject site for redevelopment. ESP have not been provided with a proposed development plan, however we understand that an extension is proposed to the front of the existing building in the north east of the site with access road layouts proposed alongside the construction.

In addition, a wind turbine construction/maintenance pit is also included in the proposed development to the front of the existing building in the north of the site. We understand that this construction/maintenance could potentially involve an excavation to up to 10m below the surface level. Based on this and the-- above, the intrusive investigation has been designed to provide details on any potential issues that may be present for excavating the ground to such a depth.

The Earth Science Partnership Ltd (ESP), Consulting Engineers, Geologists and Environmental Scientists, were instructed by the Client to undertake a geotechnical and geo-environmental Phase Two investigation and assessment to identify and evaluate potential ground hazards which could impact on the proposed development. The site location is shown on Figure 1.

A Phase One Desk Study report was undertaken by ESP in May 2016 (Ref: 6283b/2258) and a summary of this report is detailed in Section 2.3.

1.2 Objective and Scope of Works

The objective of the investigation was to obtain information on the geotechnical character and properties of the ground beneath the site, potential risks posed by contamination and ground gas, and to allow an assessment of these ground conditions with particular reference to the potential impact on the proposed development.

The scope of works for the investigation was designed by ESP within an agreed budget, and comprised a review of the Phase One desk study undertaken by ESP in May 2016, a field reconnaissance visit, the supervision and direction of trial pits, one rotary drill hole, measurement of in-situ CBR values (using DCP equipment), geotechnical and geo-environmental laboratory testing, assessment of foundation options, risks to human health and controlled waters, and reporting.

The contract was awarded on the basis of a competitive tender quotation. The terms of reference for the assessment are as laid down in the Earth Science Partnership proposal of 26th March 2015 (ref: 6283b.02/lt1r1/db/June 2016).

The investigation and assessment was undertaken in June and July 2016

1.3 Report Format

This report includes a summary of the desk study report (Section 2), and details of the investigation undertaken of BS5930:2015 (Section 3). The Preliminary Risk Assessment stage is presented in the Phase One desk study (Appendix B1).

A preliminary evaluation of the resulting risks and any remedial measures potentially required to mitigate identified unacceptable risks from contamination and hazardous ground gas is included in Sections 6 and 7.

A preliminary risk register, identifying potential geotechnical hazards from the desk study review, is presented in full in Appendix B1 and summarised in Section 2.5. A full assessment of the geotechnical conditions including foundation and floor slab options and the potential requirement to excavate to 10m below surface level are presented in Section 8.

The assessment of the potential for hazardous substances (contamination) or conditions to exist on, at or near the site at levels or in a situation likely to warrant mitigation or consideration appropriate to the proposed end use has been undertaken using the guidance published by CIRIA (2001). This is discussed in more detail in Appendix A and in the previous desk study (Appendix B1).

1.4 Limitations of Report

This report represents the findings of the brief relating to the proposed end use and geotechnical category of structure(s) as detailed in Section 1.1. The brief did not require an assessment of the implications for any other end use or structures, nor is the report a comprehensive site characterisation and should not be construed as such. Should an alternative end use or structure be considered, the findings of the assessment should be re-examined relating to the new proposals.

Where preventative, ameliorative or remediation works are required, professional judgement will be used to make recommendations that satisfy the site specific requirements in accordance with good practice guidance.

Consultation with regulatory authorities will be required with respect to proposed works as there may be overriding regional or policy requirements which demand additional work to be undertaken. It should be noted that both regulations and their interpretation by statutory authorities are continually changing.

This report represents the findings and opinions of experienced geo-environmental and geotechnical specialists. Earth Science Partnership does not provide legal advice and the advice of lawyers may also be required.

1.5 Digital Copy of Report

A digital copy of this report (in pdf format) and any information on underground utilities obtained as part of this assessment is included on a CD in Appendix I.

2.0 SUMMARY OF PHASE 1 DESK STUDY (ESP, 2016)

Below is a summary of the Phase One Desk Study undertaken by ESP in May 2016. Any pertinent information has been included in the necessary sections throughout the report. The full Phase One Report is presented in Appendix B1.

In addition to the summary below, a further summary of the Structural Soils Ltd investigation, undertaken in 2002, has been presented below (Section 2.4).

2.1 Site Location and Description

The site is located at the existing Mabey House, in the north portion of New House Park Estate, Chepstow. The National Grid Reference of the centre of the site is (ST) 353011, 191255 and a Site Location Plan is presented as Figure 1.

The site comprises a roughly rectangular shaped parcel of land of around 500m length (south west to north east) and 100m width (north west to south east) occupying an area of around 7.6 hectares. It is presently occupied by an existing manufacturing facility and external areas occupied by Mabey Bridge, an electrical production facility.

2.2 Historical Land Use

Prior to the construction of the existing building, no significantly contaminative former use has been identified. The most plausible pollutant source is likely to be the existing manufacturing plant constructed between 2002 and 2010.

2.3 Geological Setting

The Geology underlying the site was identified from geological maps, and previous investigations at the site (Structural Soils 2002, discussed further in Section 2.4). Available information showed the site to be likely underlain by limited or absent River Terrace Deposits and the Mercia Mudstone Bedrock. The Mercia Mudstone Bedrock is classified as a Secondary B Aquifer.

There are no available BGS borehole records available for the site, however, a number of borehole records are available for the M48 highway and the wider New House Park Estate. Pertinent records are presented in Appendix C of the Phase One report (Appendix B1), however the boreholes generally indicate a cover of Made Ground, limited River Terrace Deposits followed by Mudstone bedrock. The bedrock is generally encountered at depths of between 2m and 3.5m.

The nearest major surface water feature to the site is the River Wye present to the west and south of the site. A number of other surface water features such as ponds, streams and a large reen network are present across the wider area. A stream/drain is present at the east boundary of the site and enters the site boundary at the south east corner. The stream flows into two ponds that are indicated on site. The Groundsure Report indicates that there are no surface water abstractions within 250m of the site.

From a review of topographical plans and flooding maps presented on the Environment Agency (EA) website (EA, 2015), the site is not indicated to be at risk from flooding.

2.4 Summary of Previous Investigations

Below is a summary of previous investigation undertaken at the site. The full reports are presented in Appendix B2.

2.4.1 Structural Soils Ltd Investigation (SS, 2002) – Geotechnical Investigation

- 3no. boreholes constructed to a maximum depth of 6.5m.
- 22no. trial pits excavated to a maximum depth of 5.9m.
- Limited contamination testing carried out; however, the findings of the ground conditions were indicative of no evidence of contamination.
- Ground model comprised limited superficial deposits (clay) overlying Mercia Mudstone bedrock.
- Atterberg testing indicated low to intermediate plasticity within the weathered Mercia Mudstone bedrock.
- Sulphate analysis of the recovered soils indicated low levels of sulphate within the Mercia Mudstone Bedrock

2.4.2 Atkins 2006

- No potentially contaminative former use identified at the site.
- 24no trial pits undertaken to a maximum depth of 3.6m below surface level.
- No evidence of contamination was identified throughout the investigation.

2.5 Conclusions of Phase One Preliminary Risk Assessment (PRA – ESP Desk Study, 2016)

2.5.1 Geo-environmental Considerations

Limited Made Ground is anticipated at the site, due to the construction of the existing building, however no sources of extraordinary contamination identified. The risks to Controlled Waters are considered low; the nearest major surface water feature to the site is a small stream located to the east.

A stream/drain once present in the east portion has been rerouted as part of the development works. Depending on the backfill status of the stream, there is a potential ground gas risk. A reen is also identified at the west boundary on the historical mapping from 2002.

As detailed in the Phase One desk study (Appendix B1), the Groundsure report identifies that the site lies in an area where less than 3-5% of homes are above the action level for radon. Basic radon protection measures will be required.

2.5.2 Geotechnical Considerations

Weathered Mercia Mudstone is anticipated beneath the site, which can potentially have a high plasticity index and, hence, be classified as of potential high volume change potential with changes in moisture content (shrinkage and swelling).

As detailed in Section 2.4.1, the previous investigation undertaken by Structural Soils in 2002 identified low to intermediate plasticity soils.

The risk to buried concrete (from elevated levels of sulphate) is considered to be low as extensive Made Ground is not anticipated and Mercia Mudstone is unlikely to have high levels of sulphates.

2.6 Phase Two Intrusive Investigation

The Phase One desk study recommended a full intrusive investigation to examine the potential geo-environmental and geotechnical hazards identified above. The findings of the Intrusive investigation are detailed in the subsequent Sections.

3.0 EXPLORATORY INVESTIGATION

3.1 Investigation Points

3.1.1 Introduction

The intrusive investigation was undertaken between 17th and 21st June in accordance with BS5930:2015 and BS10175:2013, and was designed to investigate both geo-environmental and geotechnical hazards identified in the desk study (Appendix B1). It comprised trial pitting, 1no. rotary cored drill hole, measurement of the correlated in-situ CBR values using DCP equipment and groundwater level monitoring.

The exploratory holes were supervised and logged by an engineering geologist in general accordance with BS5930:2015, along with published weathering schemes. Given the presence of Mercia Mudstone beneath the site, the weathering scheme published by Spink and Norbury (1993) has been adopted.

Descriptions and depths of the strata encountered are presented on the trial pit records in Appendix C and the Rotary Core drill hole record in Appendix D1. In addition, photographic records of the rotary core drill hole are presented in Appendix D2. The results of groundwater monitoring and in-situ (DCP) testing are presented in Appendices E and F respectively. The investigation point positions are shown on Figure 2.

The ground levels and co-ordinates indicated on the investigation point records are approximate only and have been interpolated from available digital mapping.

3.1.2 Investigation Strategy

The investigation strategy was generally designed in accordance with BS10171:2013, taking into account the additional potential for geotechnical hazards to be present.

As no specific potential contaminant sources or geotechnical hazards were identified in the desk study (see Section 2.5 and Appendix B1), the investigation points were spread across the site to obtain a general overview of the ground conditions present, particularly at the proposed structure locations. The investigation point locations were positioned to maximise the information that could be obtained, allowing for the constraints imposed by the physical features on site including an area of thick concrete with re-enforcement bar located in the footprint of the proposed extension. Notwithstanding the above constraints, we consider that the investigation undertaken has been sufficient to identify the key ground issues at the site.

3.1.3 Trial Pits

9no. trial pits (TP1 to TP9) were excavated across the site on 1th June using a wheeled hydraulic excavator. The trial pits were excavated to a maximum depth of 3.6m. The concrete surface was broken out prior to the excavation of the pits using a hydraulic breaker (TP9). In addition, concrete was encountered at depths of between 0.8m and 1.0m below surface level in TP7 and TP8. This was broken out using the hydraulic breaker to progress the trial pits. The trial pit records are presented as Appendix C.

Disturbed samples were collected from the trial pits for laboratory testing. On completion, the trial pits were backfilled with arisings in layers compacted with the excavator bucket. The arisings were left slightly proud of the adjacent surface to allow for future settlement. The concrete surface was not reinstated in TP9, however, a layer of coarse aggregate was placed at the surface of the pit and compacted level with the surrounding concrete to ensure vehicle movements around this area were not limited.

3.1.4 Rotary Cored Drill holes

1no. rotary cored drill hole was constructed (RC1) to a depth of 14.8m below surface level in the area of the proposed construction/maintenance pit between 20th and 21st June 2016. The ODEX 115 system of simultaneous drilling and casing was used in the Made Ground and the drill hole records are presented as Appendix D1. In addition, photographic records of the rotary core drill hole are presented in Appendix D2.

At the commencement of the borehole, the excavator being used for the trial pits was used to construct a service inspection pit to 1.2m below surface level (TP7). As detailed in Section 3.1.3, TP7 encountered concrete between 0.8m and 1.0m depth. This was broken out and the pit progressed to 1.2m prior to drilling. Compressed air and circulated water was used as a flushing medium to keep the drill bits cool.

Cores were recovered in plastic liners using a triple tube barrel system, over runs of nominal 1.5m length. Where recovery was poor, the core length was reduced for the next run to maximise the chances of good recovery. The recovered cores were sealed in the plastic liners and placed in solid core boxes to prevent disturbance and swelling before logging. The plastic liners were only cut immediately prior to logging and sampling. In addition to the nature of the rock material, the identified fractures within the rock mass were also logged in accordance with BS5930:2015. The Rock Quality Designation (RQD) recorded was for rock core 100mm or greater in length. The fracture state of the recovered cores is presented on the drillhole records.

On completion, groundwater monitoring instrumentation was installed in borehole, as detailed in Section 3.2.1.

3.1.5 Dynamic Cone Penetrometer Testing (DCP)

CBR testing using the TRL approved dynamic cone penetrometer (DCP) was undertaken at 5no. positions (DCP1 to DCP5) on 17th June 2016. The testing was undertaken within constructed trial pits, beneath the Made Ground, along areas of proposed concrete slabs. The positions of the DCP tests (within their respective trial pits) are shown on Figure 2, with the test results presented in Appendix F.

The DCP test involves the fall of a fixed weight over a fixed height to force a 20mm diameter, 60° cone into the near surface soils. The depth of penetration for varying numbers of blows is recorded and is then converted to a CBR value using well established empirical correlations (Highways Agency, 2008). In general, the tests were undertaken between the existing ground surface and 0.9m below ground level, thus providing a profile of correlated CBR values within the near-surface soils. No water was added to the soils prior to testing, so they were in their natural condition.

3.2 Instrumentation – Groundwater Well Installation

A 50mm diameter groundwater monitoring well was installed in RC1 in accordance with BS8576:2013 in order to allow short-term monitoring of the groundwater level. The well, comprising slotted plastic pipe with a gravel surround (the response zone), bentonite seal above the response zone, and a lockable vandal proof cover, were installed as detailed on the rotary core record (Appendix D).

The well was installed within the Mercia Mudstone bedrock to allow monitoring of the groundwater level. This is pertinent to this development due to the potential deep excavation (10m below surface level) proposed for the construction/maintenance pit.

3.3 Sampling Strategy

3.3.1 Soil Sampling

Soil samples were collected from the exploratory holes as discussed in the previous sections. The sampling procedures were selected on the basis of the suitability for the laboratory testing proposed.

A non-targeted, random sampling strategy was used to obtain representative information on soil contamination across the areas of proposed development as a whole.

Environmental samples were collected for possible geo-environmental laboratory testing and generally comprised a plastic tub and an amber glass jar. The sample containers are provided clean by the testing laboratory and are appropriate for the proposed testing to be scheduled. Immediately after collection the samples were placed in sealed cool boxes with ice packs where they remained during storage and transport to the laboratory.

Samples for logging and geotechnical laboratory testing purposes were collected at regular intervals within the exploratory holes.

3.3.2 Soil Sample Quality

Samples of soil recovered from investigations are classified as Classes 1 to 5 in terms of quality and depend on the investigation and sampling method, the particle size of the strata sampled, and the presence of groundwater. Class 1 and 2 samples are those in which there has been no or only slight disturbance of the soil structure, with moisture contents and void ratios being similar to the in-situ soil. Class 3 and 4 samples contain all the constituents of the in-situ soil in their original proportions, and the soil has retained its original moisture content, but the structure of the soil has been disturbed. In Class 5 samples, the soil structure and original layering cannot be identified and the water content may have changed from that in-situ. The category and class of samples are discussed further in BS EN ISO 22476:2006, EN 1997-2:2007 and BS5930:2015.

In general terms, disturbed samples recovered from trial pits (bulk bags and small tubs) are classed as Class 3 (if dry), Class 4 (fine soil below the water table), or Class 5 (coarse soils from beneath the water table).

Provided recovery is good, rock cores collected using rotary techniques are classified as Class 2 samples, provided that the plastic liners are sealed and only opened immediately prior to logging. The chippings recovered during open-holes drilling are considered Class 5 samples.

3.3.3 Groundwater Monitoring

In order to establish the groundwater level beneath the site, the groundwater level has been measured on 3no. occasions to date. Due to the proximity of the Severn Estuary (a tidal estuary), the monitoring was undertaken at times of low, high and falling tide, to investigate the influence of the tide (if any) on groundwater levels at the site. The monitoring was undertaken on the dates below and the results are presented in Appendix E:

- Thursday 30th June - Low Tide: 2.08m below ground level.
- Monday 11th July - High Tide: 2.30m below ground level.
- Friday 22nd July - Falling tide: 2.46m below surface level.

3.4 Evidence of Site Hazards Found During Site Works

3.4.1 Site Stability

No evidence of geotechnical hazards were identified in the exploratory holes.

3.4.2 Site Evidence of Contamination

No direct visual/olfactory evidence of contamination was identified in the exploratory holes. However, Made Ground was present across the site which can contain elevated levels of contaminants such as metals and polyaromatic hydrocarbon (PAH) compounds. In particular, the Made Ground encountered in the shallow soils within TP1, TP2 and TP3 identified an ashy content within the recovered material.

The Made Ground was generally identified as a gravel surface overlying limited re-worked soils to create a level surface at the site. Where the gravels were encountered, a geotextile membrane was identified overlying the natural strata.

Made Ground was encountered to a depth of 2.6m below surface level in TP4. The recovered materials largely comprised gravel and cobbles with a number of man-made materials such as brick, porcelain, glass metal and plastic.

3.5 Geotechnical Laboratory Testing

Geotechnical laboratory testing was undertaken on samples from the suitable quality classes recovered from the exploratory holes in order to obtain information on the geotechnical properties on the soils beneath the site.

The following tests were undertaken by a UKAS accredited laboratory on samples selected by ESP in accordance with the methodologies presented in BS1377:1990. The results are presented in Appendix G.

- Natural moisture content.
- Atterberg limits.
- Determination of Point Load Value Axial or Diametrical

Selected samples were also analysed for soil sulphate and pH value in accordance with the analytical methods specified in BRE Special Digest SD1 (BRE, 2005). The results of the sulphate testing are included with the geo-environmental test results in Appendix H.

3.6 Geo-environmental Laboratory Testing

Laboratory testing has been undertaken to identify the levels of selected contaminants within samples of soil. The geo-environmental analyses were carried out by a UKAS accredited testing laboratory with detection limits being generally compatible with the relevant guideline values adopted in the assessment.

3.6.1 Soil Samples

The PRA (Section 3.1.2) did not identify any particular contaminants of concern at the site. However, given the presence of Made Ground in order to allow an assessment of the potential chronic risks posed to human health, a total of six selected samples of the Made Ground have been analysed for contaminants typically found on brownfield sites in the UK. The general suite of geo-environmental laboratory testing undertaken comprised:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, chromium VI, copper, lead, mercury, nickel, selenium, vanadium, zinc;
- US EPA 16 polyaromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols;
- Total cyanide, asbestos qualitative screen (presence or absence);
- Soil organic content, pH value;

The geo-environmental soil test results are presented in Appendix H.

4.0 DEVELOPMENT OF THE REVISED CONCEPTUAL MODEL

4.1 Geology

The exploratory holes have identified the site to be generally underlain by a thin veneer of Made Ground overlying Mercia Mudstone bedrock. Deeper Made Ground was encountered in TP4 to a depth of 2.6m. These strata are discussed in more detail in the following sections.

Made Ground: encountered generally across the site as a gravel sub-base material used to create a level surface, suitable for vehicles, around the site. Deeper Made Ground was identified in TP4, comprising gravel and cobbles to a depth of 2.6m, with fractions of man-made materials.

In addition, a re-enforced concrete slab was identified in TP7 and TP8 in the area of the proposed construction/maintenance pit. Anecdotal evidence identified this area to be associated with the previous works and the concrete slab sloped into the existing structure, to a probable service area. It is likely that this concrete slab extends across a wide area of the proposed development and will require grubbing up prior to any works.

Mercia Mudstone Formation Bedrock: encountered in differing states of weathering across the site as detailed below:

Class Dc/Db Mercia Mudstone Formation
Encountered in TP4, TP5a, TP5b, TP6 and TP8 to a maximum depth of 3.5m below surface level. The bedrock was identified to be extremely weak (in terms of rock strength) and was recovered as a firm to stiff clay with fractions of sand and gravel with visible mudstone lithorelics.

Laboratory testing within the Class Dc/Db weathered bedrock indicated liquid limits between 41% and 49%, plasticity indices of 21% and natural moisture contents between 21% and 27%. The modified plasticity indices (after the coarse-grained particles have been removed) suggest that the soils are generally of medium volume change potential and would be generally classified as clays of intermediate plasticity.

Class Da/C Mercia Mudstone Formation
Encountered in RC1 only between depths of 12.3 to 12.7m below surface level. The bedrock was identified to be weak to medium strong mudstone recovered as dense to very dense mudstone gravel.

Class B Mercia Mudstone Formation
Encountered in TP1, TP2 and TP3 in the south of the site to a maximum depth of 3.6m below surface level. The bedrock was identified to be weak to very weak (in terms of rock strength) and was recovered as medium dense to dense fine to coarse angular gravel with angular cobbles. A fraction of sand sized materials (weathered rock) was identified within the recovered arisings. The Class B weathered rock was also encountered within RC1 at depths of between 6.0m to 9.2m and 12.7m to 14.8m.

Class B/A Mercia Mudstone Formation
Encountered in TP9 only, immediately below the concrete slab to a maximum depth of 1.6m below surface level. The bedrock was identified to be weak to medium strong mudstone recovered as dense becoming very dense fine to coarse angular mudstone gravel with medium to high angular mudstone cobble content and medium angular mudstone boulder content.

Further discussion on the strengths of the recovered Mercia Mudstone bedrock within the rotary core drill hole is continued in Section 7.1.5.

4.2 Hydrogeology

4.2.1 Groundwater Bodies

The groundwater conditions identified in the investigation are summarised in Table 1 below:

Table 1: Summary of groundwater ingress in the investigation

Hole ID	Stratum	Comment on groundwater encountered
TP1	Made Ground	Very slow seepage of probable perched water at 0.55m depth.
TP2	Made Ground	Medium flow of probable perched water at 0.55m depth.
TP3	Made Ground	Very slow seepage of probable perched water at 0.50m depth.
TP4	Mercia Mudstone	Very slow seepage of probable groundwater at 2.8m depth.
TP8	Made Ground	Slow seepage of probable perched water at 0.85m depth.
RC1	Mercia Mudstone	Water strike at 2.0m depth during borehole construction. Monitored at levels of 2.08m, 2.30m and 2.46m below surface level between 30th June and 22nd July 2016 during period of dry and warm weather.

Based on the above findings and the Conceptual Ground Model, we consider that the main groundwater body beneath the site is within the Mercia Mudstone bedrock, at around 2.0 to 2.5m depth. However, a perched water table also appears to be present within the Made Ground soils at around 0.5 to 0.8m depth, dependant on where the threshold between the Made Ground and the Mercia Mudstone exists. Due to the fine grained nature of the bedrock, the perched water will stay within the coarse Made Ground, not penetrating significantly into the weathered rock below.

4.2.2 Hydraulic Gradient

Short-term monitoring of groundwater levels within one borehole has been undertaken at the site to date. Based on the site setting and available information, we consider that the hydraulic gradient beneath the site is likely to be towards the south/south east to the Severn Estuary.

4.3 Site Instability

4.3.1 Global Site Stability

No evidence was identified of potential landslips or unstable ground in the Preliminary Geotechnical Risk Register (Appendix B1) and we identified no evidence of any global instability issues on the site.

4.3.2 Excavation Stability

During the excavation of the trial pits, some spalling of the pit walls was experienced, particularly within the Made Ground stratum where encountered to greater depths (TP4).

4.4 Chronic Risks to Human Health – Generic Assessment of Risks

4.4.1 Assessment Methodology

The long term risks to health have been assessed using methodologies and frameworks determined by the Environment Agency within documents SR2, SR3, SR4 and the CLEA Technical Review published to support the Contaminated Land Exposure Assessment Model (CLEA). Where applicable, reference has been made to the supporting toxicological reports (TOX Series) and the Soil Guideline Value reports (SGV Series). It is assumed that the reader is familiar with the above documents and it is not intended to repeat these described methodologies in detail, for further information, please refer directly to the specific documents.

In order to provide an initial 'screen' to identify elevated levels of contaminants, a Generic Quantitative Risk Assessment (GQRA) has been undertaken using the most appropriate Generic Assessment Criteria (GAC) determined by assessment of exposure frequency/duration relevant to the critical receptor.

4.4.2 Assessment Criteria

In 2014, DEFRA published the Category 4 Screening Levels (C4SL) for use in Part 2A determinations. The C4SL are designed to be more pragmatic, but still strongly precautionary, assessment criteria compared to the previous assessment criteria (SGV – see below) used to assess chronic human health risks. They are designed for use in deciding whether land is suitable for use and definitely not contaminated, and DEFRA and the Welsh Government have recommended that they be used in assessing human health risks during the planning regime (i.e. as part of standard development investigations). However, the C4SL have been calculated for a limited number of contaminants at this stage, and range of land uses including residential, commercial and public open space, but are based on a 'low level' of risk rather than the 'minimal level' of risk adopted by the Environment Agency in preparing their Soil Guideline Values (SGV). At the time of writing, the use of the C4SL in planning has not yet been accepted by many parties, including some regulators. The C4SL have also only been published for a limited number of contaminants. The C4SL have not been generally adopted in this assessment.

In this assessment, where available, the Soil Guideline Values (SGV) published by the Environment Agency have been adopted as the Generic Assessment Criteria (GAC) in the first instance. However, the SGV are only available for a limited number of contaminants for three proposed land uses (residential, commercial and allotments - not public open space). Where no SGV is available, the Suitable For Use Levels (S4ULs) published in January 2015 by the Chartered Institute of Environmental Health (CIEH) and Land Quality Management (LQM) have been adopted (Nathanail et al, 2015). These assessment criteria adopt updated toxicological data and exposure models, but the same 'minimal level' of risk as the SGV (i.e. unlike the C4SL). The S4ULs have been published for a large number of contaminants typically found on brownfield sites in the UK, and for the same range of land uses as the C4SL, i.e. including public open space scenarios.

For more exotic, predominantly organic, compounds no SGV, S4UL or C4SL assessment criteria have been published. In this instance, GAC published by CL:AIRE and the Environmental Industries Commission (CL:AIRE/EIC, 2010) have been adopted.

These GAC have also been developed using the CLEA UK software based on a 'minimal level' of risk and for the same land use scenarios as the SGVs (i.e. not public open space).

At the time of writing there is no published SGV, S4UL or CL:AIRE/EIC assessment criteria for lead. For the purposes of this assessment, and in the absence of any other current authoritative guidance, the Category 4 Screening Level (C4SL) value published by DEFRA has been adopted.

Details of the source of the GAC adopted for each contaminant are presented on the assessment table below.

The proposed development comprises a commercial/industrial unit and office facilities, with external hardstanding and landscaping. Therefore, the GAC appropriate for the commercial land use have been adopted in this assessment.

The GAC for most organic compounds are dependent on the organic content of the soil. Analysis has shown that the soil organic content in the soils analysed ranged from 0.1 to 8.5% with an average of 2.3%. Therefore, for the purposes of this assessment, GAC for a soil organic content of 1% has been adopted. This again is considered a conservative approach for the majority of the soils at the site.

4.4.3 Generic Quantitative Risk Assessment

The samples analysed for soil contaminants comprised 6no samples of Made Ground. At this stage, all samples have been considered across the site as one averaging area. If any exceedances are identified, a statistical analysis based on particular averaging areas may be undertaken to further assess the risks. The risks from asbestos are considered further in Section 5.4.4.

The results of the Generic Quantitative Risk Assessment are presented in Table 2 below.

Table 2: Summary of Geo-environmental Soil Results

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	2.6 - 37mg/kg	640mg/kg	SGV[2]	None of 6
Barium	100 – 1,500mg/kg	22,000mg/kg	CL:AIRE[4]	None of 6
Beryllium	<0.2 – 0.6mg/kg	12mg/kg	S4UL[3]	None of 6
Boron	<0.2 – 1.7mg/kg	240,000mg/kg	S4UL[3]	None of 6
Cadmium	<0.1 – 1.5mg/kg	230mg/kg	SGV[2]	None of 6
Chromium (total)[6]	6.2 - 19mg/kg	8,600mg/kg	S4UL[3]	None of 6
Chromium (hexavalent)	<1.0mg/kg	33mg/kg	S4UL[3]	None of 6
Copper	5.9 - 21mg/kg	68,000mg/kg	S4UL[3]	None of 6
Lead	6.3 - 68mg/kg	200mg/kg	C4SL[5]	None of 6
Mercury[7]	<0.05 – 0.05mg/kg	3,600mg/kg	SGV[2]	None of 6
Nickel	4.7 - 18mg/kg	980mg/kg	S4UL[3]	None of 6
Selenium	<0.5 – 0.7mg/kg	13,000mg/kg	SGV[2]	None of 6
Vanadium	11 - 27mg/kg	9,000mg/kg	S4UL[3]	None of 6
Zinc	33 - 140mg/kg	730,000mg/kg	S4UL[3]	None of 6

Table 2: Summary of Geo-environmental Soil Results (cont.)

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Polyaromatic Hydrocarbons (PAH)				
Acenaphthene	<0.03 – 2.0mg/kg	84,000mg/kg*	S4UL[3,8]	None of 6
Acenaphthylene	<0.03 – 2.5mg/kg	83,000mg/kg*		None of 6
Anthracene	<0.03 – 7.4mg/kg	520,000mg/kg		None of 6
Benzo(a)anthracene	<0.03 - 25mg/kg	170mg/kg		None of 6
Benzo(a)pyrene	**<0.03 - 47mg/kg**	**35mg/kg**		**1 of 6**
Benzo(b)fluoranthene	**<0.03 - 59mg/kg**	**44mg/kg**		**1 of 6**
Benzo(ghi)perylene	<0.03 - 32mg/kg	3,900mg/kg		None of 6
Benzo(k)fluoranthene	<0.03 - 17mg/kg	1,200mg/kg		None of 6
Chrysene	<0.03 - 27mg/kg	350mg/kg		None of 6
Dibenzo(a,h)anthracene	**<0.03 – 6.3mg/kg**	**3.5mg/kg**		**1 of 6**
Fluoranthene	<0.03 - 52mg/kg	23,000mg/kg		None of 6
Fluorene	<0.03 – 1.8mg/kg	63,000mg/kg*		None of 6
Indeno(123-cd)pyrene	<0.03 - 30mg/kg	500mg/kg		None of 6
Naphthalene	<0.03 – 0.41mg/kg	190mg/kg*		None of 6
Phenanthrene	<0.03 - 17mg/kg	22,000mg/kg		None of 6
Pyrene	<0.03 - 49mg/kg	54,000mg/kg		None of 6
Other Organic Compounds				
Phenol	<0.3 – 2.8mg/kg	760mg/kg	S4UL[3,8]	None of 6

Notes to Table 2:

1. Assessment for commercial land use.
2. CLR SGV: Soil Guideline Value published by Environment Agency.
3. S4ULs Suitable 4 Use Levels. Copyright Land Quality Management Limited, reproduced with permission; Publication No. S4UL3156. All Rights Reserved.
4. CL:AIRE/EIC GAC published by CL:AIRE and Environment Industries Commission.
5. C4SL: Category 4 Screening Level. No current SGV, S4UL or CLAIRE/EIC assessment criteria for lead. Category 4 Screening Level adopted in assessment.
6. In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted.
7. GAC for inorganic mercury adopted.
8. GAC for organic compounds based on 1% soil organic content.
9. Exceedances highlighted in red and bold.
10. Laboratory results presented in Appendix H.

From Table 2, it is clear the majority of the determinands analysed were below their respective GAC, however marginal elevations of Benzo(a)pyrene, Benzo(b)fluoranthene and Dibenzo(a,h)anthracene were identified in TP3 with in the Made Ground at 0.55m depth.

The levels of Benzo(a)pyrene ranged from <0.03 to 47mg/kg, with an average of 14.2mg/kg, well below the GAC of 35mg/kg.

The levels of Benzo(b)fluoranthene ranged from <0.03 to 59mg/kg, with an average of 17.9mg/kg, well below the GAC of 44mg/kg.

The levels of Dibenzo(a,h)anthracene ranged from <0.03 to 6.3mg/kg, with an average of 2.5mg/kg, well below the GAC of 3.5mg/kg.

It should be noted that the only elevations encountered were within TP3 at 0.55m depth and all of the other samples tested were well below the associated GAC's.

4.4.4 Asbestos

No evidence of asbestos was identified in the samples analysed.

4.5 Ground Gas

No evidence of decaying organic material associated with the historical woodland at the site or potentially putrescible materials associated with the diverted water drain were identified during the investigation, therefore the risks from hazardous ground gas at the site are considered low.

In addition to the above, the following conditions at the site will mitigate and limit the migration of gas beneath the site:

- The fine grained nature of the mudstone beneath the site will limit the migration of any gases;
- Shallow groundwater measured at between 2.08 and 2.46m below ground level with further limit the movement of ground gas;
- The proposed end use as a commercial development is considered to be of low sensitivity.

Based on the above, we consider the potential risk from hazardous ground gas at the site to be low.

As detailed in the Pahe One desk study (Appendix B1), the Groundsure report identifies that the site lies in an area where less than 3-5% of homes are above the action level for radon, with basic radon protection measures required.

4.6 Sulphate Attack

The assessment of the concrete protection against sulphate attack has been undertaken in accordance with BRE SD1 (2005).

Site Setting
Due to the presence of up to 2.6m of Made Ground comprising on the site, we consider that it should be classified as 'brownfield' in terms of concrete classification.

Groundwater Setting
Groundwater was monitored in the borehole (RC1) within the installed well at a minimum depth of 2.08m in the weathered bedrock. This is likely to be close to the depth to which buried concrete will be placed. Therefore, groundwater has been considered as mobile in this assessment.

Sulphate Levels:
Laboratory test results indicate the levels of water soluble sulphate (as SO_4) in the Made Ground soils to be between 14mg/l and 160mg/l. As levels of water soluble sulphate are less than 3,000mg/l, there is no need to consider the levels of magnesium present in the soils. Levels of acid soluble sulphate varied between 0.02% and 0.08% and total sulphur between,0.01% and0.03%.

From these results, the calculated levels of total potential sulphate are between 0.03% and 0.09%, and oxidisable sulphides are between 0.01% and 0.02%. As the levels of oxidisable sulphide are well below 0.3%, pyrite is unlikely to be present.

pH values Varied between 7.8 and 11.4, indicating near neutral to alkaline soil conditions to exist. As the pH levels all exceed 5.5, there is no need to further assess the soils for the types of acids present (e.g. hydrochloric and nitric acids).

Foundation Concrete Design:

Using the above results, we consider that the following characteristic values are applicable for the shallow soils at the site (all as SO_4):

Water soluble sulphate:	160mg/l;
Total potential sulphate:	0.09%
pH value:	7.8

5.0 PHASE TWO GEO-ENVIRONMENTAL RISK ASSESSMENT

5.1 Discussion on Occurrence of Contamination and Distribution

Prior to the construction of the existing building, no significantly contaminative former use has been identified. The most plausible pollutant source is likely to be the existing manufacturing plant constructed between 2002 and 2010.

Made Ground has been encountered generally across the site as a gravel sub-base material used to create a level surface, suitable for vehicles, around the site. Deeper Made Ground was identified in TP4, comprising gravel and cobbles to a depth of 2.6m, with fractions of man-made materials. In addition, a re-enforced concrete slab was identified in TP7 and TP8 in the area of the proposed construction/maintenance

Laboratory testing has identified the majority of the determinands analysed were below their respective GAC, however marginal elevations of Benzo(a)pyrene, Benzo(b)fluoranthene and Dibenzo(a,h)anthracene were identified in TP3 with in the Made Ground at 0.55m depth. It should be noted that the only elevations encountered were within TP3 at 0.55m depth and all of the other samples tested were well below the associated GAC's.

5.2 Revised Risk Evaluation & Relevant Pollutant Linkages

As discussed in detail within Section 3.2.1, the methodology set out in CIRIA C552 (2001) has been used to assess whether or not risks are acceptable, and to determine the need for collating further information or remedial action.

The risks evaluated at the desk study stage of this report (Table 4, Section 3.2.2) have been updated and revised in Table 3 following information learned from the exploratory works and results of monitoring and laboratory testing.

Table 3: Revised Risk Evaluation & Relevant Pollutant Linkages (RPL).

Source	Pathway	Receptor	Classification of Consequence	Classification of Probability	Risk Category	Further Investigation or Remedial Action to be Taken
Potential contaminants in Made Ground	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users (workers/visitors)	Medium – potential for chronic levels.	Unlikely[2]	Low Risk	See Section 6.0 for further discussion.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	Low likelihood[2]	Very Low Risk	
	Leaching of soil contaminants	Impact on Groundwater	Medium – site lies on Secondary B Aquifer	Unlikely[3]	Low Risk	See Section 6.0 for further discussion.
	Leaching of soil contaminants	Impact on Surface Water	Medium – site lies adjacent to small stream	Unlikely[3]	Low Risk	
Soil sulphate	Aggressive groundwater	Buried Concrete	Mild – damage to structures	Unlikely[4]	Very Low Risk	See Section 6.4.2 for further discussion.
Asbestos in shallow soils	Ingestion of fibres	Demolition/ Construction Workers	Medium – potential for chronic levels	Unlikely[5]	Low Risk	See Section 6.1.1 for further discussion.
Radon Gas	Migration into Buildings	Site Users (workers/visitors)	Medium – potential for chronic levels	Low Likelihood[6]	Moderate/Low risk	See Section 6.3.2 for further discussion.
Ground gas generated in organic alluvial soils	Asphyxiation/ poisoning, injury by explosion	Site Users / Visitors	Severe	Unlikely[7]	Moderate/Low risk	See Section 6.3.1 for further discussion.
	Damage through explosion	Buildings	Severe	Unlikely[7]	Moderate/Low risk	
	Asphyxiation/ poisoning, injury by explosion	Construction/ Maintenance Workers	Severe	Unlikely[7]	Moderate/Low risk	

Notes:

1. This table updates the Preliminary Risk Assessment undertaken as part of the Phase One desk study (Appendix B1). Methodology and details of risk consequence, probability and category presented in Appendix A.
2. Levels of benzo[a]pyrene, benzo{b}fluoranthene and dibenzo{a,h}anthracene exceed the Generic Assessment Criteria in shallow soils from TP3 only.
3. Site is underlain by a secondary B aquifer and the fine grained soils beneath the site will limit the migration of contamination. Furthermore, the development in the area of TP3 where the elevated levels were identified will comprise a concrete slab. This will limit break the migration path way to receptors (site users).
4. Low levels of sulphates identified in the laboratory testing.
5. No asbestos was identified in the samples tested.
6. Radon risk identified in Phase One desk study (Appendix B1) – basic radon protection measures will be required.
7. No evidence of decaying organic material associated with the historical woodland at the site or potentially putrescible materials associated with the diverted water drain were identified during the investigation, therefore the risks from hazardous ground gas at the site are considered low.

6.0 REMEDIAL STRATEGY FOR CONTAMINATION RISKS

The following recommendations are based on interpretations made from the relatively limited site investigation data obtained to-date, and do not form the full Options Appraisal stage of CLR11. If at any stage of the construction works, contamination or a potential for such contamination is identified that is different to that presented within this report, all of the following should be reviewed and the advice of a geo-environmental specialist sought immediately.

6.1 Risks to Health

6.1.1 Asbestos

No asbestos was detected during this phase of works. If any ACM are encountered during development, the advice of a suitably qualified specialist should be sought, and any identified ACM removed from site by a licensed specialist contractor.

6.1.2 Site End Users

Assuming an end use as a commercial development, the identified levels of soil contamination at the site are not considered to pose a risk to future site users. Therefore, no specific remedial measures are considered necessary for the development.

In the area of TP3 where a concrete slab is proposed, we recommend that targeted shallow sampling is undertaken in order to robustly assess the potential contamination issues. Depending on the findings, removal of the contaminated soils may be required to mitigate the short term risks to human health. The long term risks will be mitigated by the proposed concrete slab. If removal is preferred, sufficient space to allow a minimum 600mm thickness of clean cover to be constructed will be required. A suitable geotextile should be placed at the base of the cover layer and immediately overlain by a capillary break layer to prevent contaminants being drawn up into the cover system.

6.1.3 New Service Connections

The current water industry guidance for the suitability of pipe materials on potentially contaminated sites (Blackmore et al, 2010) has onerous requirements and it is likely/possible, based on this guidance, that the levels of contaminants on site may prevent the use of plastic pipework. We recommend that enquiries are made to the local water authority to confirm their requirements for underground service materials for this development.

6.1.4 Risk to Construction and Maintenance Workers

Short term (acute) risks to construction and maintenance workers are generally poorly understood within the industry, certainly when compared to the volume of research undertaken on long term risks. However, we anticipate that the levels of contamination at the site are not likely to pose a severe acute risk to construction workers or future maintenance workers. Ground workers would need to undertake their own assessment of the risks to their workers. We recommend that construction workers adopt careful handling of the soils and good standards of personal hygiene should be adopted to reduce the risk of possible ingestion and skin contact should any hotspots be encountered. The contractor should comply with the appropriate current Health and Safety at work legislation.

6.1.5 General Public/Neighbouring Properties

We do not anticipate any significant risks to the general public from the development of the site. However, careful dust control measures should be adopted during construction to minimise the risk (and nuisance) to the general public and neighbouring residents.

6.2 Risks to Controlled Waters

No specific assessment of the risks to controlled waters has been undertaken to date. However, the following points are considered salient based on the exploratory works (trial pits and 1no. rotary cored drill hole) undertaken to date:

- Prior to the construction of the existing building, no significantly contaminative former use has been identified. The most plausible pollutant source is likely to be the existing manufacturing plant constructed between 2002 and 2010.
- Made Ground has been encountered generally across the site as a gravel sub-base material used to create a level surface, suitable for vehicles, around the site. Deeper Made Ground was identified in TP4, comprising gravel and cobbles to a depth of 2.6m, with fractions of man-made materials. In addition, a re-enforced concrete slab was identified in TP7 and TP8 in the area of the proposed construction/maintenance
- The levels of soil contaminants are generally below their associated GAC, with marginal elevations of PAH's identified in TP3 within the Made Ground. These are likely to be removed a part of the development works.
- The proposed development comprises a commercial construction which will include areas of car parking and hard surfaces.
- The site is underlain by fine grained weathered bedrock which contains a high fine-grained fraction in its upper layers, limiting the migration of contamination.
- The bedrock beneath the site is classified as a Secondary B aquifer. Groundwater is anticipated within the weathered bedrock at depths of around 2.0m below surface level.

Given the above, we consider that the overall risk to controlled waters from the development of the site is likely to be low and no further assessment is warranted. However, some risk mitigation is likely to be required if soakaways are used to dispose of surface water run-off.

Notwithstanding the above, no exploratory works were undertaken beneath the existing building. Strict diligence and care to evaluate potential pollution sources from within the existing building should be undertaken throughout the development works. Any potential sources of contamination or evidence of contamination identified in areas not explored during the investigation should be assessed by a qualified geo-environmental engineer.

6.3 Risks from Ground Gas

6.3.1 Risk to the Development – Degradation of Organic Material

No potential source of hazardous ground gas has been identified, so the risks are considered low and no risk mitigation measures are considered necessary.

6.3.2 Risk to the Development – Radon

The Preliminary Risk Assessment (Appendix B1) has indicated that basic radon protection is required.

6.3.3 Risk to Construction and Maintenance Workers

Based on the above results we do not consider there is a particular risk to construction and maintenance workers, and there is no requirement to define shallow excavations as confined spaces. However, we recommend good site practice and all excavations should be considered potentially confined spaces.

Carbon dioxide is a particular risk in Made Ground materials as it is commonly present and as it is heavier than air, it can displace it at the base of excavations, which can then lead to workers being at risk from asphyxiation. If during construction any organic materials are encountered they should be excavated and replaced.

Notwithstanding the above, the significant earthworks proposed for a 10m construction/maintenance pit will require substantial temporary works to ensure the stability of the excavation throughout the development. The temporary works will require careful design (taking into account shallow groundwater) and include consideration of all potential contamination implications given the depth (below the water table) of the proposed pit.

6.4 Risks to Property

6.4.1 Spontaneous Combustion

No evidence of combustible materials has been identified in the shallow soils. Therefore, the risk from spontaneous combustion is considered to be low.

6.4.2 Sulphate Attack on Buried Concrete

From Section 4.6, the following characteristic values are applicable for the shallow soils at the site (all as SO_4):

Water soluble sulphate:	160mg/l;
Total potential sulphate:	0.09%
pH value:	7.8

Based on these characteristic values, we consider that the site would be classified as Design Sulphate Class DS-1 and Aggressive Chemical Environment for Concrete Class AC-1, allowing for mobile groundwater.

6.5 Re-Use of Materials/Disposal of Excess Arisings

All soils or other materials excavated from any site are generally classified as waste under the Waste Framework Directive (European Union, 2008) and their re-use is controlled by this legislation.

If the soils are to be re-used on site (e.g. within the red-line planning boundary), provided that they are 'uncontaminated' or other naturally occurring deposits and they are certain to be used for the purposes of construction in their natural state on the site from which they are excavated, they may be excluded from waste regulation (CLAIRE, 2011). A Materials Management Plan (MMP) may be required – further guidance can be provided by this office once proposals have been finalised. However, if they are man-made or contaminated materials, their use on the site may be limited.

If the soils are to be removed from site, they are automatically classified as waste, and they may only be:

1. Disposed at a licensed landfill;
2. Disposed at a licensed, permitted soil treatment centre; or
3. Removed to a Receiver Site for beneficial re-use.

In Scenarios 1 and 2, the materials must be transferred by a licensed waste carrier and the waste producer (the developer) must ensure that the destination landfill or treatment centre is a legitimate operation (e.g. by requesting a copy of the Environmental Permit before releasing the soils). Prior to removal from site, the excavated arisings would need to be classified as either 'hazardous' or 'non-hazardous' waste based on the hazard that they pose – a WM2 assessment (note that this is a different assessment to the risk assessments reported on in earlier sections of this report). This can commonly be undertaken on the results of soils testing undertaken during the investigation, although further sampling and testing may be required. Only once the soils have been classified under the WS2 assessment, would Waste Acceptability Criteria (WAC) testing then be required to determine the type of landfill in which the arisings could be disposed in Scenario 1. Further testing and assessment may also be required by the soil treatment centre in Scenario 2.

In Scenario 3, management of soils could be undertaken via an Environmental Permit or Exemption. However, these can take time and are costly to arrange. Therefore, in certain circumstances, it is permissible to use the protocols laid down in the CL:AIRE Definition of Waste, Development Industry Code of Practice (DoWCoP, Duckworth, 2011) to classify the arisings and put a management plan in place to control the use. This involves approval of the proposals by a Qualified Person and is generally more efficient (in terms of time and cost) to implement.

Further guidance on the legislative requirements of the re-use/disposal of materials generated by the development can be provided by this office once the development proposals have been finalised.

7.0 GEOTECHNICAL COMMENTS

7.1 Site Preparation and Earthworks

7.1.1 Invasive Plants

No evidence of invasive plants such as Japanese Knotweed and Himalayan Balsam were identified on the site during the site works.

7.1.2 Existing Foundations and Services

The site has been previously developed as a manufacturing plant and old foundations and underground structures are anticipated beneath the site, within the footprint of the proposed development areas (see Figure 2). The investigation identified the following sub-surface structures:

- A re-enforced concrete slab was identified in TP7 and TP8 in the area of the proposed construction/maintenance pit. Anecdotal evidence identified this area to be associated with the previous works and the concrete slab sloped into the existing structure, to a probable service area.
- A re-enforced concrete slab is present at the surface of the proposed building development.

These sub-structures and any others identified during development should be grubbed up within the zone of influence of the development as part of the site preparation works.

A non-operational water main is identified underlying the site in the south west corner, trending south east to north west. No other services (gas, electric, sewer, BT etc.) are identified on the service plans obtained, however, these services are likely to be present around the existing development and entering the building present.

During the works, ESP were shown plans of existing electric and sewer lines across the site and a representative on site pointed out their approximate position during the walkover. These plans should be obtained and the locations of existing services determined prior to any works.

In addition, a small electrical cable was encountered within green coloured ducting in TP5a (see Appendix C).

The presence and positions of services along with an allowable exclusion zone should be made when planning the development and site works. Further details should be obtained from the service providers.

A network of land drains is likely to be present and may provide a seepage path into excavations. The land drains should be diverted where they enter foundation excavations.

7.1.3 New Services

For new services, flexible pipework and connections should be provided as a safeguard against potential settlements. Consideration could be given to increasing the gradients on sewage connections to mitigate against possible settlements.

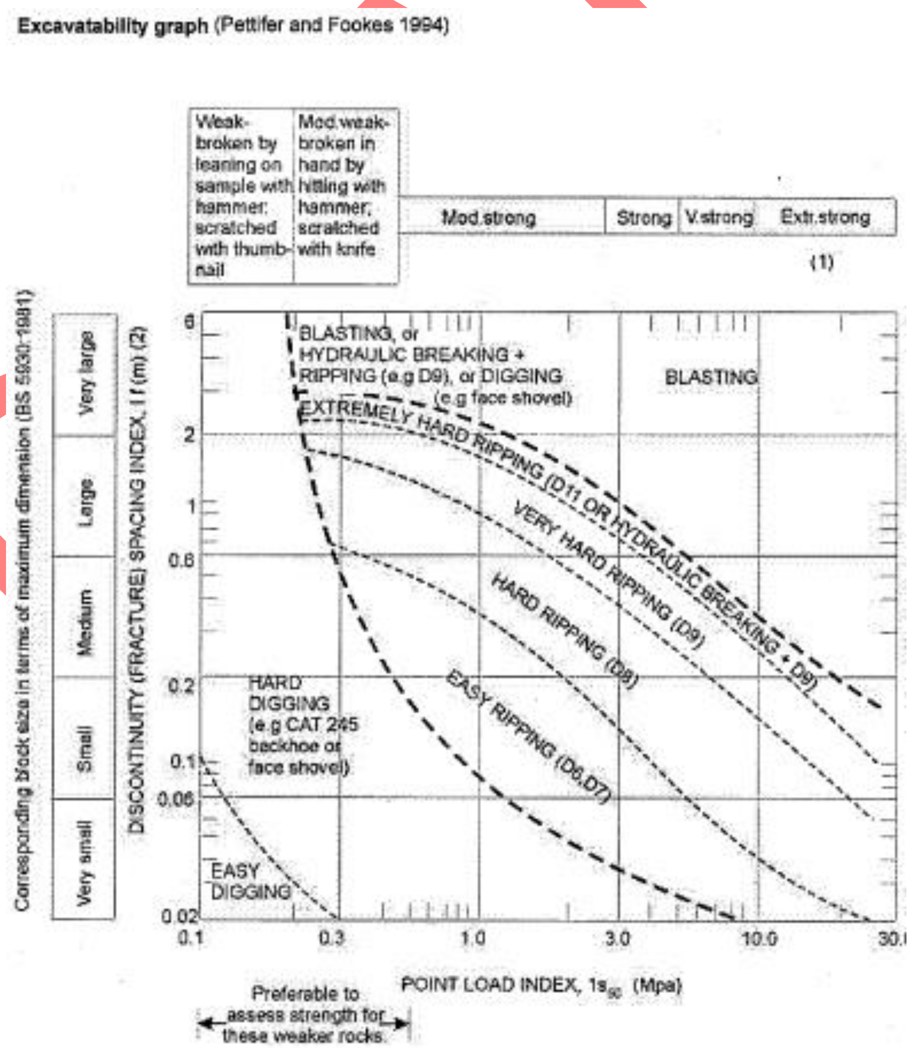
7.1.4 Earthworks

We have been advised that the proposed development will involve the excavation of a construction/maintenance pit to a potential depth of 10m below surface level.

The rotary cored drill hole (RC1) has identified weathered rock to a depth of 14.8m and selected samples were collected from the cores at suitable intervals to provide an estimate on how easy the bedrock would be to excavate, i.e. the 'rippbility' of the underlying Mercia Mudstone bedrock.

As the proposed construction/maintenance pit may require the ground to be excavated to approximately 10m depth, information with regards to the rippability of the ground underlying the proposed development footprint would provide information to aid the design. TP8, located some 10m from RC1, was excavated to greater than 3m depth and therefore, samples were collected at intervals from 5m below surface level to undergo Point Load testing. This enabled a correlation of the Point Load testing results with the probable rippbility of the rock.

Based on the point load test results presented in Appendix G and using the relationships developed by Pettifer and Fookes (1994) presented in Insert 1 below, the rippability of the underlying bedrock can be determined.



Insert 1: Excavatability (rippability) of rocks (Pettifer and Fookes, 1994)

Below are the results of the Point Load tests to determine the Mpa value for use with the above chart. This is used in conjunction with the fracture spacing identified in the rotary core drill hole. The recovered core samples identified a generally weak strength mudstone, becoming moderate with depth. Bands of weathered 'non intact' Mudstone were also identified.

Borehole Number	Sample Number	Depth (m)	Type of Test d a b/i	Type of Test I //	Width (W) (mm)	Platen Separation (D) (mm)	Failure Load (P) (kN)	Equivalent Diameter (D_e) (mm)	Point Load (I_s) (MPa)	Size Factor (F)	Point Load Index ($I_{s(50)}$) (MPa)
RO1		5.10	a		73	69	0.11	80	0.02	1.24	0.02
RO1		7.00	a		73	62	0.31	76	0.05	1.21	0.06
RO1		9.00	d			74	0.12		0.02	1.19	0.03
RO1		12.50	d			73	0.10		0.02	1.19	0.02
RO1		14.00	d			73	0.12		0.02	1.19	0.03

Insert 2: Results of Point Load Testing – full report presented in Appendix G.

In addition to the above, the fracture spacing index identified in the recovered core samples showed a range from non-intact to 0.25 I_f(m). With the determined point load index results ranging from 0.02 to 0.06 $I_{s(50)}$ and based on the relationships developed by Pettifer and Fookes, the weathered Mercia Mudstone underling the proposed maintenance/construction pit would be determined as 'Easy Digging' to 'Hard Digging' and an excavator such a CAT 245 (or equivalent) would be able to excavate the rock, based on the information obtained and the ground conditions observed.

Notwithstanding the above, it is possible that samples will have slightly relaxed/weakened from their in-situ condition prior to testing and bands of more competent rock may be encountered, therefore appropriate contingencies should be allowed for.

7.2 Geotechnical Risks

7.2.1 Shrinkage and Swelling

Laboratory testing has indicated, based on the modified plasticity index (which excludes the non-plastic coarser fraction within the soil), that the fine-grained soils at shallow (probable foundation) depth are of intermediate volume change potential. Based on this volume change potential, the minimum foundation depth would need to be 0.9m across the site, outside of the influence of any trees. However, this depth would need to be increased in accordance with NHBC/BRE guidelines within the zone of influence of recent, existing or future planting. Based on our understanding, the proposed development will not be within the zone of influence of any trees, however this should be carefully considered prior to any development/landscaping works.

The use of trench fill foundations in these circumstances should be used with great caution as lateral swelling pressures on such large foundation surfaces can lead to rotation or other movement which could lead to failure of the foundation, and they may be subject to uplift forces from the soil swelling.

Swelling pressures can be reduced with the use of suitably dimensioned compressible layers, such as Clayboard or similar, on the sides of the foundations. BRE report 298 provides further guidance on other methods which may be adopted. In addition, the use of deep spread footings (strips or trench fill) can also initiate swelling in the fine-grained soils where roots are severed.

Once the design proposals have been finalised, further advice can be provided by this office as to the required safe depth of foundations across the development.

7.2.2 Sulphate Attack

As discussed in Section 6.4.2 a Design Sulphate Class DS-1 and Aggressive Chemical Environment for Concrete Class AC-1, is considered appropriate for the shallow weathered rock.

7.3 Foundation Design and Construction – Proposed extension

It is understood that the site is being considered for potential development with a proposed extension (see Figure 2) and the comments and recommendations in this report assume that the development will involve a conventional portal frame construction point loads, and line loads from conventional load-bearing brickwork construction.

In TP9, excavated in the area of the proposed extension, Grade B/A weathered Mercia Mudstone bedrock was encountered beneath the concrete slab from a depth of 0.5m. The rock was rippable with a wheeled hydraulic 8 tonne 'rubber duck' excavator to a depth of 1.6m. On the basis of the available investigation information we consider that mass concrete spread foundations could be used at the site, constructed in the Grade B/A weathered Mercia Mudstone bedrock encountered from depths of 0.5m beneath ground level. The rock was identified as a light brownish red and bluish grey mudstone gravel with cobbles and boulders.

We consider that for foundations placed in this stratum, a presumed bearing value of around 150kPa should maintain total and differential settlements to less than 25mm.

The proposed founding stratum is coarse-grained in composition and, therefore, should not be affected by seasonal changes in moisture content. We recommend that the minimum foundation depth should be 1.0m below ground level.

TP8, excavated some 20m west of TP9 identified probable Class Dc/Db weathered rock which may possess lower bearing capacity. In addition, RC1, located some 10m from TP9 identified Class Dc/Db weathered rock. The boundary between the two rock classes identified in TP9 and TP8/RC1 could not be determined during the time limits of the investigation.

Should the proposed development footprint span these two classes of weathered rock, additional testing may be required to ensure no differential settlement occurs across the foundations.

For all spread foundation options, the formations should be cleaned, and subsequently inspected by a suitably qualified engineer prior to placing concrete. Should any soft, compressible or otherwise unsuitable materials be encountered they should be removed and replaced by lean mix concrete or suitable compacted granular material. We recommend that a blinding layer of concrete be placed on the formation after excavation and inspection in order to protect the formation against softening and disturbance.

7.4 Floor Slab Foundations

The use of cast in-situ ground bearing floor slabs is considered suitable for the development. Once the concrete slab has been removed, the underlying ground should be compacted for a depth of at least 300mm below slab formation level.

7.5 Construction/Maintenance Pit Development

As detailed in Section 7.1.5 and based on the information obtained, using a suitable excavator (e.g. CAT 245 or equivalent) will likely allow the ground to be excavated to a depth of 10m. Due to the presence of shallow groundwater and possible perched water within the Made Ground, temporary works (such as sheet piles) and pumping from screened sumps within the excavations will be required.

The significant earthworks proposed for a 10m construction/maintenance pit will require substantial temporary works to ensure the stability of the excavation throughout the development. The temporary works will require careful design (taking into account shallow groundwater) and include consideration of all potential contamination implications given the depth (below the water table) of the proposed pit.

No further information has been provided as to the proposals/requirements of the proposed pit.

7.6 Concrete Slab and Pavement Design

We understand that a concrete slab is proposed in the south of the site in the area of TP1 to TP3 and that a further concrete slab is possible in the area of TP4 to TP6. In addition, vehicle access roads/hardstanding are proposed as part of the development works.

7.6.1 Design CBR Value

An assessment of the likely CBR values beneath the Made Ground in the areas of the proposed concrete slab have been undertaken using a dynamic cone penetrometer (DCP). Testing was undertaken at 5no. locations concentrated along the proposed positions of the concrete slabs. The tests were undertaken beneath the Made Ground within the trial pits. The results of the DCP testing are converted to CBR values using correlations published by the Highways Agency (2008).

The DCP results and the correlated CBR values are presented in Appendix F. From the DCP testing, we consider that the following CBR values are appropriate for the soils beneath the site surface (excluding the surface Made Ground).

Table 4: Summary of Correlated CBR Values from DCP Testing (beneath the surface Made Ground)

DCP Ref.	Location	Depth range	CBR Value	Probable Soils
DCP1	Test started at 0.55m depth within TP1 in area of proposed concrete slab	0.6 – 0.81m 0.81 – 1.5m	>10% >20%	Class B Mercia Mudstone
DCP2	Test started at 0.7m depth within TP2 in area of proposed concrete slab	0.8 – 1.33m 1.33 – 1.53m 1.53 – 1.61	>20% 8% >20%	Class B Mercia Mudstone
DCP3	Test started at 0.5m depth within TP3 in area of proposed concrete slab	0.5 – 1.0m	>30%	Class B Mercia Mudstone
DCP4	Test started at 0.3m depth within TP5b in area of proposed concrete slab	0.35 – 0.4m 0.4 – 1.0m 1.0 – 1.2	>20% 4% >10%	Class Dc/Db Mercia Mudstone
DCP5	Test started at 0.25m depth within TP6 in area of proposed concrete slab	0.25 – 0.5m 0.5 – 1.0m 1.0 – 1.15	>20% 4% >10%	Class Dc/Db Mercia Mudstone

Notes to Table 4:
1. Some thin slightly lower strength bands present.
2. Soils with CBR values less than 2.5% (highlighted in red) are not suitable for road pavements without treatment.
3. Correlation based on Highways Agency (2008) methodology.

Based on the above testing, we consider that a Design CBR value of 8-10% would be suitable for preliminary design purposes for the slab in the south of the site and 4% for the slab in the north west.

The near-surface soils comprise fine-grained materials. The CBR value is particularly sensitive to changes in moisture content. Careful consideration should be given to whether in the long term, the existing moisture content at which the test was undertaken is appropriate. If the formation were to become wetter the long term Design CBR value would reduce, possibly dramatically. In accordance with the recommendations in IAN73/06 (Highways Agency, 2009a), we recommend that the sensitivity of the Design CBR value of the fine-grained soils to variations in moisture content be assessed by further laboratory testing.

As indicated by the results, localised areas of lower CBR vales exist and therefore, we recommend that the final sub-grade should be inspected by a qualified engineer, and any soft or loose material removed and replaced as necessary, to ensure that the Design CBR value is achieved. It is further recommended that the sub-grade be proof-rolled with a suitable roller prior to the placement of the sub-base materials. In order to improve the sub-base performance, the use of a suitable geo-grid may be considered.

We consider that it would be prudent to re-measure the CBR values of the sub-grade on exposure to confirm that they are equal to or better than the values measured in this investigation (as recommended by the Highways Agency [HA, 2009a]). If the CBR values in the sub-grade are found to be lower than the Design CBR, the subgrade must be improved to achieve the Design CBR or the road pavement foundation redesigned.

The investigation has identified shallow groundwater across the site. We recommend that suitable drainage is installed in the road pavement to ensure that water is kept out of the sub-base.

7.6.2 Susceptibility to Frost Action

Given their plasticity, the near surface fine grained soils are considered to be potentially frost susceptible. A total thickness of 450mm non-frost susceptible pavement construction will be required to avoid frost heave. In coastal areas such as this, this thickness may be reduced subject to the Mean Annual Frost Index (MAFI) and the agreement of any parties who will adopt the highway.

7.7 Excavation and Dewatering

It is anticipated that excavation throughout most of the site will be within the capabilities of conventional mechanical excavators. As detailed in Section 7.1.5 and based on the information obtained, using a suitable excavator (e.g. CAT 245 or equivalent) will likely allow the ground to be excavated to a depth of 10m. Due to the presence of shallow groundwater and possible perched water within the Made Ground, temporary works (such as sheet piles) and pumping from screened sumps within the excavations will be required.

For shallow excavations where there is no danger to life, support of excavation sides is unlikely to be necessary. Should any indication of excavation instability be noted at any depth, support should be provided as appropriate.

Based on our understanding of the proposed development, no significant groundwater ingress is anticipated above 2m depth. Where water ingress occurs it is likely that pumping from screened sumps within shallow excavations will be adequate.

7.8 Soakaway Drainage

7.8.1 Soakaway Design

No soakaway infiltration testing has been undertaken at the site, however the underlying bedrock is fine grained in nature and therefore soakaways are unlikely to be feasible.

8.0 RECOMMENDATIONS

Based on the information to date, and our understanding of the proposed works, we do not consider that any further work is required at this stage in order to progress the design. The following should be considered for the proposed works:

- Large capacity excavator such a CAT 245 (or equivalent) will be required to excavate the rock, based on the information obtained and the ground conditions observed. Notwithstanding the this, it is possible that samples will have slightly relaxed/weakened from their in-situ condition prior to testing and bands of more competent rock may be encountered, therefore appropriate contingencies should be allowed for.
- Old foundations and underground structures (as identified in TP7 and TP8) will require grubbing up prior to the development works.
- A deep (approximately 10m) excavation is proposed in an area where shallow groundwater is anticipated (approximately 2.0m below surface level) and temporary works will be need to be carefully designed with consideration to all potential stability and contamination implications.
- The significant earthworks proposed for a 10m construction/maintenance pit will require substantial temporary works to ensure the stability of the excavation throughout the development. The temporary works will require careful design (taking into account shallow groundwater) and include consideration of all potential contamination implications given the depth (below the water table) of the proposed pit.
- No exploratory works were undertaken beneath the existing building. Strict diligence and care to evaluate potential pollution sources from within the existing building should be undertaken throughout the development works. Any potential sources of contamination or evidence of contamination identified in areas not explored during the investigation should be assessed by a qualified geo-environmental engineer.

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