



Joule Consulting Engineers Limited

Talbot Mill, Manchester

Geo-environmental Site Assessment

11264

MARCH 2019





RSK GENERAL NOTES

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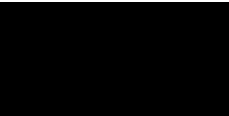
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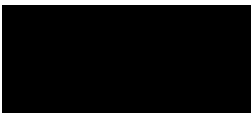
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This work has been undertaken in accordance with the quality management system of RSK Environment Ltd.

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Client drawing – 'Proposed Site Plan' produced by shedkm, drawing number TM SKM (00) 021 d, dated 27/06/2018

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EXECUTIVE SUMMARY

Site description and proposed development	The site is situated off Ellesmere Street to the south of Manchester city centre. It is currently occupied by a complex of former mill buildings, originally constructed around 1855. The proposed development of the site comprises the residential refurbishment of the mill buildings and demolition of courtyard buildings to create a new external works landscape for the residents with the construction of a new ten storey residential building in the north of the site.
Purpose of assessment	The purpose of the assessment is to further assess potentially complete contaminant linkages identified in the preliminary risk assessment, from which appropriate measures can be defined to allow the safe redevelopment for residential end-use. The assessment will also support a planning application for residential redevelopment of the site and designed to provide information on the underlying ground conditions to enable an assessment of the engineering properties of soils beneath and adjacent to building foundations and to investigate the depth and engineering properties of the sandstone bedrock.
Existing report	A geo-environmental preliminary risk assessment (PRA) was completed by Delta-Simons in January 2017. The object of the report was to identify likely environmental and geotechnical constraints to the proposed development associated with soil and groundwater conditions. The PRA noted several potential sources of contamination: • potential site-wide made ground from previous development • hydrocarbons and asbestos relating to an above ground supply tank, boiler room and garage • contaminated soils, groundwater and hazardous ground gases from historical uses of site. The report recommended a phase of intrusive investigations be undertaken to assess the potential subsurface contamination present at the site.
Conceptual model	RSK used the information provided in the Delta-Simons PRA to develop several potentially complete contaminant linkages: • contaminant linkage (1): risks to future site users from direct contact pathways with potentially contaminated soils on site • contaminant linkage (2): risk to future site users and buildings in the event of gas build-up from on and off-site sources (methane and carbon dioxide) • contaminant linkage (3): risk to groundwater in underlying Secondary A aquifer with subsequent downward migration to the principal aquifer by leaching of contaminants from on-site sources and vertical migration of contaminants • contaminant linkage (4): risk to surface water course via surface run-off and/or lateral migration of contaminated water • contaminant linkage (5): risk to building infrastructure from chemical attack via sulphate impacted soil and groundwater.

SITE ASSESSMENT	
Site investigation	RSK carried out intrusive investigation work in two phases: phase 1 took place between 14 and 18 May 2018 with subsequent groundwater and gas monitoring in June, and phase 2 took place between 26 and 30 November. The phase 1 intrusive investigation consisted of four boreholes to bedrock and at least 9.0m in to bedrock, two machine excavated trial pits to target historic features, and 17 hand dug trial pits inside and outside the existing mill buildings to inspect current foundations. Additionally, chemical and geotechnical laboratory analysis, in-situ testing, and subsequent groundwater and gas monitoring were collected from all deep boreholes. The phase 2 intrusive investigation consisted of seven hand dug trail pits inside the existing mill buildings to inspect current foundations with subsequent chemical analysis. Following the findings of phase 1, water testing of the adjacent canal arm (upstream and downstream) was carried out.
Refined conceptual site model	The laboratory data were compared to generic assessment criteria to evaluate whether the pollutant linkages in the conceptual model require further consideration or mitigation measures. The linkages found to be complete and that may require mitigation measures are: • Linkage 1 - Direct contact via dermal contact, ingestion and inhalation of dust and asbestos fibres by future site residents in landscaped areas by shallow soil impact due to historic site activities and/or made ground and demolition material • Linkage 3 - leaching of contaminants in shallow soil due to historic site activities to groundwater • Linkage 6 - Contaminants associated with historic site uses permeating potable water supply pipes.
CONCLUSIONS AND RECOMMENDATIONS	
Environmental assessment	To mitigate direct contact linkages to future site residents it is recommended that either a cover layer of clean material is used within landscaped areas or the made ground at JBH04 and JTP25 is excavated to remove the source. Ground gas concentrations at the site were generally low and the resulting gas assessment gave the site a classification of Green. The concentrations of PAH in made ground and in a sample of groundwater taken from JBH03, which indicates a slight exceedance of benzo(a)pyrene indicate that leaching to groundwater could be a relevant pollutant linkage.
Geotechnical assessment	The investigation findings confirm that the existing mill buildings are supported off sandstone/masonry pad and strip footings founded within the sand/gravel of the Glaciofluvial deposits and locally sandstone, i.e. JTP11. Given the presence of competent sandstone at estimated depths of 1.90m to 2.70m bgl, locally 3.50m+ at JTP31A, it is considered that spread footings would be suitable for supporting the new building. The depth of such foundations may vary considerably where former foundations/sub-structures are encountered and the new foundations need to be extended beneath these into the underlying competent sandstone strata, the depth to which is also likely to vary across the building. Deep excavations will require support and

	may require dewatering. Alternatively, pile foundations taken to the underlying competent sandstone would provide a suitable alternative. The recommended sub-grade soil CBR value for preliminary road pavement design is just less than 2% for the existing made ground. The available chemical data indicates an Aggressive Chemical Environment for Concrete (ACEC) Classification of AC-2 with a Design Sulphate Class of DS-2.
Recommendations including issues for further assessment	To mitigate direct contact linkages to future site residents it is recommended that either a cover layer of clean material is used within landscaped areas or the made ground at JBH04 and JTP25 is excavated to remove the source. The linkage of permeation of plastic utilities was found to be potentially complete, with numerous exceedances of the GAC for shallow soil. It is recommended that barrier pipes are used and a targeted investigation is carried out once the route of the planned water supply is known to potentially mitigate against the use of barrier pipes. Ground gas assessment resulted in a classification of green, indicating that gas protection measures are not required.
<i>The information given in this summary is necessarily incomplete and is provided for initial briefing purposes only. The summary must not be used as a substitute for the full text of the report.</i>	

1 INTRODUCTION

RSK Environment Limited (RSK) was commissioned by Joule Consulting Engineers Limited ('The Engineer') on behalf of Capital and Centric (Adored) ('the Client') to carry out a geo-environmental assessment of the site known as Talbot Mill located in Manchester city centre. Capital and Centric (Adored) is the overall client but for the duration of the investigation Joule Consulting Engineers Limited dealt with the day-to-day queries.

It is understood the proposed end use of the development is residential.

This report is subject to the RSK service constraints given in Appendix A.

A summary of legislation and policy relating to contaminated land is given in Appendix B.

1.1 Background

The proposed development is subject to planning permission 117595/FO/2017 which was granted on 22 March 2018. Within the planning application, Condition 6 refers specifically to undertaking further investigation should a preliminary risk assessment (PRA) identify potential sources and impacts of ground contamination, groundwater contamination and/or ground gas. The condition specifically states:

'In the event of the Preliminary Risk Assessment identifying risks which in the written opinion of the Local Planning Authority require further investigation, the development shall not commence until a scheme for the investigation of the site and the identification of remediation measures (the Site Investigation Proposal) has been submitted to and approved in writing by the City Council as local planning authority.'

The measures for investigating the site identified in the Site Investigation Proposal shall be carried out, before the development commences and a report prepared outlining what measures, if any, are required to remediate the land (the Site Investigation Report and/or Remediation Strategy) which shall be submitted to and approved in writing by the City Council as local planning authority.'

1.2 Objective

The purpose of this assessment is to further assess potentially complete contaminant linkages identified in the preliminary risk assessment, from which appropriate measures can be defined to allow the safe redevelopment for residential end-use. Additionally, the work will provide an assessment of the engineering properties of soils beneath and adjacent to the existing building foundations to investigate the depth and engineering properties of the sandstone bedrock for the proposed site development.

1.3 Scope

The scope and layout of this investigation has been designed in line with the recommendations of BS5930: 2015 Code of practice for ground investigations, which maintains compliance with BS EN 1997-1 and 1997-2 and their related standards, CLR11

(Environment Agency, 2004a), BS 10175: 2011 (BSI, 2011), and guidance on land contamination reports issued by the Environment Agency (2010a).

The project was carried out in line with the initial brief as set out in the Joule Consulting document titled 'Talbot Mill – Site Investigation, Specification for Site Investigation'. The scope of work was agreed in RSK's proposal (ref. 11264-TL01 (rev1), dated 24 January 2018) and included:

- borehole drilling – four boreholes to bedrock and at least 9.0m into bedrock
- trial pitting – two machine excavated trial pits
- hand pitting – 19 hand dug pits (1.5m to 2.0m deep)
- in-situ and ex-situ testing
- groundwater and ground gas monitoring
- reporting.

Due to access constraints within areas of the mill buildings, Joule Consulting requested the intrusive investigation be carried out in two phases. Phase 1 comprised the borehole drilling, two machine excavated trial pits, six external hand dug trial pits and ten internal hand dug trial pits within the accessible areas of the mill buildings. Phase 2, undertaken approximately seven months later, comprised the excavation of three hand dug trial pits in previously inaccessible locations during phase 1, two additional hand dug trial pits added later by Joule, and the re-dig of two previously excavated hand dug trial pits.

Following the first issue of this report, it was recommended upstream and downstream water sampling of the canal be undertaken to further assess a potentially complete contaminant linkage. This water sampling was carried out as part of the phase 2 intrusive investigation works.

1.4 Preliminary geotechnical category

Based on the information provided by the Engineer and knowledge of the prevailing ground conditions, a Geotechnical Category 2 has been assumed for the purposes of this report.

1.5 Existing reports

The following report detailing previous work at the site was made available to RSK:

- Delta-Simons Environmental Consultants Limited. Geo-environmental Preliminary Risk Assessment: Talbot Mill, Ellesmere Street, Manchester. Presented to Capital and Centric Ltd. Issued January 2017. Reference 16-1144.01.

1.6 Limitations

The comments given in this report and the opinions expressed are based on the ground conditions encountered during the site work and on the results of tests made in the field and in the laboratory. However, there may be conditions pertaining to the site that have



not been disclosed by the investigation and therefore could not be considered. It should be noted that there may be areas of made ground not detected due to the limited nature of the investigation or the thickness and quality of made ground across the site may be variable. In addition, groundwater levels and ground gas concentrations and flows may vary from those reported due to seasonal, or other, effects.

2 THE SITE

2.1 Site location and description

The site is situated off Ellesmere Street to the south of Manchester city centre. It is currently occupied by a complex of former mill buildings, originally constructed around 1855. The former buildings, referred to as Mill 1 and Mill 2, are situated within a local conservation area. The buildings are five storeys high and typically comprise load bearing masonry external walls with 'Jack Arch' floors and roofs, although Mill 1 has timber floors at ground, first and third floors. The floors are supported on cast iron columns. There are various outbuildings on site, notably the 'Timekeepers Cottage', which is proposed to be rebuilt as part of the development.

The mills are currently used by several businesses including textile works, storage and warehousing. A construction firm, developing a site across the road from Talbot Mill, used the third floor as office space during phase 1 of the intrusive works. During phase 2 of the investigation, the mill buildings had been vacated and were being stripped of any cabling and furniture by a building contractor.

The external courtyard which is partly cobbled and partly covered in concrete is used as a car park by users of the mill buildings.

During the initial site walkover carried out by RSK prior to site works, the northwest corner of the site was occupied by several drums, batteries, above ground storage tanks and mechanical excavators within a gated compound. This equipment was removed prior to commencement of the investigation works.

The site access is via an archway off Ellesmere Street, which is to the south of the site. The site is bordered by Burton Place to the east, Worsley Street and Timber Wharf to the north and an inlet of the Bridgewater Canal to the west.

An indicative postcode for the site is M15 4JY and National Grid reference is 382704 397296. A site location plan is shown on Figure 1.

2.2 Proposed development

The proposed development of the site comprises the residential refurbishment of the mill buildings and demolition of courtyard buildings to create a new external works landscape for the residents. Mill 1 is to be extensively rebuilt to the rear with a new steel frame and an additional storey. Mill 2 is to have its roof removed and the building increased by two storeys. Access will be maintained through the existing archway. There is no car parking planned within the scheme. To the north, parallel to Worsley Street a new ten storey framed building is to be constructed.

The proposed development layout is depicted on the client drawing produced by shedkm referenced TM SKM (00)021 d, dated 27th June 2018, which is included in the figures section.

3 EXISTING PRELIMINARY RISK ASSESSMENT

3.1 Review of existing PRA report

The following section provides a review of a PRA that was issued by Delta-Simons in January 2017.

The objection of the Delta-Simons report was to identify likely environmental and geotechnical constraints associated with soil and groundwater conditions that may affect the proposed development of the site.

3.1.1 Environmental information

3.1.1.1 *Geology*

The 1:50,000 British Geological Survey (BGS) Geological Map for the Site (Sheet 85, Manchester) indicates that much of the Site is not underlain by drift deposits apart from the southern boundary of the site which is shown to be underlain by glaciofluvial sheet deposits of Devensian age, comprising sand and gravel. The underlying bedrock is the Chester Pebble Beds Formation (sandstone) of Triassic age. Given the current development, it is likely to be Made Ground overlying the Glaciofluvial Sheet Deposits at the site.

RSK Comment: With reference to the BGS the underlying bedrock is named the 'Chester Formation'.

3.1.1.2 *Hydrogeology*

The Environment Agency (EA) classifies the superficial glaciofluvial sheet deposits at the southern boundary of site as a Secondary A Aquifer, whilst the Chester Pebble Beds Formation is classified as a principal aquifer. The EA data also indicates that the site is not in a designated groundwater Source Protection Zone. The Envirocheck® Report indicates there are no licensed groundwater abstraction records from groundwater located within 1 km of the site.

3.1.1.3 *Hydrology*

The nearest surface water feature is a basin connected to the Bridgewater Canal, adjacent to the west of the Site. The Bridgewater Canal is located approximately 40m north of the site.

3.1.1.4 *Coal Authority*

A Coal Mining Report obtained as part of the PRA indicates that the site is not within an area, which could be affected by past, present or future underground or opencast mining. There are no known mine entries on-site or within 20m of the site boundary.

3.1.1.5 *Radon*

The site is located within a low probability radon area, as less than 1% of homes are above the action level. Radon protective measures are not required.

3.1.1.6 *Site history*

The earliest reviewed map of 1848 indicates the site to be undeveloped. By 1891 the site is occupied by Talbot Mills (cotton and braid). Most of the area is covered by buildings with a chimney and tank located in the north-east. The building layout has changed slightly by 1950 with several buildings extended. A warehouse is shown encroaching to the north by 1999, but no longer shown on the 2006 map. By 2016 the site is recorded as a works, the layout of the site has changed very little since it was first developed prior to 1891.

3.1.1.7 *Previous reports*

The Delta Simons PRA report referred to and reviewed a ground investigation report at Talbot Mill' Peter Cowshill Limited, issued in March 2004 was reviewed by Delta-Simons. The ground investigation comprised the excavation of six machine dug trial pits, to a maximum depth of 3.0m below ground level (bgl). Made Ground was encountered in all locations, to a maximum depth of 2.0m bgl. Sandstone bedrock was encountered between 0.6m and 2.0m (bgl). Chemical analysis results for soil samples tested have been compared to GAC for residential end use without home grown produce. Elevated concentrations of chromium and lead were identified.

3.1.2 **Initial conceptual site model**

The following sections lists the findings of the preliminary Conceptual site model (CSM) presented in the Delta-Simons PRA. Where appropriate, RSK have commented on the adequacy of the CSM.

3.1.2.1 *Potential sources of contamination*

Potential sources of contamination identified in the Delta-Simons PRA included:

- potential made ground deposits site-wide from previous development of the site
- hydrocarbons and asbestos related to boiler room, engine room, storage of drums, AST in the northwest corner of the site and the existing garage
- contaminated soils, groundwater and hazardous ground gases from historical uses of the site as cotton mill, garage, varnishing works, sheet metal works and linen works.

RSK comment – Delta-Simons do not consider the historic off-site land uses to be a potential source however, given the heavy industrial nature of the immediate surrounding buildings, RSK consider the nearby dye-works, saw mill, garages, engineering works and in-filled land to be a potential source of hydrocarbons, metals, VOCs, PAHs and hazardous ground gases.

3.1.2.2 *Potential receptors*

Potential receptors identified in the Delta-Simons PRA included:

- construction workers

- neighbouring site users
- future residents
- groundwater in the underlying Secondary A aquifer and Principal Aquifer
- surface waters
- building infrastructure.

RSK comment – RSK considers potential risks to construction workers to be managed through health and safety procedures, including CDM (construction design management) regulations.

3.1.2.3 *Summary of plausible pathways*

Potential contaminant pathways identified in the Delta-Simons PRA included:

- direct contact, ingestion or inhalation of soil bound contaminants / dust / asbestos fibres
- inhalation of vapours associated with contamination
- migration of ground gas into on-site buildings causing asphyxiation or risk of explosion
- leaching of contamination into groundwater followed by migration of groundwater to the wider groundwater environment or surface waters.

RSK comment – RSK considers the contaminant pathways proposed by Delta-Simons as all being viable pathways but would add sulphate impacted soil and groundwater resulting in chemical attack on buried concrete and risks to water supply pipes via penetration.

3.1.2.4 *Potentially complete contaminant linkages*

To allow specific assessment of potentially complete individual contaminant linkages at the site RSK has used the information provided in the Delta-Simons PRA report to develop several potentially complete contaminant linkages. The risk classification has been undertaken in accordance with CIRIA C552. There is a summary of this in Appendix C.

- contaminant linkage (1): risks to future site users from direct contact pathways with potentially contaminated soils on site
- contaminant linkage (2): risk to future site users and on and off-site buildings in the event of gas build-up from on and off-site sources (methane and carbon dioxide):
- contaminant linkage (3): risk to groundwater in underlying Secondary A aquifer with subsequent downward migration to the Principal Aquifer by leaching of contaminants from on-site sources and vertical migration of contaminants
- contaminant linkage (4): risk to surface water course via surface run-off and/or lateral migration of contaminated water:
- contaminant linkage (5): risk to building infrastructure from chemical attack via sulphate impacted soil and groundwater.

- contaminant linkage (6): risk to potable water supply pipes from permeation of contaminants in soil and groundwater.

3.1.3 Geotechnical constraints

The Delta-Simons PRA report stated that the existing foundations are likely to be founded on shallow weathered sandstone bedrock. They go on to note that the viability of spread foundations is dependant on the depth to competent strata. If the depth is too great, alternative foundations such as piling may be considered.

In terms of geotechnical risks, Delta-Simons identified a potential risk from shallow groundwater and flooding, along with a risk of encountering hard strata or obstructions at depth due to previous development of the site.

3.1.4 Recommendations

The report recommended a phase of intrusive investigations be undertaken to assess the potential subsurface contamination present at the site and to provide geotechnical information of the ground conditions for preliminary foundation design.

4 SITE INVESTIGATION METHODOLOGY

RSK carried out intrusive investigation work in two phases. Phase 1 was undertaken between 14 and 18 May 2018 with subsequent groundwater and gas monitoring site visits in June. Phase 2 was undertaken between 26 and 30 November 2018. The ground investigation has been carried out using intrusive ground investigation techniques in general accordance with the recommendations of BS5930: 2015 Code of practice for ground investigations, which maintains compliance with BS EN 1997-1 and 1997-2 and their related standards. The exploratory holes were logged by an engineer in general accordance with the recommendations of BS 5930:2015 (which incorporates the requirements of BS EN ISO 14688-1, 14688-2 and 14689-1). Whilst every attempt is made to record full details of the strata encountered in the exploratory holes, techniques of hole formation and sampling will inevitably lead to disturbance, mixing or loss of material in some soils and rocks.

4.1 Sampling strategy and methodology

To assess the significance of the potentially complete pollutant linkages identified in the Delta Simons PRA report and listed in section 3.1.2.4 of this report, the site investigation was undertaken inside the current mill buildings and within the external courtyard to obtain both geotechnical and environmental data.

The techniques adopted for the investigation have been chosen considering the anticipated ground conditions, existing land use and the proposed development. Four boreholes were drilled in the external courtyard using dynamic sampling with rotary follow-on technique using a Commachio drill rig; 16 trial pits were excavated by hand inside the mill buildings along external walls and central supporting beams, and ten trial pits were excavated using a mixture of hand tools and a machine (5t tracked excavator). Combined gas and ground water monitoring wells were installed in all exploratory boreholes.

4.1.1 Health, safety and environment considerations

All subcontractors were inducted on to the site-specific RSK health and safety plan before site works began. Prior to the investigation, all exploratory hole locations were cleared via a full geophysical (GPR) survey. A full review of service plans was undertaken, and as a final check, each trial pit and borehole was scanned with a cable avoidance tool (CAT). All boreholes commenced with a hand dug pit to 1.2m bgl.

An RSK permit to dig was completed for each investigation location.

4.1.2 Investigation locations

The investigation and the soil descriptions were carried out in general accordance with 'BS 5930:1999. Code of Practice for Site Investigations' (BSI, 1999). An exploratory hole location plan is presented on Figure 2 and the exploratory hole records are presented in Appendix D.

The exploratory hole locations and naming system were devised by Joule Consulting. RSK located the exploratory holes with reference to physical features present on the site

at the time of investigation in line with the 'Site Investigation Site Plan' (referenced 251-05-SI40-A).

Table 1 below provides a summary and rationale for the exploratory hole locations.

Table 1: Exploratory hole and monitoring well location rationale

Investigation Phase	Investigation Type	Exploratory hole number	Response zone	Rationale
Phase 1 (May 2018)	Rotary boreholes	JBH01	Deep install to target groundwater within sandstone bedrock	Drilling through made ground and superficial deposits to allow logging and sampling of soils with 9.0m of rotary coring through sandstone bedrock. Boreholes located within footprint of proposed ten storey apartment-block to assess underlying bedrock quality for foundation design.
		JBH02		Drilling through made ground and superficial deposits to allow logging and sampling of soils with 9.0m of rotary coring through sandstone bedrock. Boreholes located within external courtyard adjacent to existing mill buildings to assess depth of underlying bedrock and groundwater depth.
		JBH03		
		JBH04		
	Hand excavated trial pits	JTP01 – JTP07	N/A	Locations within Mill 1, hand excavated to approximately 1.5m-2.0m to expose the form / depth and bearing of existing foundations.
		JTP10, JTP10A, JTP12		Locations within Mill 2, hand excavated to approximately 1.5m-2.0m to expose the form / depth and bearing of existing foundations.
	Mixture of machine and hand excavated trial pits	JTP20 - JTP25		External pits located in the courtyard and within the entrance arch via a mixture of machine and hand excavation to a depth of approximately 1.5m-2m to expose the form/depth and bearing of existing foundations.
		JTP30		Machine excavated to expose the canal arm wall (approx. 2m-2.5m deep) and to establish the location and condition of a high-level culvert in this area.
		JTP31 and JTP31A		Machine excavated into the base of the chimney to expose the mass and bearing of the chimney base.
	Hand excavated trial pits	JTP11, JTP13, JTP14		Locations within Mill 2, hand excavated pit to approximately 1.5m-2.0m to expose the form / depth and bearing of existing foundations.

Investigation Phase	Investigation Type	Exploratory hole number	Response zone	Rationale
		JTP32 and JTP33		Locations within the north of Mill 2, hand excavated pit to approximately 1.5m-2.0m in a raised area to expose the form / depth and bearing of existing foundations.
		Re-dig of JTP10A		Location within Mill 2, hand excavated pit to approximately 1.5m-2.0m to confirm the form / depth and bearing of existing foundations.
		Re-dig of JTP30		Hand excavated pit in external area of site to the north of Mill 2 to confirm the formation of the canal arm wall

4.1.3 Soil sampling, in-situ testing and laboratory analysis

The sampling and in-situ testing strategy was designed to characterise the made ground and natural soils and rock beneath the site, and to provide information on the mechanical characteristics of the underlying soils for geotechnical design purposes.

The rotary drilling was carried out with a Commachio hydraulic drill rig. The drilling consisted of dynamic sampling followed by rotary coring. Water was used as the drilling flush medium. A clear Perspex liner was incorporated within the inner barrel to maximise the quality of core recovery. The cores were retained in rigid core liners and placed into core boxes.

Soils collected for laboratory analysis were collected in a variety of containers appropriate to the anticipated testing suite required. Samples were stored in accordance with the RSK quality procedures to maintain sample integrity and preservation and to minimise the chance of cross contamination.

Environmental samples and geotechnical samples (including SPTs, bulk bags and disturbed samples) were taken and are recorded together with their depths on the exploratory hole records in Appendix D. The environmental samples were transported to the laboratory in chilled cool boxes. Laboratory chain of custody forms can be provided if required. Samples of made ground, superficial deposits and rock cores were tested for a range of determinants for environmental and geotechnical purposes.

Soil samples were analysed for a selection of the following:

- pH, metals, sulphate and cyanide
- total petroleum hydrocarbon using criteria working group (TPHCWG) including benzene, toluene, ethylbenzene and xylene (BTEX)
- speciated polycyclic aromatic hydrocarbon (PAH)
- total organic content.

Soils sampled from made ground deposits only were also analysed for the following:

- asbestos analysis followed by asbestos quantification in those samples where asbestos was identified.

- leachable metals.

Standard penetration tests (SPTs) were carried out within the made ground and the unconsolidated natural strata at regular intervals of approximately 1m intervals until bedrock was encountered. The tests were undertaken in accordance with BS EN ISO 22476-3:2005 using a hammer, which had been calibrated for efficiency. Test results are given on the borehole records presented in Appendix D.

Geotechnical tests undertaken on samples obtained from the intrusive investigation are listed below, the main purpose of which was to determine the physical properties of the underlying soils and rocks. The testing was undertaken in accordance with BS 1377:1990 Method of Tests for Soils for Civil Engineering Purposes or, where superseded, by the relevant part of BS EN ISO 17892:2014 Geotechnical investigation and testing - Laboratory Testing of Soil. The tests were carried out within RSK's UKAS accredited laboratory.

- moisture content
- liquid/plastic limits
- particle size distribution
- california bearing ratio
- sulphate, chloride and PH suite.

Rock core samples were analysed for the following:

- point load index
- unconfined compressive strength
- sulphate, chloride and PH suite.

Soil analysis results are presented in Appendix E and geotechnical laboratory analysis results are presented in Appendix F.

4.1.4 Groundwater monitoring and levelling

Depths to groundwater were recorded using an electronic interface probe during subsequent monitoring visits. The groundwater monitoring data are given in Appendix H.

4.1.5 Groundwater developing, sampling and analysis

After the installation of groundwater monitoring wells, the installations were developed at least one week before sampling.

Groundwater samples were retrieved using a United States Environment Protection Agency (USEPA) approved low-flow purging and sampling methodology. The low-flow method relies on moving groundwater through the well screen at approximately the same rate as it flows through the geological formation. This results in a significant reduction in the volume of water extracted before sampling and significantly reduces the amount of disturbance of the water in the monitoring well during purging and sampling. Drawdown levels in the monitoring well and water quality indicator parameters (pH, temperature, electrical conductivity, redox potential and dissolved oxygen) are monitored during low-flow purging and sampling, with stabilisation indicating that purging is complete, and sampling can begin. As the flow rate used for purging, in most cases, is the same or only

slightly higher than the flow rate used for sampling, and because purging and sampling are conducted as one continuous operation in the field, the process is referred to as low-flow purging and sampling.

In-situ water quality measurements undertaken during the low-flow sampling process are provided in Appendix I.

The groundwater samples were collected in containers appropriate to the anticipated testing suite required. The containers were filled to capacity and placed in a cool box to minimise volatilisation. Samples were transported directly to the testing laboratory under chain of custody documentation.

Groundwater samples were analysed for the following:

- metals and pH
- hardness, chloride, sulphate and DOC suite
- TPHCWG including BTEX
- PAH.

The results certificates of groundwater analysis are presented in Appendix G.

4.1.6 Surface water sampling

Following the phase 1 investigation it was recommended that samples of the Bridgewater Canal are taken and chemically assessed. Two samples of surface water; an upstream sample taken from the arm of the canal immediately adjacent to the site and a downstream sample taken from the Bridgewater Canal, were collected using a long-arm bailer. The surface water samples were collected in containers appropriate to the anticipated testing suite required. The containers were filled to capacity and placed in a cool box to minimise volatilisation. Samples were transported directly to the testing laboratory under chain of custody documentation.

Surface water samples were analysed for the following:

- metals and pH
- hardness, chloride, sulphate and DOC
- biological oxygen demand
- total suspended solids
- TPH banded testing
- PAH.

The results certificates of surface water analysis are presented in Appendix Q.

4.1.7 Ground gas monitoring

Six monitoring rounds have been undertaken over a period of three months, to provide data to support the conceptual model. Monitoring included periods of falling atmospheric pressures and after/during rainfall.

An infrared gas meter was used to measure gas flow, concentrations of carbon dioxide (CO₂), methane (CH₄) and oxygen (O₂) in percentage by volume, while hydrogen sulphide

(H₂S) and carbon monoxide (CO) were recorded in parts per million. Initial and steady state concentrations were recorded. In addition, during the first monitoring round, all wells were screened with a PID to establish if there are any interferences and cross-sensitivity of other hydrocarbons with the infrared gas meter.

The atmospheric pressure before and during monitoring, together with the weather conditions, was recorded.

The ground gas monitoring visits were undertaken during a variety of pressure events. Table 2 includes a summary of the atmospheric conditions during the monitoring visit and the three days preceding the visit. The data for the preceding three days has been taken from the weatherunderground website (www.weatherunderground.com) for the closest identified weather station, located in Hulme, Manchester (weather station reference ISTRETFO2).

Table 2: Atmospheric trends during gas monitoring

Date	Atmospheric pressure (three preceding days)			Atmospheric pressure recorded on gas analyser during ground gas monitoring
	3	2	1	
23/05/2018	1022	1018	1024	1023
29/05/2018	1023	1020	1022	1016
14/06/2018	1016	1019	1019	996
20/06/2018	1013	1017	1022	1009
05/07/2018	1021	1022	1018	1008
16/07/2018	1023	1021	1017	1007

All monitoring results together with the temporal conditions are contained within Appendix H and discussed in Section 6.2.2.

5 GROUND CONDITIONS

The results of the intrusive investigation and subsequent laboratory analysis are detailed below. The descriptions of the strata encountered, notes regarding visual or olfactory evidence of contamination, list of samples taken, field observations of soil and groundwater, in situ testing and details of monitoring well installations are included on the exploratory hole records presented in Appendix D.

5.1 Soil

The exploratory holes reveal the site is generally underlain by a relatively thin layer of granular made ground, generally ranging from 0.3m (JTP02) to 1.6m (JBH01), with locally thicker deposits associated with below ground historic features and structures in the north and west of the site (1.95m in JTP30 and 3.4m in JTP31A). Made ground was found to be underlain by Glaciofluvial deposits, generally comprising gravelly sand to depths of between 0.65m (JTP05) to 5.4m (JBH04). Sandstone bedrock was encountered below the Glaciofluvial deposits at depths of between 0.45m and 5.4m bgl to a maximum (unproven) depth of 16.2m bgl (JBH02).

The ground conditions are summarised in Table 3 and the strata discussed in subsequent subsections.

Table 3: General succession of strata encountered

Strata	Exploratory holes encountered	Depth to base of stratum m bgl	Elevation of base of stratum (m AOD)
Made ground	All exploratory holes	0.3 (JTP02) to 1.6 (JTP21) Locally deep deposits at JTP30 (1.95m) and JTP31A (3.4m) due to historic features	29.01 (JTP20) to 23.81 (JTP31A)
Glaciofluvial deposits	All exploratory holes with the exceptions of JTP20-JTP22, JTP30 and JTP31A	0.65 (JTP05) to 5.4 (JBH04)	25.49 (JTP25) to 22.63 (JBH02)
Weathered Sandstone (Chester Formation)	JBH01 to JBH04, JTP02, JTP07, JTP10A, JTP11, JTP13, JTP24, JTP25, JTP30, JTP31A	2.5 (JBH01) to 5.7 (JBH02)	23.93 (JBH01) to 21.73 (JBH02)
Sandstone (Chester Formation)	JBH01 to JBH04, JTP02, JTP07, JTP11, JTP13, JTP24, JTP25, JTP30, JTP31A	2.5 (JBH01) to 5.7 (JBH02)	23.93 (JBH01) to 21.73 (JBH02)

5.1.1 Surface coverings

A variety of surface coverings were encountered across the site.

Made ground described as greyish brown gravelly sand was encountered from the ground surface in several locations; JBH01, JBH02, JTP30 and JTP31 to depths of around 0.2m bgl.

Cobble setts set with bituminous tar, were encountered at the ground surface to depths of between 0.15m and 0.2m bgl at JBH03, JBH04, JTP20, JTP21, JTP22, JTP23 and JTP24 (all located in the external courtyard and below the entrance archways).

Asphalt tile with woven geotextile and bituminous binding was encountered at the ground surface in JTP01, JTP03, JTP04 (all located in Mill 1) and JTP14 (located in Mill 2).

Wooden floorboards (MDF/PLY) attached to wooden floor joists were encountered from the ground surface in JTP02, JTP06, JTP07 and JTP13. The Wooden floor was suspended above a void measuring approximately 0.25-0.53m thick.

Concrete was encountered from the ground surface in JTP05, JTP25 and JTP31A to depths of between 0.1m and 0.15m bgl.

Yorkstone flags were encountered from the ground surface in JTP10, JTP10A, JTP11, JTP12, JTP32 and JTP33 (all located in Mill 2) measuring 0.08m thick.

5.1.2 Made ground

Made ground was encountered in every exploratory hole location below surface coverings to depths ranging between 0.3m (JTP02) to 1.6m bgl (JTP21). Locally, made ground deposits were found to extend deeper in areas of historic features. In JTP30, located in the northwest of the site (the location of a suspected culvert, made ground was encountered to a depth of 1.95m bgl. In JTP31A, located in the north of the site and targeting a historic chimney, made ground was encountered to a depth of 3.4m bgl.

Shallow made ground deposits were encountered within the existing mill buildings. In Mill 1 the depth to the base of the made ground ranged between 0.3m and 0.75m bgl (25.42m AOD and 25.86m AOD). In Mill 2, the depth to made ground ranged between 0.53m and 0.7m bgl (25.44m AOD to 25.65m AOD).

A multicoloured crystallised gravel with a hard outer shell of yellow was encountered in JTP14 at depths of 0.19m to 0.27m bgl. The unknown material had a sweet perfumery odour. RSK is unsure of the provenance and composition of this material but assume it is a by-product of a previous industrial process present on site.

Made ground deposits generally comprised blackish to greyish brown gravelly, slightly clayey fine to coarse sand with brick, concrete, glass, ash, clinker, bituminous fragments and ceramic pipe fragments.

A dry clay pipe was encountered within made ground deposits in JTP20 and JTP21 (running along the western site boundary through the main archway into the site) at a depth of 0.4m bgl. The pipe appeared to be dipping away from the site (i.e. taking water out of the site to Ellesmere Road).

An SPT at 1.2m bgl was undertaken within 0.1m of the base of the made ground in JBH01 and JBH02. SPT 'N'-values of 46 and >50 (refusal) were calculated. The made ground was noted to contain angular gravel and cobbles of brick and mudstone with the next

barrel run terminating due to a cobble. It is likely that the high SPT value and refusal are due to cobble obstructions within the made ground.

A summary of the in-situ test and laboratory results in this stratum is presented in Table 4 below.

Table 4: Summary of in-situ and laboratory test results for the made ground

Soil parameters	Range	Reference
Water soluble sulphate (WSO ₄) (mg/l)	<10 - 1340	Appendices E and F
Chloride (mg/l)	38 - 123	
pH value	6.87 – 7.99	

5.1.3 Superficial deposits (glaciofluvial)

Glaciofluvial deposits were encountered beneath made ground deposits in all exploratory holes with the exceptions of JTP11, JTP20 – JTP22, JTP30 and JTP31A (where the holes were terminated either within made ground deposits or made ground was underlain directly by sandstone bedrock). The base of the glaciofluvial stratum was measured to be between 0.65m (JTP05) and 5.4m bgl (JBH04). In terms of elevation data, the base of the glaciofluvial deposits was found to be between 22.63m AOD in JBH02 (north of the site) and 28.93m AOD (in south of the site).

Generally, the glaciofluvial deposits were described as yellowish brown and reddish brown slightly clayey, slightly gravelly sand with gravel of mudstone and sandstone. However, in JTP06, firm to stiff slightly sandy slightly gravelly clay was encountered below granular glaciofluvial deposits at 0.8m bgl.

SPT tests undertaken in the glaciofluvial deposits resulted in refusals (>50) in most tests. Only two SPT tests resulted in <50 blows; JBH04 resulted in N-values of 15 and 30 indicating medium dense soils. In JBH02 there was poor recovery of the superficial deposits, likely due to the granular nature of the soils.

A summary of the in-situ test and laboratory results in this stratum is presented in Table 5.

Table 5: Summary of in-situ and laboratory test results for the glaciofluvial deposits

Soil parameters	Range		Reference
Moisture content (%)	23 ¹		Appendix F
Liquid limit (%)	36 ¹		
Plasticity limit (%)	20 ¹		
Plasticity index (%)	16 ¹		
Plasticity term	Intermediate ¹		
Grading (%)	Gravel	2 to 72	
	Sand	25 to 86	
	Silt/clay	3 to 12	
SPT 'N' values	15 to >50		Appendix D; Fig 3

Soil parameters	Range	Reference
Density term	Medium Dense to Very Dense	Appendix D
Laboratory CBR Test (%)	16 to 27 (100)	Appendix F
Water soluble sulphate (WSO ₄) (mg/l)	<10 to 247	Appendices E and F
Chloride (mg/l)	<7 to 104	Appendices E and F
pH value	7.13 to 8.50	Appendices E and F
Notes: ¹ Testing from localised clay layer in JTP06		

5.1.4 Weathered sandstone

Weathered sandstone, described as orangish red gravelly coarse sand with gravel of weak coarse sandstone, was encountered below superficial deposits is JBH01, JBH04, JTP02, JTP07, JTP10A, JTP24, JTP25 and JTP31 at depths of between 1.0m and 3.0m bgl. In JTP11, JTP30 and JTP31A weathered sandstone was encountered directly below made ground deposits at depths of 1.95m and 3.4m bgl respectively. In JBH02 there was poor recovery noted in the core liner from 1.2 to 4.2m bgl however, the engineer noted the presence of weak sandstone gravels and cobbles, assumed to be weathered sandstone.

In JBH01 and JBH04 where sandstone bedrock was encountered beneath the weathered zone, the weathered sandstone was found to measure between 0.7m and 2.4m thick. Trial pits JTP12 and JTP13 terminated before reaching the base of the foundation due to difficult digging with hand dug tools. JTP02, JTP10, JTP10A and JTP11 found the base of the foundation and terminated due to difficult digging with hand tools at the bottom of the foundation level. In trial pits JTP30, JTP31 and JTP31A, the excavations were terminated due to scraping on rock at the base by the excavator, assumed to be the top of the bedrock. The thickness of the weathered zone in these excavations was measured between 0.1m and 1.1m.

A summary of the in-situ test and laboratory results in this stratum is presented in Table 6.

Table 6: Summary of in-situ and laboratory test results for the weathered sandstone

Soil parameters	Range		Reference
Grading (%)	Gravel	5	Appendix F
	Sand	89	
	Silt/clay	6	
SPT 'N' values	46 to >50		Appendix D, Fig 4
Unconfined Compressive Strength (MPa) inferred from SPT N value	0.46 to 1.57		Fig 5
Strength term	Dense / Extremely weak to Very Weak		Appendix D
Water soluble sulphate (WSO ₄) (mg/l)	<10 to 60		Appendix F
Chloride (mg/l)	<7 - 12		Appendix F

pH value	7.48 to 8.67	Appendix F
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5.1.5 Bedrock (Sandstone of Chester Formation)

Sandstone of the Chester Formation was encountered in the boreholes directly beneath either superficial deposits (in JBH03) or beneath weathered sandstone (in JBH01, JBH02 and JBH04). The stratum was encountered at depths ranging between 2.5m bgl (JBH01) and 5.7m bgl (JBH02). In terms of an elevation, the sandstone bedrock was encountered at levels between 23.93m AOD in JBH01 (located in the northwest of the site) and 21.73m AOD in JTP02 (located in the east of the site). From the elevation data, it can be inferred that bedrock is dipping down towards the northeast.

In the rotary cores, the sandstone has been described as very weak to weak thinly bedded reddish brown fine to coarse grained sandstone. Bedding fractures are sub-horizontal and shallowly dipping very closely to closely spaced.

A summary of the in-situ test and laboratory results in this stratum is presented in Table 7.

Table 7: Summary of in-situ and laboratory test results for the sandstone

Soil parameters	Range	Reference
Moisture content (%)	3.8 to 12	Appendix F
Bulk Density (Mg/m ³)	1.97 to 2.11	Appendix F
Unconfined compressive strength (MPa)	3.3 to 11.0	Appendix F
Point Load Strength Is_{50} (MPa)	0.07 (0.01*) to 0.49	Appendix F
Unconfined Compressive Strength (MPa) inferred from Is_{50}	1.15 to 7.58	Appendix F, Fig 5
Strength term	Very weak to Weak	Appendix D
Water soluble sulphate (WSO ₄) (mg/l)	<10 to 40	Appendix F
Chloride (mg/l)	<7	Appendix F
pH value	7.51 to 8.15	Appendix F
Notes: *Considered uncharacteristically low possibly due to sample disturbance		

5.1.6 Groundwater

Groundwater was encountered during the investigation as detailed in Table 8 below.

Table 8: Groundwater results during investigation

BH/TP	Stratum	Strike in m b (conditions after 20 minutes))	Strike elevation (m AOD)
JBH01	Sandstone	6.2 (rising to 4.1)	20.23
JBH02	Sandstone	7.2 (rising to 5.7)	20.23
JBH03	Sandstone	5.7 (rising to 3.2)	21.14
JBH04	Sandstone	6.0 (rising to 5.1)	22.95

BH/TP	Stratum	Strike in m b (conditions after 20 minutes))	Strike elevation (m AOD)
JTP30	Weathered sandstone	2.1	23.86

A slight groundwater seepage was encountered within the upper weathered zone of the sandstone bedrock in JTP31A at 3.50m.

The results of the first groundwater monitoring visit are summarised in Table 9 below.

Table 9: Groundwater monitoring data (23 May 2018)

Monitoring well	Depth to product (m bgl)	Depth to water (m bgl)	Depth to water elevation (m AOD)
JBH01	N/D	2.17	24.26
JBH02	ND	3.10	24.33
JBH03	ND	2.57	24.27
JBH04	ND	4.75	24.20

5.1.7 Visual/olfactory evidence of soil and groundwater contamination

Evidence of olfactory or visible contamination on soil or groundwater was not noted during the site investigation.

5.2 Ground gas regime

The results of the ground gas monitoring and testing carried out are given in Appendix H. The minimum and maximum results are recorded in Table 10.

Table 10: Summary of ground gas monitoring results

Borehole	Response zone/strata	Number of monitoring visits	Methane (%)	Carbon dioxide (%)	Oxygen (%)	Flow rate (l/hr)
JBH01	SST	6	<0.1	0.9	19.3	0.1
JBH02	SST	6	<0.1	0.9	20.3	0.1
JBH03	SST	6	<0.1	<0.1	20.7	0.1
JBH04	SST	6	<0.1	1.0	19.4	0.1
Note: SST - sandstone Maximum (minimum for oxygen) steady state gas concentrations and flows are presented in this table.						

5.3 Investigation of the canal wall (JTP30)

A single trial pit was excavated perpendicular to the wall of the Bridgewater Canal, located on the western site boundary. The aim of this trial pit was to investigate the wall arrangement and a suspected culvert which engineers anticipated to run parallel to the canal. A GPR survey was undertaken in the area thought to be the location of the culvert and a positive signal was picked up on the equipment. During excavation, evidence of a culvert was not observed, however a brick feature and void could be the source of the signal induced by the GPR equipment.

As part of the trial pit excavation process at JTP30, the wall of the canal was inspected. This process was extremely difficult due to the presence of dense vegetation and bricks making up the wall being extremely fragile. As shown on trial pit log JTP30 Face C, made ground was encountered to 0.5m bgl with a layer of concrete flags encountered between 0.2m and 0.3m bgl. The made ground sat on top of a brick wall measuring 5 brick courses or 0.3m deep (base of brick wall at 0.8m bgl). The brick wall in turn was sat directly on sandstone bedrock.

During the investigation of JTP30 the water level in the canal arm was surveyed and measured to be at an elevation of 25.29m AOD. Relating this back to ground level at JTP30, there is a difference between the site level and the water level in the canal of 1.07m. This would put the water level within the canal at a level that is within the weathered sandstone however, there was no water ingress observed at this level during the excavation of the trial pit. A groundwater strike was observed at 2.10m bgl (24.26m AOD) but this is at 1.03m below the canal water level.

5.4 Refinement of the initial conceptual site model

The initial conceptual model presented in the PRA, highlighted the existence of the bedrock at shallow depth beneath the site, classified as a principal aquifer. In this respect, the contaminant linkage between contaminated soils, shallow groundwater and the groundwater in the underlying sandstone was identified as being potentially complete.

Exploratory hole logs report that the site is underlain by a relatively thin layer of granular made ground (to depths of between 0.3m bgl and 1.6m bgl) with locally thicker deposits in areas associated with historic site features, such as buildings and chimneys (to a maximum depth of 3.4m bgl in JTP31A). The made ground is underlain by glaciofluvial deposits, generally described as a gravelly sand, to varying depths of between 0.65m bgl (JTP05) to 5.4 m bgl (JBH04). These granular superficial deposits are underlain by sandstone of the Chester Formation, designated as a Principal Aquifer. Localised downward migration of potentially contaminated groundwater and soil leachate to the principal aquifer cannot be ruled out. Therefore, groundwater monitoring wells were installed in the sandstone aquifer at depth to allow groundwater level gauging and groundwater samples to be collected.

In line with current guidance, namely BS8576 (2013), the ground gas generation potential for the site was anticipated to be 'very low' based on limited deposits of made ground being present with low degradable organic content. This was confirmed during the site investigation whereby made ground thicknesses at the borehole location were limited to 1.0m to 1.3m in thickness and no evidence of degradable or putrescible materials were identified. Given the 'very low' gas generation potential, gas monitoring is not necessarily

required in line with the decision matrix in Figure 6 of BS8576. Due to the observations made on site, the response zones of the monitoring wells were installed within the sandstone to target groundwater, but gas monitoring was undertaken as a precautionary measure. The conceptual model, therefore, does not consider the risk of ground gas a complete linkage, however, the results are discussed in section 6.2.2 for completeness.

The initial conceptual model presented in the PRA, highlighted the existence of a potentially complete contaminant linkage between lateral migration of shallow groundwater from the site, and the adjacent surface water body (arm of the Bridgewater Canal). Canal water sampling has been undertaken to assess this potential linkage and the results are discussed in section 6.2.5 for completeness.

6 QUANTITATIVE RISK ASSESSMENT

In line with CLR11 (EA, 2014), there are two stages of quantitative risk assessment, generic and detailed. The GQRA comprises the comparison of soil, groundwater, soil gas and ground gas results with generic assessment criteria (GAC) that are appropriate to the linkage being assessed. This comparison can be undertaken directly against the laboratory results or following statistical analysis depending upon the sampling procedure that was adopted.

6.1 Linkages for assessment

Section 5.4 presents the refined conceptual model, which identified the linkages that required assessment after the findings of the site investigation had been considered. These linkages together with the method of assessment are presented in Table 11.

Table 11: Linkages for generic quantitative risk assessment

Potentially relevant pollutant linkage	Assessment method
1. direct contact via dermal contact, ingestion and inhalation of dust and asbestos fibres by future site residents in landscaped areas from shallow soil impact due to historic site activities and/or made ground.	Human health GAC in Appendix J for a proposed residential end use without home grown produce since proposed the end use includes a landscaped area in the centre of the site. Qualitative assessment based on the asbestos minerals present, their form, concentration, location and the nature of the proposed development.
2. migration of hazardous gases including methane and carbon dioxide into future residential buildings on site via granular strata and service channels with subsequent inhalation by residents and potential accumulation, creating an explosive atmosphere.	Gas screening values (GSV) have been calculated using maximum methane and carbon dioxide concentrations with maximum flow rates recorded at the site. The GSV have been compared with the generic Traffic Lights, as presented within the NHBC ground gases guide (Boyle and Witherington, 2007) and the CIRIA report C665 referred to previously, owing to the development comprising low-rise housing with suspended floors. In addition, the gas regime is considered within the context of a conceptual model as required by both previously referred to guidance documents and BS8576.
3. leaching of contaminants in shallow soil due to historic site activities to groundwater	Comparison of leachate data to lowest of those recorded in Table 1 of Appendix K for principal and secondary aquifers owing to linkages identified to both a Principal aquifer and a river upon which the GAC for Secondary aquifers are based.
4. lateral and vertical migration on impacted shallow groundwater to the underlying principal aquifer.	Comparison of groundwater data to lowest of those recorded in Appendix K for drinking water.

Potentially relevant pollutant linkage	Assessment method
5. lateral migration of contaminants to the adjacent arm of the Bridgewater Canal.	Comparison of groundwater data and upstream/downstream canal water samples to lowest of those recorded in Appendix K for Secondary aquifers/surface water.
6. contaminants associated with historic site uses permeating potable water supply pipes.	Comparison of shallow soil data to GAC in Appendix L for plastic water supply pipes using UKWIR (2010) guidance.
7. risk to building infrastructure from chemical attack via sulphate impacted soil and groundwater.	Qualitative assessment of sulphate, chloride and pH data in the geotechnical section of the report (section 7).

6.2 Methodology and results

The methodology and results of the GQRA are presented for each relevant pollutant linkage in turn.

6.2.1 Direct contact with impacted soil by future residents

Soil results were compared to the GAC for residential without home grown produce (presented in Appendix J). The results of the screening are presented in Appendix M.

Six shallow soil samples were analysed for some or all the contaminants specified in section 4.1.3. The soil samples were taken from the made ground and shallow superficial deposits located in the external courtyard of the site to the north of the existing mill buildings, as this is likely to be the location of proposed landscaping.

A deep sample of made ground was obtained from the base of the chimney structure in JTP31A at 3.0-3.2m bgl. Exceedances of arsenic and lead were reported in this sample; concentrations of 1130 mg/kg of arsenic (against the GAC of 40 mg/kg) and 746 mg/kg for lead (against the GAC of 310 mg/kg). Levels of chromium and mercury were reported to be above the T1 threshold set but did not exceed the GAC. Soils at the base of the chimney were described as black and likely to contain by-products of the chimney flue which have been deposited over time. The depth of this material is deep enough to not pose a risk to future users; however, this may pose a different risk if classified as a waste, which is discussed in section 8.

Out of five samples analysed for metals, two samples of made ground exceeded the generic acceptance criteria (GAC) of 310 mg/kg for lead. Concentrations of 490 mg/kg and 430 mg/kg were reported in JBH02 (0.0-0.1m bgl) and JTP25 (0.15-0.25m bgl) respectively.

None of the TPH aromatic or aliphatic bands exceeded the specified GAC values and all the samples analysed for BTEX were noted to be below the limit of detections (LOD) of <0.01mg/kg.

Exceedances of several PAH compounds were reported, largely in one sample (out of three analysed) as shown in Table 12.

Table 12: PAH exceedance summary table

PAH Compound	No. of exceedance	GAC (mg/kg)	Location / depth (mbgl) of maximum exceedance	Reported concentration (mg/kg)
Benzo(a)anthracene	1	15	JBH04 / 0.3-0.9mbgl	15.7
Benzo(a)pyrene	1	5.3	JBH04 / 0.3-0.9mbgl	12
Benzo(b)fluoranthene	1	4.1	JBH04 / 0.3-0.9mbgl	14.2
Dibenzo(ah)anthracene	2	0.32	JBH04 / 0.3-0.9mbgl JTP25 / 0.15-0.25mbgl	1.22 0.41

The made ground of JBH04 was reported to contain bituminous macadam and is likely the source of the elevated PAHs.

A total of five samples of made ground have been analysed for the presence of asbestos in soil. No asbestos has been identified in the samples tested. Additionally, visible asbestos was not noted in any of the exploratory holes during the investigation.

Given the presence of made ground across the site and the varied site history it is possible that localised contaminants are present in shallow soils, in areas not covered as part of this investigation. To mitigate direct contact linkages to future site residents it is recommended that either a cover layer of clean material (or hardstanding surface) is used within landscaped areas or the made ground at JBH04 and JTP25 is excavated to break the contact pathway. If a clean cover system is to be adopted, it is advised that cover soils of 450mm thickness comprising a suitable topsoil and subsoil, should be installed. Underneath the cover soils a geotextile membrane (or similar) should be installed, which remains insitu to prevent soils at depth (below 450mm) from mixing with shallower soils that form the cover system.

Although asbestos has not been found to be present in soils at the site, it is likely that asbestos will be found in the mill buildings. During the Phase 2 investigation, an asbestos removal company, employed directly by the Client, was carrying out a survey and removal of asbestos within Mill 1. Access to several areas of the ground floor and upper floors of Mill 1 were restricted due to the presence of temporary, air-tight sheeted rooms. The asbestos removal company was onsite for four days during the five day RSK investigation and performed asbestos in air monitoring during and after asbestos removal. RSK did not enter Mill 1 during the asbestos removal work.

6.2.2 Migration of hazardous ground gases

As part of the intrusive investigation carried out by RSK, four monitoring wells were installed in the underlying sandstone.

In line with current guidance, namely BS8576 (2013), the ground gas generation potential for the site was anticipated to be 'very low' based on limited deposits of made ground being present with low degradable organic content. This was confirmed during the site investigation whereby made ground thicknesses at the borehole location were limited to 1.0m to 1.3m in thickness and no evidence of degradable or putrescible materials were identified. Given the 'very low' gas generation potential of the made ground, gas

monitoring is not necessarily required in line with the decision matrix in Figure 6 of BS8576. Due to the observations made on site, the response zones of the monitoring wells were installed within the sandstone to target groundwater, but gas monitoring was undertaken as a precautionary measure. Six rounds of gas monitoring were undertaken over a three-month period, to characterise the ground gas regime over a range of atmospheric conditions. An assessment of the data is reported below.

6.2.2.1 *Method of assessment*

The results of the monitoring have been assessed in accordance with the guidance provided in BS8576 and *CIRIA Report C665*. In the assessment of risks and selection of appropriate mitigation measures, both reports highlight the importance of the conceptual model in characterising the gas regime.

CIRIA C665 identifies two types of development, termed Situation A (modified Wilson and Card method), appropriate to all development excluding traditional low-rise construction, and Situation B (National House-Building Council, NHBC) only appropriate to traditional low-rise construction with ventilated sub-floor voids.

Both methods are based on calculations of the limiting borehole gas volume flow for methane and carbon dioxide, renamed as the gas screening value (GSV). The GSV (litres of gas per hour) is calculated by multiplying borehole flow rate (litres per hour) and gas concentration (percent by volume).

In both situations, it is important to note that the GSV thresholds are guideline values and not absolute. The GSV thresholds may be exceeded in certain circumstances, if the site conceptual model indicates it is safe to do so. Similarly, consideration of additional factors such as very high concentrations of methane, should lead to consideration of the need to adopt a higher risk classification than the GSV threshold indicates.

The site is to be redeveloped with a residential apartment block and therefore falls under Situation A.

Situation A relates to all development types except low-rise housing and, by combining the qualitative assessment of risk (see refined conceptual model in Section 5.4) with the gas monitoring results, provides a semi-quantitative estimate of risk for a site. The method uses both gas concentrations and borehole flow rates to define a characteristic situation for a site based on the limiting borehole gas volume flows for methane and carbon dioxide. Having calculated the worst case GSVs for methane and carbon dioxide, the Characteristic Situation is then determined from Table 8.5 of CIRIA C665.

6.2.2.2 *Results of gas assessment*

The maximum carbon dioxide concentration of 1.2% was measured in JBH01 and methane concentrations were measured as <0.1% in all boreholes during all monitoring rounds. Gas flows ranged from 0.0 to <0.1 l/hr in all boreholes.

A maximum carbon monoxide (CO) concentration of 114ppm was measured during the first monitoring visit in JBH03. During the following five monitoring visits the concentration of carbon monoxide reduced significantly to concentrations of 38ppm (during visit 2) and 3ppm (during visit 6).

6.2.2.3 Data assessment

The maximum calculated GSV for carbon dioxide is 0.001l/hr and given the methane concentration has been measured to be <0.1%v/v in all boreholes, no GSV can be calculated. Based on this information, the site is characterised as Green, indicating that gas protection measures relating to carbon dioxide and methane are not required for the development.

Carbon monoxide is a colourless, odourless, and tasteless gas that arises from both natural and anthropogenic (human-made) sources. It is produced as a primary pollutant during the incomplete combustion of fossil fuels and biomass, including internal combustion engines, wildfires, and controlled burns. Carbon monoxide is also produced indirectly from the photochemical oxidation and vegetation can emit carbon monoxide into the atmosphere as a metabolic by-product. The elevated CO concentration was measured in JBH03. The ground conditions encountered during the site investigation and the historic usage of this part of the site do not identify a specific source of carbon monoxide as there was no documented fossil fuel combustion in this area of the site and the ground conditions do not indicate significant organic content within the soils. The elevated CO concentration was measured during the first visit and reduces significantly over time. It is therefore, considered likely that the cause of the elevated CO is the action of drilling the borehole and introduction of oxygen into the ground from the drilling process, leading to partial oxidation of carbon-containing compounds. Given that the CO concentration reduces significantly over time and recorded flow rates are negligible, RSK does not consider it necessary to install protective measures specifically for carbon monoxide.

6.2.3 Leaching of contaminants in shallow soil due to historic site activities to groundwater

Two shallow made ground samples located within the proposed landscaped area were analysed for leachable metals. None of the concentrations exceed the GAC set for groundwater. However, soil samples were not analysed for leachable PAH or TPH. The concentrations of PAH in made ground (as discussed in section 6.2.1) and in a sample of groundwater taken from JBH03, which indicates a slight exceedance of benzo(a)pyrene at a concentration of 0.04µ/l compared to a GAC of 0.01µ/l, indicate that leaching to groundwater could be a relevant pollutant linkage.

The site is currently covered with a mixture of concrete, cobble setts and gravelly sand, allowing for leaching to occur in areas of permeable ground cover. Since the proposed development includes a minimal landscaped area in the centre of the residential apartment blocks, there will be a proportion of permeable ground cover post development. It is recommended that either contaminated made ground is removed or a clean cover system is installed above made ground in areas of soft landscaping therefore, the potential for leaching of contaminants in shallow soils to the underlying groundwater is likely to decrease and is not considered to pose a significant risk.

6.2.4 Vertical and lateral migration of contaminants to the underlying principal aquifer

Groundwater concentrations were compared to the drinking water GAC for principal aquifers presented in Appendix K.

Contaminant concentrations reported in groundwater are generally low, with no indication of non-aqueous phase liquid (NAPL).

PH levels in groundwater from the sandstone aquifer measured between 6.98 and 7.59, and sulphate levels were measured to be relatively low (between 23mg/l and 165mg/l).

The only exceedance of the DWS in the sandstone aquifer, reported in JBH03 in the south of the site, installed within the sandstone at 5 to 8m bgl was for benzo(a)pyrene, with a measured concentration of 0.04µg/l against a GAC of 0.01µg/l. The benzo(a)pyrene detected could potentially have leached from the made ground, through the granular superficial deposits to the underlying sandstone, however, given the relatively low level of exceedance and the distance to the drinking water abstraction, >1km from the site, it is considered unlikely that these concentrations pose a potential risk to the abstraction.

6.2.5 Migration of contaminants to surface water in Bridgewater Canal

Appendix K presents the comparison of groundwater results compared to the GAC for freshwaters.

Three groundwater samples have been analysed for a suite of contaminants and the results exceeding the GAC are summarised in Table 13.

Table 13: Summary of groundwater results with respect to freshwater EQS

Determinant	GAC (µg/l)	Exceedances (max concentration µg/l)
Copper	1	3 (2 µg/l)
Chromium	8.1	2 (14 µg/l)
Lead	1.2	1 (3 µg/l)
Nickel	4	1 (5 µg/l)
Zinc	10.9	2 (14 µg/l)
Benzo(a)pyrene	0.00017	1 (0.04 µg/l)
Benzo(b)fluoranthene		1 (0.04 µg/l)
Benzo(ghi)perylene		1 (0.02 µg/l)
Benzo(k)fluoranthene		1 (0.02 µg/l)
Indeno(123-cd)pyrene		1 (0.02 µg/l)
Fluoranthene	0.0063	2 (0.09 µg/l)

There are several exceedances of inorganic and organic contaminants within the three groundwater samples taken from the sandstone aquifer, however these exceedances are considered to be minor with all exceedances calculated to be of the same order of magnitude as the relevant EQS value.

The greatest exceedance is for chromium in JBH03; a concentration of 14µg/l was detected against an EQS value of 8.1µg/l which is considered to be a minor exceedance.

In terms of the PAHs, the EQS value of 0.00017µg/l is set at a value below the limit of detection (LOD) of <0.01 µg/l for several compounds. The compounds which exceed the EQS are only slightly above the LOD; concentrations ranging between 0.02µg/l and 0.09µg/l compared to the LOD of <0.01µg/l.

The receiving water is an arm of the Bridgewater Canal, a well-established water course flowing through the historically heavily industrialised city of Manchester. It is highly likely that the chemical quality of the water contained within the Bridgewater Canal is significantly worse given the industrial nature of the land uses along its length.

As part of the Phase 2 investigation two samples of canal water were taken to assess the quality of the water both upstream and downstream of the site. Given the location of Talbot Mill it was not possible to take an upstream water sample, as the length of the arm of the Bridgewater Canal runs only the length of the building. As such, a sample was taken from along the length of the mill building (Canal 1) to indicate a worst case scenario if contamination was migrating from the site to the canal. The downstream water sample (Canal 2) was taken from within the Bridgewater Canal itself and to the north, and downstream of Talbot Mill. The table below compares the canal water results with the EQS and the maximum concentration encountered within groundwater in the boreholes at the site.

Table 14: Summary of Bridgewater Canal results with respect to freshwater EQS

Determinant	GAC (µg/l)	Upstream (Canal 1)	Downstream (Canal 2)	Maximum concentration in onsite groundwater
Copper	1	9	10	2
Chromium	8.1	<1	5	14
Lead	1.2	3	2	3
Nickel	4	2	2	5
Zinc	10.9	10	28	14
Benzo(a)pyrene	0.00017	<0.01	<0.01	0.04
Benzo(b)fluoranthene		<0.01	<0.01	0.04
Benzo(ghi)perylene		<0.01	<0.01	0.02
Benzo(k)fluoranthene		<0.01	<0.01	0.02
Indeno(123-cd)pyrene		<0.01	<0.01	0.02
Fluoranthene	0.0063	0.03	0.02	0.09

In the case of the majority of determinants, the concentrations within groundwater beneath the site are marginally greater than the concentration in the canal water samples. This indicates that despite there being a greater level of contamination within the site boundary, this contamination is not having a significant impact on the canal, either in the arm of the canal directly adjacent to the site, or down gradient of the site. It should be noted that with the exception of chromium and nickel, all concentrations within the canal water samples exceed the EQS values. This indicates that in its current state, the canal is already in a poor condition, likely due to its location within a historically heavily industrialised city.

Generally, it is considered that the groundwater within the site is not having a significantly negative impact on the Bridgewater Canal.

During the excavation of JTP30 the water level in the Bridgewater Canal was surveyed and measured to be at an elevation of 25.29m AOD. Relating this back to ground level at JTP30, there is a difference between the site level and the water level in the canal of 1.07m. This would put the water level within the canal at a level that is within the sandstone bedrock however, there was no water ingress observed at this level during the excavation of the trial pit. A groundwater strike was observed at 2.10m bgl (or 24.26m AOD) but this is at 1.03m below the canal water level.

Taking in account the above evidence, it is considered that the contaminant linkage is potentially incomplete given that only slight exceedances of the EQS values have been detected and that dilution during migration to the canal and within the canal will result in significant reductions in compound concentrations.

6.2.6 Impact of organic contaminants on potable water supply pipes

For initial assessment purposes, the shallow soil (<1.5m bgl) results from the investigation have been compared with the GAC presented in Appendix L for this linkage, which are reproduced from *UKWIR Report 10/MM/03/21. Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites* (UKWIR, 2010).

The results indicate that a relevant linkage may exist associated with organic contaminants PAH and TPH in the made ground and therefore pollutant polyethylene (PE) and/or polyvinyl chloride (PVC) water supply pipes are expected to be unsuitable for use on the development unless remedial measures are implemented that mitigate the risk.

As such RSK recommend the use of barrier pipes at the site. It should be noted that at the time of this investigation the future routes of water supply pipes had not been established, hence the investigation and sampling strategy may not be fully compliant with UKWIR recommendations. Consequently, a targeted investigation and specific sampling/analytical strategy may be required later once the routes of the supply pipes are known to mitigate the use of barrier pipes if required. In addition, it is recommended that the relevant water supply company be contacted at an early stage to confirm its requirements for assessment, which may not necessarily be the same as those recommended by UKWIR.

6.3 Environmental assessment conclusions

The results of the GQRA are presented in Table 15 below.

Table 15: Summary of GQRA results

Relevant Contaminant Linkage	Linkage status
1. direct contact via dermal contact, ingestion and inhalation of dust and asbestos fibres by future site residents in landscaped areas from shallow soil impact due to historic site activities and/or made ground.	Out of five samples analysed for metals, two samples of made ground exceeded the generic acceptance criteria (GAC) of 310 mg/kg for lead. None of the TPH aromatic or aliphatic bands exceeded the specified GAC values. Exceedances of several PAH compounds were reported, largely in one sample (JBH04 at 0.3-0.9mbgl). Asbestos

Relevant Contaminant Linkage	Linkage status
	has not been identified in the samples tested and no visible asbestos was noted during the investigation. To mitigate direct contact linkages to future site residents it is recommended that either a cover layer of clean material is used within landscaped areas or the made ground at JBH04 and JTP25 is excavated to break the contact pathway.
2. migration of hazardous gases including methane and carbon dioxide into future residential buildings on site via granular strata and service channels with subsequent inhalation by residents and potential accumulation, creating an explosive atmosphere.	Gas assessment gave a classification of Green, indicating that gas protection measures are not required.
3. leaching of contaminants in shallow soil due to historic site activities to groundwater	Incomplete – The concentrations of PAH in made ground (as discussed in section 6.2.1) and in a sample of groundwater taken from JBH03, which indicates a slight exceedance of benzo(a)pyrene at a concentration of 0.04 µ/l compared to a GAC of 0.01 µ/l, indicate that leaching to groundwater could be a relevant pollutant linkage. The site is currently covered with a mixture of concrete, cobble setts and gravelly sand, allowing for leaching to occur in areas of permeable ground cover. Since the proposed development includes a minimal landscaped area in the centre of the residential apartment blocks, there will be a proportion of permeable ground cover post development. It is recommended that either contaminated made ground is removed or a clean cover system is installed above made ground in areas of soft landscaping therefore, the potential for leaching of contaminants in shallow soils to the underlying groundwater is likely to decrease and is not considered to pose a significant risk.
4. lateral and vertical migration on impacted shallow groundwater to the underlying principal aquifer.	Incomplete - Contaminant concentrations reported in groundwater are generally low, with no indication of non-aqueous phase liquid (NAPL). The only exceedance of the DWS in the sandstone aquifer, reported in JBH03 in the south of the site, installed within the sandstone at 5 to 8m bgl was for benzo(a)pyrene, with a measured concentration of 0.04µg/l against a GAC of 0.01µg/l. It is considered unlikely that these concentrations pose a potential risk to the abstraction.
5. lateral migration of contaminants to the adjacent arm of the Bridgewater Canal.	Incomplete - slight exceedances of the EQS values have been detected in groundwater beneath the site with similar, if not reduced, concentrations in two

Relevant Contaminant Linkage	Linkage status
	samples taken from the Bridgewater Canal. Given that further dilution during migration to the canal and within the canal will result in significant reductions in compound concentrations, it is considered that the groundwater beneath the site is not having a significant negative impact on the canal.
6. contaminants associated with historic site uses permeating potable water supply pipes.	Potentially complete – use of barrier pipes recommended. Targeted investigation to be undertaken once the proposed pipeline route is known to mitigate against the use of barrier pipes.

7 GEOTECHNICAL SITE ASSESSMENT

7.1 Engineering considerations

The current proposals comprise the residential refurbishment of the mill buildings (Mill 1 and Mill 2) and demolition of the courtyard buildings to create new landscaping for the residents. Mill 1 is to be extensively rebuilt to the rear with a new steel frame and an additional storey. Mill 2 is to have its roof removed and the building increased by 2 storeys. A new 10 storey framed building is also to be constructed in the northern part of the site parallel to Worsley Street. The proposed development is shown on Figure 2.

Existing and proposed loading information has been provided by Joule Consulting as presented in Appendix N. This information indicates that it is proposed to reuse the existing foundations to the mill buildings with local underpinning where required. The preferred foundation solution for the new building is a combination of pad and strip foundations bearing on the sandstone.

7.2 Geotechnical hazards

A summary of commonly occurring geotechnical hazards is given in Table 16 together with an assessment of whether the site may be affected by each of the stated hazards.

Table 16: Summary of main potential geotechnical hazards that may affect site

Hazard category (excluding contamination issues)	Hazard status based on investigation findings and proposed development			Engineering considerations if hazard affects site
	Found to be present on site	Could be present but not found	Unlikely to be present and/or affect site	
Sudden lateral changes in ground conditions	✓	Presence of Glaciofluvial deposits laterally variable and sandstone surface vertically variable		Likely to affect ground engineering and foundation design and construction
Shrinkable clay soils			✓	Design to NHBC Standards Chapter 4 or similar
Highly compressible and low bearing capacity soils, (including peat and soft clay)			✓	Likely to affect ground engineering and foundation design and construction
Silt-rich soils susceptible to loss of strength in wet conditions			✓	Likely to affect ground engineering and foundation design and construction

Hazard category (excluding contamination issues)	Hazard status based on investigation findings and proposed development			Engineering considerations if hazard affects site
	Found to be present on site	Could be present but not found	Unlikely to be present and/or affect site	
Running sand at and below water table	✓	Should be anticipated in open excavations in the sand/gravel deposits where groundwater is encountered		Likely to affect ground engineering and foundation design and construction
Karstic dissolution features (including 'swallow holes' in Chalk terrain)			✓	May affect ground engineering and foundation design and construction.
Evaporite dissolution features and/or subsidence			✓	May affect ground engineering and foundation design and construction
Ground subject to or at risk from landslides			✓	Likely to require special stabilisation measures
Ground subject to periglacial valley cambering with gulls possibly present			✓	Likely to affect ground engineering and foundation design and construction
Ground subject to or at risk from coastal or river erosion			✓	Likely to require special protection/stabilisation measures
High groundwater table (including waterlogged ground)	✓	Groundwater level ~24.00mAOD locally below sandstone surface		May affect temporary and permanent works
Rising groundwater table due to diminishing abstraction in urban area			✓	May affect deep foundations, basements and tunnels
Underground mining		✓		Likely to require special stabilisation measures
Existing sub-structures (e.g. tunnels, foundations, basements, and adjacent sub-structures)	✓	Existing foundations & former sub-structures, i.e. former chimney		Likely to affect ground engineering and foundation design and construction
Filled and made ground (including embankments, infilled ponds and quarries)	✓	Made ground locally present in area of the new building to depths of up to 3.40m		Likely to affect ground engineering and foundation design and construction

Hazard category (excluding contamination issues)	Hazard status based on investigation findings and proposed development			Engineering considerations if hazard affects site
	Found to be present on site	Could be present but not found	Unlikely to be present and/or affect site	
Adverse ground chemistry (including expansive slags and weathering of sulphides to sulphates)	✓	See section 6.2.1		May affect ground engineering and foundation design and construction
Note: Seismicity is not included in the above table as this is not normally a design consideration in the UK.				

7.3 Ground model and characteristic values

The preliminary ground model summarised in Table 17 has been adopted for the preliminary foundation design recommendations.

Table 17: Ground model derived from ground investigation

Stratum	Elevation at top of stratum	Thickness (m)
Made ground	27.00	1.00 / 3.40
Glaciofluvial Deposits	26.00 / Absent	1.00 / -
Weathered Sandstone	25.00 / 23.60	1.50 / 0.60
Sandstone	24.50 / 23.00	Proven to 16.20mbgl / 11.23 ¹
Notes: ¹ 1 st values indicate depths considered for spread foundation design / 2 nd values for piled foundations ² base of stratum not proven		

Groundwater has been recorded within the installations at elevations ranging between 24.28m and 23.71m AOD.

The geotechnical design parameters presented in Table 18 below are based on the results of the fieldwork, in-situ and laboratory testing, and reflect RSK's understanding of the proposed construction at the time this report was written. The designer should assess the applicability of the characteristic values provided below for the design situation under consideration and to ensure that it is a cautious estimate of the value affecting the occurrence of the relevant limit state(s).

Table 18: Summary of characteristic geotechnical design parameters

Design parameter	Stratum			
	Made Ground	Glaciofluvial Deposits	Weathered Sandstone	Sandstone
Unit weight - γ_k (kN/m ³)	18.0 ¹	19.0 ¹ (Dry) 20.0 ¹ (Sat.)	19.0 ¹ (Dry) 20.0 ¹ (Sat.)	20.0
Effective Angle of Friction - ϕ'_{k} (°)	28 ²	34 ³	38 ⁴	-
Unconfined compressive strength - UCS' _k (MPa)	-	-	-	1 - 5
Notes: ¹ Estimated from soil descriptions using Figure 1 & 2 of BS 8002:2015 ² Assumed empirical values in the absence of testing ³ Estimated using equation 4 for coarse soils from BS 8002:2015 ⁴ Presumed value for non-intact sandstone				

7.4 Existing foundations

7.4.1 General

This section discusses the implications of the load changes to the existing foundations in the mill buildings associated with refurbishment, change of use and extensions. The Engineer has provided a detailed breakdown of the existing and proposed loads/bearing pressures for specific column/wall locations where investigations have been completed to establish the foundation geometry. Foundation widths to the walls are taken as per the assumed widths provided by the Engineer. Based on the foundation geometries assumed from the investigations this indicates typical existing bearing pressures in the range of 84 to 437kN/m², locally 1263 kN/m² at JTP11, and the proposed bearing pressures in the range of 80 to 435kN/m², locally 1208 kN/m² at JTP11.

The findings of the trial pitting completed generally indicate that the existing mill buildings are supported on a combination of pad and strip footings constructed of sandstone blocks and masonry founded within the sand/gravel of the Glaciofluvial deposits and locally underlying weathered sandstone, i.e. JTP11.

Where exposed the existing foundation depths range from 0.53m to 1.58m below the existing floor levels with the corresponding elevations to the underside of foundation estimated to range from approximately 25.64m AOD to 24.59m AOD. The pad widths across the foundations investigated are estimated to range from approximately 0.90m to 1.23m and strips indicated to range in width from 0.92m to 1.24m.

The general ground profile beneath the footings comprises medium dense to very dense gravelly sand/sand & gravel (Glaciofluvial deposits) or weathered weak sandstone bedrock over sandstone bedrock.

The principle exception to the above being JTP11 where a very weak sandstone layer was encountered at the foundation level. Due to the limited exposure in the hand excavated trial pit it was not possible to determine the lateral or vertical extent of the sandstone and whether this comprises competent bedrock. The bearing resistance at this location has therefore been assessed using conventional bearing capacity equations for a granular soil in the case of a non-intact weathered sandstone and with reference to presumed bearing resistances

for rock given in EN 1997-1:2004 Fig G.1 for the case of competent sandstone bedrock, proportioned for the approximately 1m wide foundation for 15mm settlement.

7.4.2 Bearing resistance

The bearing capacity of selected existing foundations for which load take down information has been supplied has been assessed to Eurocode 7 (BS EN 1997-1).

Based on the ground model above, the ultimate limit state (ULS) design resistances (DA1-2) have been calculated for the estimated foundation geometries and compared with the associated design pressures to determine the degree of utilisation. The detailed bearing capacity calculations and summary are presented in Appendix O.

The Eurocode 7 assessment (BS EN 1997-1) considers Design Approach 1 – Combination 1 (DA1-C1) and Combination 2 (DA1-C2) partial factors. It has been determined that DA1-C2 is the more conservative approach and the results summarised in Table 19.

Table 19: Comparison of ULS design resistance, design pressures and utilisation

Estimated Foundation Dimensions				DA1-C2 Design Resistance (kN/m ²)	DA1-C2 Design Pressure (kN/m ²)	Utilisation
Ref.	Width (m)	Length (m)	Depth (m)			
E2/JTP01	1.10	1.10	0.85	477	182	38%
E8/JTP02	1.14	1.18	1.30	652	460	70%
GL4/JTP05	0.93	1.00	0.53	326	323	99%
GL9a/JTP06/07	1.00	1.00	0.72	411	82	20%
GL11	1.00	1.00	0.53	398	328	83%
GLG/JTP07	1.24	1.00	1.04	547	220	40%
JTP10	1.40	1.43	1.50+	754	374	50%
JTP10A	1.54	1.59	1.63	796	442	55%
JTP11 (1)	0.91	0.93	0.73	662	1277	193%
JTP11 (2)	0.91	0.93	0.73	1500	1277	85%
JTP13	1.16	1.00	1.42	691	297	43%
JTP14	1.12	1.00	1.88	865	314	36%
JTP23	0.92	1.00	0.70	398	375	94%
JTP24	0.92	1.00	0.70	398	375	94%
Notes: Utilisation >100% unacceptable (1) Weathered non-intact sandstone (2) Sandstone bedrock						

From the table above, it can be seen that the design resistances obtained for the selected foundations generally have a satisfactory degree of utilisation.

GL 4/JTP05 is indicated to be essentially fully utilised (99 utilised), but it is noted that it still maintains working stress factors of safety above 2.0 under the proposals.

The footing exposed at JTP11 is assessed as having a degree of utilisation of 193% or 85% and working stress factors of safety of 1.29 or 1.49 depending on whether its founded on non-intact weathered sandstone or intact sandstone bedrock.

It is recommended that further work is undertaken at this location to confirm the presence of sandstone bedrock or otherwise and in turn if an acceptable utilisation is achievable.

It is also necessary to check the serviceability limit state (SLS) under the proposed load increases and the results of this analysis are detailed in the following section.

7.4.3 Serviceability limit state analysis

Serviceability limit state analysis (SLS) analysis has been carried out to estimate the likely magnitude of settlement beneath the selected foundations.

The settlement calculations have been carried out using the Burland and Burbridge approach for the granular soils and linear elastic approach for sandstone bedrock. Given that settlements under the existing bearing pressures will have long since ceased and the SLS analysis only considers the settlement due to the proposed changes in pressure.

It should be appreciated, however, that the strains resulting from settlement under the existing loads may be locked into the existing structures to some degree and therefore an estimate of the original settlements is also outlined in the table to assess the likely overall total settlement.

The results of the settlement analysis are presented in Table 20.

Table 20: Results of settlement analysis

Ref.	New applied pressure (kN/m ²)	Change in applied Pressure (kN/m ²)	Estimated settlement under change (mm)	Original design pressure (kN/m ²)	Estimated original settlement (mm)	Estimated total settlement (new+old) (mm)
E2	176	-198	0	374	19	19
E8	435	51	4	384	20	24
GL 4	315	57	5	258	18	23
GL 9a	80	-4	0	84	6	6
GL 11	324	22	2	302	21	23
GL G	215	19	2	197	15	17
TP10	510	-23	0	370	25	25
JTP10A	417	-19	0	437	27	27
JTP11 (1)	1208	-56	0	1263	15	15
JTP11 (2)	1208	-56	0	1263	8	8

Ref.	New applied pressure (kN/m ²)	Change in applied Pressure (kN/m ²)	Estimated settlement under change (mm)	Original design pressure (kN/m ²)	Estimated original settlement (mm)	Estimated total settlement (new+old) (mm)
JTP13	287	9	1	278	21	22
JTP14	309	28	1	281	20	21
TP23/24	362	11	1	351	24	25
Notes:						

The results of the analysis indicate that the predicted total settlements under the new applied bearing pressures (un-factored) are in the range of 0 to 5mm and the total settlements under the original and new applied pressures are generally below or equal 25mm except for the foundations at JTP10A where settlement under the original load is estimated to be in the order of 27mm. However, it is noted that the proposals result in a reduction in applied pressure on the foundation JTP10A and therefore no additional settlement would be expected at these locations providing the foundations have fully experienced the loads indicated.

In addition to the above, the settlement estimated from the proposed increases in dead load have also been assessed and the results are provided on the summary sheet in Appendix O.

7.5 New foundations

7.5.1 General

The loading information provided by the Engineer indicates pad and strip footings associated with the new ten-storey building in the order of 1980kN and 383kN/m, respectively.

Given the presence of competent sandstone at estimated depths of 1.90 to 2.70m bgl, locally 3.50m+ at JTP31A, it is considered that spread footings would be suitable for supporting the new building. The depth of such foundations may vary considerably where former foundations/sub-structures are encountered and the new foundations need to be extended beneath these into the underlying competent sandstone strata, the depth to which is also likely to vary across the building. Deep excavations will require support and may require dewatering. Alternatively, pile foundations taken to the underlying competent sandstone would provide a suitable alternative.

Recommendations for spread foundations and piled foundations for the new building are provided in the following sections.

7.5.2 Spread foundations

The recommendations for the design and construction of spread foundations in relation to the ground conditions are set out in Table 21.

Table 21: Design and construction of spread foundations

Design/construction considerations	Design/construction recommendations
Founding stratum	Sand / Gravel - Medium dense to dense Sandstone – Very weak to weak
Depth	Foundations for underpinning existing foundations to the Mill buildings should be taken at least 0.2m into the founding stratum below any overlying made ground or clay layers. Foundations for the new multi-storey building should be taken to a minimum depth of 2.00m below finished ground level and at least 0.2m into the competent sandstone founding stratum below any overlying made ground or unconsolidated superficial sand/gravel deposits.
Presumed Bearing Resistance for Glacial Sand/Gravel and highly weathered sandstone	Spread foundations with a width of up to 1.7m and constructed on the sand/gravel at a minimum depth of 1.00m below finished ground level may be designed using a presumed bearing resistance of 350 kN/m ² . Settlement for the presumed bearing pressure should not exceed 25mm.
Presumed Bearing Resistance for Competent Sandstone	Spread foundations with a width of up to 2.50m and constructed on the sandstone at a minimum depth of 2.00m below finished ground level may be designed using a presumed bearing resistance of 500 kN/m ² . Settlement for the presumed bearing pressure should not exceed 15mm.
Stability of excavations	The trial pits were locally unstable during excavation. It is therefore recommended that excavation sides are battered back to a safe angle where space permits or support systems are made available during the groundwork stage of the development. No man entry should be allowed within excavations without battering back to a safe angle or appropriate temporary support in place.
Dewatering	Groundwater was encountered at a highest level of 24.2mAOD, which is generally below the sandstone surface. However, where excavations have to be deepened groundwater may be encountered and allowance should be made for localised dewatering of excavations as required.
Construction considerations	All foundation excavations should be inspected, and any made ground and soft, organic or otherwise unsuitable materials removed and replaced with mass concrete.

7.5.3 Piled foundations

Recommendations for the design and construction of pile foundations in relation to the ground conditions are set out in Table 22.

Table 22: Design and construction of piled foundations

Design/construction considerations	Design/construction recommendations
Pile type	The construction of both conventional rotary bored and CFA piles is considered technically feasible at this site.

Design/construction considerations	Design/construction recommendations	
Possible constraints on choice of pile type	Driven piles will not be suitable due to presence of hard strata at shallow depths. CFA piles may not be able to achieve sufficient penetration into the sandstone and there may be a risk of flighting within any overlying unconsolidated Glaciofluvial deposits with uncased CFA piles because of slow penetration rates in the underlying sandstone. However, it is recommended that the advice of a piling specialist is sought in respect to this.	
Temporary casing	The presence of perched groundwater has been recorded and the made ground/Glaciofluvial deposits are non-self-supporting therefore bored piles will require temporary casing. Alternatively, the use of continuous-flight-auger (CFA) injected bored piles usually overcomes this issue, subject to possibility of flighting as mentioned above.	
Made ground / Alluvium	For assessing preliminary pile capacities, the made ground has been presumed not to contribute to the load-carrying capacity for the piles.	
Man-made obstructions	The presence of buried sub-structures or other obstructions within made ground may lead to some difficulty during piling. It is recommended that once the proposed pile layout has been determined, pre-pile probing be carried out at each of the pile positions. Where buried obstructions are encountered, it will be necessary to either relocate the pile(s) or make allowance for removing the obstruction.	
Hard strata	An allowance should be made for forming rock sockets in the sandstone.	
Pile design parameters for Glaciofluvial Deposits/ Weathered Sandstone	Shaft Friction Factor ($k_s \tan \delta$)	0.22
	Average limiting shaft friction (kN/m^2)	110
Pile design parameters for Unweathered Sandstone	Ultimate Shaft Resistance q_s (kN/m^2)	200
	Ultimate Base Resistance q_b (kN/m^2)	6,000
	Model factor (γ_{Rd})	1.4
Special precautions relating to bored pile shafts and bases	Bored pile concrete should be cast as soon after completion of boring as possible and in any event the same day as boring. Prior to casting the base of the pile bore should be clean, otherwise a reduced safe working load will be required. Similarly, if the pile bore is left open the shaft walls may relax/soften, leading to a reduced safe working load.	

The design resistance has been calculated in accordance with BS EN 1997-1 and the UK National Annex, using partial resistance factors for bored/CFA piles, given in Table 23.

Table 23: Partial resistance factors (γ_R)

Resistance	Set	
	DA1 C1	DA1 C2 ¹⁾
Base - γ_b	1.0	2.0
Shaft (compression) - γ_s	1.0	1.6
Total (compression) - γ_t	1.0	2.0

¹⁾ no serviceability verification

The design procedure for piles varies considerably, depending on the proposed type of pile. However, for illustrative purposes Table 24 gives likely working pile loads for traditional bored/CFA, cast-in-situ concrete piles of various diameters and lengths, based on the design parameters given in Table 19.

Table 24: Typical pile design resistances for bored/CFA piles - compression

Typical Design resistance for DA1 – Combinations C1 & C2 (kN)						
Depth of Pile toe below Level - 27.00mOD	Pile diameter					
	300mm		450mm		600mm	
	C1	C2	C1	C2	C1	C2
8.00	846	491	1497	850	2299	1285
9.00	981	575	1699	976	2568	1454
10.00	1116	659	1901	1103	2838	1622
11.00	1250	743	2103	1229	3107	1790
12.00	1385	827	2305	1355	3376	1958

When dimensioning a pile, the design load must be multiplied by the appropriate partial factor, γ_G .

It should be stressed that the above capacities do not take into consideration limiting concrete stress (to be verified by a separate load case as defined in EC2) nor pile group effects, the latter of which is more pronounced for many closely spaced piles.

Notwithstanding the above, it is recommended that a specialist piling contractor should be contacted at an early stage for their advice on the most suitable pile type and capacity for the strata encountered at this site. The piling specialist will need to confirm the ability of their equipment to form of rock sockets within the bedrock and depth of penetration practically achievable based on their previous experience in the local area.

7.6 Floor slabs

Lightly loaded ground floor slabs are envisaged for the new building, i.e. not exceeding a maximum design loading of 5kN/m².

The exploratory holes excavated in the northern part of the site typically indicate a moderate thickness (0.75m to 1.95m), locally up to 3.40m at JTP31. Based on the exploratory records, these materials appear to be predominately granular in nature and in a variable state of compaction with buried sub-structures also encountered.

It is common practice to suspend ground floor slabs where existing made ground is of significant thickness and variable state of compaction due to the risk of excessive settlement. However, lightly loaded ground bearing slabs may be suitable providing that suitable measures are taken to minimise the risk of settlement. Such measures should include removal of a suitable thickness of existing made ground, say 1.00m or so, careful examination and rolling of the formation, replacement of exceptionally hard (i.e. old structures) and soft material at the formation level with well compacted suitable granular fill, engineering back in the granular made ground materials (oversize or otherwise unsuitable material removed), placement of a suitable blanket of well-compacted imported granular fill and provision of some light reinforcing. It may also be prudent to ensure that ground floor slabs are suitably disconnected from the main structure.

Alternatively, suspended ground floor slabs should be adopted for the new buildings, particularly where floor slabs are required to support any heavy or sensitive equipment.

7.7 Roads and hardstanding

In the 1.0m to 1.5m below the proposed finished ground level the exploratory holes have revealed a soil profile comprising moderate thickness of variable made ground over gravelly sand or sand and gravel.

In pavement design terms, the groundwater conditions are anticipated to comprise a low water table, i.e. at least 1 m below the pavement formation level.

The recommended sub-grade soil CBR value for preliminary road pavement design is therefore less than 2% for the existing made ground. It is recommended that in situ plate bearing tests are conducted at final formation level following treatment/compaction to confirm the final design CBR values.

During construction the formation level should be carefully compacted, and any soft spots removed and replaced with well-compacted granular fill.

The sub-grade soils can be regarded as non-frost-susceptible, based upon the criteria given in Appendix 1 of TRRL (1970) Report Road Note 29.

7.8 Chemical attack on buried concrete

This assessment of the potential for chemical attack on buried concrete is based on current BRE guidance. The available information for the site indicates that for the purposes of this assessment of the aggressive chemical environment, the site should be considered as a brownfield development unlikely to contain pyrite. An appropriate suite of chemical analyses for this site classification was carried out on soil samples by RSK.

Based on testing results, Table 25 gives the characteristic pH and water-soluble sulphate content values soil for each of the geological units encountered on site.

Table 25: Characteristic water-soluble sulphate values for soils and groundwater beneath the site

Soil type	Characteristic pH	Characteristic WSO_4 (mg/l)
Made ground	7.69	382
Glaciofluvial Deposits	8.14	54.6
Sandstone	7.87	17.6
Groundwater	7.16	107.7

Based on the results above and following the steps outlined in the BRE guidance, the Design Sulphate Classes and Aggressive Chemical Environment for Concrete classifications are summarised in Table 26, based on water soluble sulphate contents.

Table 26: DS and ACEC Class – based on water soluble sulphate

Soil type	Design Sulphate (DS) Class	Aggressive Chemical Environment for Concrete (ACEC) Class
Made ground	DS2	AC-2
Glaciofluvial Deposits	DS1	AC-1
Sandstone	DS1	AC-1
Groundwater	DS-1	AC-1

The recommended ACEC Classification is therefore AC-2 with a Design Sulphate Class of DS-2.

7.9 Natural drainage system

Infiltration testing was not undertaken as part of the investigation. Notwithstanding this, natural superficial deposits beneath the site, generally comprising sands and gravels, are not considered to impede the natural percolation of water. The proposed design includes the use of permeable paving in external courtyard areas. This form of surface covering will offer a diffuse form of recharge, and coupled with the largely granular superficial deposits, is considered to be a suitable form of drainage system. It should be noted that section 6.2.3 recommends that either contaminated made ground be removed or a clean cover system is installed above made ground in areas of soft landscaping therefore, the potential for leaching of contaminants in shallow soils to the underlying groundwater is likely to decrease and is not considered to pose a significant risk.

8 REUSE OF MATERIALS AND WASTE

8.1 Reuse of suitable materials

Under the Waste Framework Directive, naturally occurring soils are not considered waste if reused on the site of origin for the purposes of development.

In accordance with the definition provided in the Waste Framework Directive, materials are only considered waste if 'they are discarded, intended to be discarded or required to be discarded, by the holder'. Thus, soils that are not of clean and natural origin, i.e. made ground (whether contaminated or not) and other materials such as recycled aggregate, do not become waste until the criteria are met.

The Definition of Waste: Development Industry Code of Practice (CL:AIRE, 2011) (CoP) was developed in consultation with the Environment Agency and development industry to enable the re-use of materials under certain scenarios and subject to demonstrating that specific criteria are met. The current reuse scenarios covered by the CoP comprise

- reuse on the site of origin (with or without treatment)
- direct transfer of clean and natural soils between sites
- use in the development of land other than the site of origin following treatment at an authorised Hub site (including a fixed soil treatment facility).

The importation of made ground soils (irrespective of contamination status) or crushed demolition materials is not permitted currently under the CoP and requires either a standard rules environmental permit or a U1 waste exemption (see below).

In the context of excavated materials used on sites undergoing development, four factors are of relevance in determining if the material is a waste or when it ceases to be waste:

- the aim of the Waste Framework Directive is not undermined, i.e. if the use of the material will create an unacceptable risk of pollution of the environment or harm to human health it is likely to be waste
- the material is certain to be used
- the material is suitable for use both chemically and geotechnically
- only the required quantity of material will be used.

The CoP requires the preparation of a materials management plan (MMP) that confirms the above factors will be met. This plan needs to be reviewed by a 'Qualified Person' (QP) who will then issue a declaration form to the EA. As the project progresses, data must be collated and on completion a verification report produced that shows the MMP was followed and describes any changes.

The MMP establishes whether specific materials are classified as waste and how excavated materials will be treated and/or reused in line with the CoP. The MMP is likely to form part of the site waste management plan.

The site has been developed previously and the investigation has confirmed the presence of made ground generally to depths of between 0.3m bgl and 1.6m bgl with locally deeper

deposits associated with historic site features (to 1.95m bgl associated with mill building and to 3.4m bgl associated with chimney).

Detailed designs for the proposed development have not been provided to RSK. It is understood that a ten-storey apartment building will be developed in the north of the site. There is no basement, but the lowest level will be roughly level with the basement of the mills and level access will be provided to the courtyard. Given that piled foundations are the likely foundation solution, it is anticipated that some degree of soil (likely to be made ground but also natural superficial deposits) will be removed from this area and generally at shallow depths across the site to allow for site reprofiling and the implementation of landscaped areas in the centre of the site.

It should be noted that before any excavation works begin on-site, an MMP will need to be prepared, reviewed by a QP; and a Declaration lodged with the EA.

As noted above, under the Waste Framework Directive naturally occurring soils are not considered waste and therefore arisings of clean natural soils, e.g. from foundation and drainage excavations, may be reused on the site. However, it is important that these soils should be stockpiled separately and not become cross-contaminated with made ground / contaminated soils or construction wastes.

If it were proposed to import clean and naturally occurring soils direct from another site, the receiving site's MMP would need to be updated in advance of importation.

8.2 Treatment to meet suitable-for-use criteria

Where materials do not meet the suitable for use criteria, it may be possible to treat them under an environmental permit (mobile treatment licence) to enable them to be reused on-site.

To enable the treatment options to be determined, an options appraisal and a remediation strategy document will be necessary to support discussion of the issues with regulators and third parties.

8.3 Reuse of waste materials

If material is discarded as waste, then its reuse on site may still be possible. Waste soils and recycled aggregate can be reused on site under a standard rules environmental permit or a U1 waste exemption from the Environmental Permitting (England and Wales) Regulations 2010 if they are suitable for the proposed use, i.e. not cause harm to human health or the environment. However, it should be noted that these have strict limits on the quantity of material that can be reused.

8.4 Wastes for landfill disposal

Wastes require pre-treatment prior to disposal at landfill. Pre-treatment must be a physical, thermal, chemical or biological process (including sorting) that changes the characteristics of the waste to reduce its volume, reduce its hazardous nature, facilitate its handling and enhance its recovery.

The latest edition of the EA's 'Technical Guidance WM3' (2015), Guidance on the classification and assessment of waste, requires that within a mixed waste the separately

identifiable wastes are assessed separately. Mixing of different types of hazardous waste and hazardous waste with other waste substances is prohibited under the Waste Framework Directive. Wastes that have been mixed must be separated whenever possible.

It is best practice to provide your waste carrier (or the disposal site) with details of how the waste has been treated. Your waste carrier may provide a pre-treatment confirmation form or space on the waste transfer note to detail the pre-treatment.

The classification of waste soil is a two-stage process, the first being an assessment of whether the soil is considered hazardous or not following the guidance within Technical Guidance WM3. For off-site disposal to landfill the results of Waste Acceptance Criteria (WAC) testing must then be reviewed to establish if the soil is acceptable at the relevant class of landfill or requires pre-treatment to reduce specific hazardous properties.

8.4.1 Waste acceptance criteria

All inert, stable non-reactive hazardous and hazardous wastes have limit values (waste acceptance criteria) set out in legislation that must be met before that class of landfill can accept the waste. Currently, no WAC are in place for non-hazardous waste.

Soil and other materials that are found not to be hazardous may be classified as either non-hazardous or inert. To determine whether they can be classed as inert the soil must be tested and found to be below the inert waste acceptance criteria.

8.4.2 Waste sampling plan

Technical Guidance WM3 sets out requirements for waste sampling. It is a legal requirement to correctly assess and classify waste. The level of sampling should be proportionate to the volume of waste and its heterogeneity. At this stage, RSK consider that the level of soil sampling is/is not sufficient to categorise the material robustly/fully.

RSK recommends that a Sampling Plan be prepared to support any waste classifications and hazardous waste assessments, prior to development.

8.4.3 Preliminary waste assessment

Given the level of data obtained and the scale of the development, the following assessment should be considered indicative and further assessment should be undertaken following the preparation of a waste sampling plan.

EnviroLab, an RSK company, has developed a waste soils characterisation assessment tool (HASWASTE), which follows the guidance within Technical Guidance WM3. The analytical results have been divided into three categories based on their depth and soil type:

- shallow made ground (between ground level and 1.1m bgl)
- deep made ground (associated with historic chimney at 3.0-3.2m bgl)
- natural superficial deposits.

Eight samples of shallow made ground, taken at depths of between 0.0m and 1.1m bgl, have been analysed for a suite of contaminants and the results have been assessed using the EnviroLab HasWaste tool. None of the samples were classified as hazardous waste.

Therefore, to determine whether waste might be classified as inert or non-hazardous WAC testing will need to be undertaken.

Three samples of natural superficial deposits taken at depths ranging between 0.8m bgl and 1.4m bgl have been analysed for a suite of contaminants and the results have been assessed using the Envirolab HasWaste tool. None of the samples were classified as hazardous waste. Therefore, to determine whether waste might be classified as inert or non-hazardous WAC testing will need to be undertaken.

A single sample of deep made ground was taken at a depth of 3.0m bgl. This sample is associated with the historic chimney and is located within the outline of the proposed development. Results have been assessed using the Envirolab HasWaste tool and indicate an exceedance of the Carcinogenic HP7 threshold of 0.1% with a value of 0.14916, likely associated with elevated arsenic and lead concentrations. Based on this

The HasWaste sheet is presented in Appendix P.

8.5 Landfill tax

Waste producers disposing of material to landfill are required to pay landfill tax by HM Revenue and Customs.

The tax is chargeable by weight (tonnage) and two rates apply, either standard or lower rate. The lower rate only applies to those less polluting wastes as set out in the Landfill Tax (Qualifying Material) Order 2011, which include naturally occurring rock and soil, concrete, some minerals, some furnace slags and ash, and some low-activity organic compounds. Evidence confirming that the waste qualifies for the lower rate will be required, and standard rate tax will apply for the whole waste load for any loads of mixed waste.

Currently (since 1 April 2018), standard rate landfill tax is £88.95 per tonne.

The lower rate of landfill tax applicable to less polluting wastes (i.e. 'inert' wastes) remains at £2.80 per tonne.

Material disposed of at a soil treatment centre will not be subject to landfill tax.

8.6 Groundwater

When there is an intention to discard groundwater, chemical test results will indicate the appropriate disposal options. This could include disposal to treatment facility, via consent (issued by the water authority) to foul sewer or via consent (issued by the EA) to a watercourse or land.

8.7 Recommendations

RSK recommends that consideration as to how potentially waste soils will be dealt with as part of this development/remediation is given as early in the project planning process as possible. Such planning can lead to cost savings where potentially waste soils are viewed as a resource and retained on-site as part of the development. We also recommend, where off-site disposal is being considered, that appropriate facilities are



identified, and discussions initiated to confirm suitability of the facility to take the material. Potentially, these may include soil treatment facilities as well as landfills.

RSK can provide specialist advice to assist in this process, which can be complex and subject to regular regulatory change.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Environmental

A deep sample of made ground was obtained from the base of the chimney structure in JTP31A at 3.0-3.2m bgl. Exceedances of arsenic and lead were reported in this sample; concentrations of 1130mg/kg of arsenic (against the GAC of 40mg/kg) and 746mg/kg for lead (against the GAC of 310mg/kg). It is considered that materials at this depth are unlikely to pose a risk to future users.

Two of five samples of made ground analysed for metals, exceeded the generic acceptance criteria (GAC) of 310 mg/kg for lead. Concentrations of 490mg/kg and 430mg/kg were reported in JBH02 (0.0-0.1m bgl) and JTP25 (0.15-0.25m bgl) respectively.

Given the presence of made ground across the site and the varied site history it is possible that localised contaminants are present in shallow soils, in areas not covered as part of this investigation. To mitigate direct contact linkages to future site residents it is recommended that either a cover layer of clean material is used within landscaped areas or the made ground at JBH04 and JTP25 is excavated to break the contact pathway. If a clean cover system is to be adopted, it is advised that cover soils of 450mm thickness comprising a suitable topsoil and subsoil, should be installed. Underneath the cover soils a geotextile membrane (or similar) should be installed, which remains insitu to prevent soils at depth (below 450mm) from mixing with shallower soils that form the cover system.

The concentrations of PAH in made ground and in a sample of groundwater taken from JBH03, which indicates a slight exceedance of the DWS for benzo(a)pyrene, indicate that leaching of contaminants to groundwater could be a relevant pollutant linkage. Since the proposed development includes a minimal landscaped area in the centre of the residential apartment blocks, there will be a proportion of permeable ground cover post development. It is recommended that either contaminated made ground is removed or a clean cover system is installed above made ground in areas of soft landscaping therefore, the potential for leaching of contaminants in shallow soils to the underlying groundwater is likely to decrease and is not considered to pose a significant risk.

The slightly elevated concentration of benzo(a)pyrene above the DWS is considered to be a minor exceedance and given the distance to the drinking water abstraction is >1km from the site, it is considered unlikely that these concentrations pose a potential risk to the underlying aquifer and abstraction.

There are several exceedances of inorganic and organic contaminants within the three groundwater samples taken from the sandstone aquifer when compared against the EQS values protective of a surface water body (the adjacent Bridgewater Canal), however these exceedances are considered to be minor with all exceedances calculated to be of the same order of magnitude as the relevant EQS value. In addition, dilution during migration to the canal and within the canal will result in significant reductions in compound concentrations.

Two samples of canal water (upstream and downstream) have been analysed for a suite of contaminants and indicate, for the majority of determinants, lower concentrations compared to those in the groundwater beneath the site. This indicates that concentrations

from within the site are not having a significantly negative impact on the canal. It is therefore unlikely that the groundwater between the site and the canal is in continuity, and if it is, the dilution during migration and within the canal is reducing the levels of contamination.

During the Phase 2 investigation, an asbestos removal company, employed directly by the Client, was carrying out a survey and removal of asbestos within Mill 1. Access to several areas of the ground floor and upper floors of Mill 1 were restricted due to the presence of temporary, air-tight sheeted rooms. The asbestos removal company were onsite for four days during the five-day RSK investigation and performed asbestos in air monitoring during and after asbestos removal. RSK did not enter Mill 1 during the asbestos removal work. The linkage of permeation of plastic utilities was found to be potentially complete, with numerous exceedances of the GAC for shallow soil. It is recommended that this linkage is assessed in more detail once the route of the planned water supply is known.

Ground gas assessment has characterised the site as Green, meaning that gas protection measures will not be required.

9.2 Geotechnical

The investigation findings confirm that the existing Mill buildings are supported off sandstone/masonry pad and strip footings founded within the sand/gravel of the Glaciofluvial Deposits. The existing foundation depths were found to range from 0.53m to 1.58m below the existing floor levels with pad widths estimated to range from approximately 0.90m to 1.23m and strips indicated to range in width from 0.92m to 1.24m.

The design resistances obtained for the selected existing foundations generally show a satisfactory degree of utilisation under the proposals. GL 4/JTP05 appears to be essentially fully utilised (99 utilised), but it is noted that it still maintains working stress factors of safety above 2.0 under the proposals. JTP11 is assessed as having a degree of utilisation of 193% or 85% depending on whether its founded on weathered non-intact sandstone or intact sandstone bedrock.

The results of the analysis indicate that the predicted total settlements under the new applied bearing pressures (un-factored) are in the range of 0 to 5mm and the total settlements under the original and new applied pressures are generally below or equal 25mm. A principal exception being the foundation at JTP10A where settlement under the original load is estimated to be in the order of 27mm, although the proposals result in a reduction in applied pressure on the foundation JTP10A and therefore no additional settlement would be expected at this location providing the foundations have fully experienced the loads indicated.

It is recommended that further work is undertaken at JTP11 to confirm the founding stratum and available bearing resistance in order to confirm the available degree of utilisation. Plate testing would normally provide the most suitable means of assessing the load – settlement performance of weathered rocks but is not practical in this instance due to the site constraints. Therefore, the recommended scope of work comprises the following:

- 3no. additional hand excavated trial pits to expose the opposing corner of JTP11 and two adjacent foundations to check the lateral persistence. If the trial pits confirm a consistent bedrock level in this area:
- sink a rotary borehole with a specialist low headroom rig to a minimum depth of 3m to investigate the vertical persistence discontinuity spacing and recover core samples for unconfined compressive strength testing
- alternatively, enlarge a trial pit and attempt to recover a core sample with diamond coring techniques and use a breaker to progress the excavation below rock head to recover intact pieces for sub-sampling.

Given the presence of competent sandstone at estimated depths of 1.90 to 2.70m bgl, locally 3.50m+ at JTP31A, it is considered that spread footings would be suitable for supporting the new building. The depth of such foundations may vary considerably where former foundations/sub-structures are encountered and the new foundations need to be extended beneath these into the underlying competent sandstone strata, the depth to which is also likely to vary across the building. Deep excavations will require support and may require dewatering. Alternatively, pile foundations taken to the underlying competent sandstone would provide a suitable alternative.

Ground bearing slabs may be suitable within the existing buildings or for the new building, providing that suitable measures are taken to minimise the risk of settlement. Alternatively, suspended ground floor slabs should be adopted for the new buildings.

The recommended sub-grade soil CBR value for preliminary road pavement design is just less than 2% for the existing made ground. It is recommended that in situ plate bearing tests are conducted at final formation level following treatment/compaction to confirm the final design CBR values.

9.3 Re-use of materials and waste

The results of analysis for soil samples collected during the recent investigation have been assessed to allow characterisation in the event the material is planned to be removed from site for disposal to landfill.

EnviroLab (an RSK company) has developed a waste soils characterisation assessment tool (HASWASTE), which follows the guidance within Technical Guidance WM3. The analytical results have been assessed using this tool for potential off-site disposal of materials in the future. The assessment identifies if the material would be classified as hazardous (or not) if it was decided to dispose of the material to landfill. The analysis does not determine if the material is inert. Inert wastes can only be identified through WAC analysis.

The HASWASTE assessment used data from eight samples of shallow made ground, taken at depths of between 0.0m and 1.1m bgl, and three samples of natural superficial deposits taken at depths ranging between 0.8m bgl and 1.4m bgl. None of the samples were classified as hazardous waste. A single sample of deep made ground, taken at a depth of 3.0m bgl, resulted in an exceedance of the Carcinogenic HP7 due to elevated arsenic and lead concentrations. This deep made ground associated with the historic chimney is classified as hazardous.



Further WAC testing of soils requiring offsite disposal is recommended to determine whether waste might be classified as inert or non-hazardous.

10 OUTLINE REMEDIATION STRATEGY

10.1 Remedial actions

The general principles underpinning the outline remediation strategy are presented in the following sections. It should be noted that the outline strategy is based on the current level of knowledge and may be subject to change when the full remedial strategy for the site is developed.

A remedial strategy and implementation plan will be developed once the final approach to remediation of the site has been developed. At this stage of development of the remedial strategy, the following sections set out a general approach to the remediation which is anticipated. It is likely to require refinement to identify planned remedial works in areas known to require remediation and contingency for managing previously unidentified or unanticipated potential sources.

10.1.1 Primary source removal

Primary sources of contamination (e.g. buried tanks, chemical drums, etc.) have not been identified in the shallow ground underlying the site. However, should any be encountered during redevelopment earthworks the source should be removed and disposed from site by an appropriate method and, if required, by a suitably qualified contractor. An environmental specialist is recommended to undertake assessment of the chemical status of the surrounding soils.

10.1.2 Secondary source mitigation

In principal, and based on findings to date, the identified risks to human health receptors may be managed by incorporation of engineered measures into the built development, which may preclude the need to remove and/or treat hotspots of contamination. However, removal and/or treatment of contaminated soils may be required should:

- risks to controlled waters from soil contamination be identified
- the presence of significant contamination (e.g. phase separated 'free' hydrocarbons) be encountered during the redevelopment.

Should source removal be required it is currently envisaged this would be carried out by excavation.

Engineered measures to isolate site users and maintenance workers from direct contact with potentially contaminated made ground on the site comprises use of building ground slabs, hard surfaced roads, car parking and footway areas, and providing a simple soil cover for areas of landscaping underlain by made ground.

In general, any made ground currently on site should not be present within 450mm of the surface of any landscaping areas. It is advised that cover soils of 450mm thickness comprising a suitable topsoil and subsoil, should be installed. Underneath the cover soils a geotextile membrane (or similar) should be installed, which remains insitu to prevent soils at depth (below 450mm) from mixing with shallower soils that form the cover system.

10.1.3 Watching brief demolition and site clearance

There is currently a building located in the centre of the site, known as the Time Keepers Cottage, which has been previously used as a garage. It is understood this building is to be removed as part of the development phase. It is recommended that a general 'overdig' of the made ground (if present) underlying the concrete slab of this building is undertaken to assess for the presence of any buried features (tanks or foundations). In addition, there is a concrete slab in the north of the site to be removed to allow the construction of the new apartment block. Inspection should be maintained during its removal for signs of unexpected contamination or buried obstructions or features.

Given the historic features in this part of the site (deep made ground relating to the mill building and chimney) an environmental specialist should be in attendance during the removal of any ground bearing slabs and below ground foundations to assess the condition of the underlying soils and provide documented evidence of the work.

10.1.4 Non-remedial general excavation/soft strip

Detailed designs for the proposed development have not been provided to RSK. It is understood that a ten-storey apartment building will be developed in the north of the site and the design does not include for a basement.

It is anticipated that some soil (likely made ground but also natural superficial deposits) will be removed from the site in addition to any planned remedial excavation carried out for source removal. This includes:

- carry out a soft strip of soils below existing hard cover to re-grade the site to form the development platform
- excavations for removal of old foundations / obstructions and other hard sub-surface structures to remove constraints to development
- pile foundation arisings
- excavations to remove shallow drainage, and redundant services, if required.

These additional excavations also provide an opportunity to observe ground conditions and if necessary obtain chemical analyses under the verification plan.

10.1.5 Re-use of materials

It is unlikely excavated soils will be re-used given existing ground levels across the site. Any excavated soils including materials excavated for redevelopment purposes will require excavation and disposal to a suitably licensed off-site facility.

Materials may be generated from break out of concrete slabs and old foundations and processed to provide a suitable granular fill, which can be re-used on site. Such recycled material would first require verification to confirm its suitability.

Waste soils and recycled aggregate can be reused on site under a standard rules environmental permit or a U1 waste exemption from the Environmental Permitting (England and Wales) Regulations 2010 if they are suitable for the proposed use, i.e. not cause harm to human health or the environment. However, it should be noted that these have strict limits on the quantity of material that can be reused.

10.1.6 Water supply and drainage

Due to the potential risk from residual organic contamination within the made ground it is considered the risk from contaminants permeating plastic water supply pipes to be potentially complete. As a consequence, water supply pipes may be required to be hydrocarbon-resistant “barrier pipe” materials.

The local water company will require a risk assessment for installation of water supply pipes and this will manage and control water supply installation.

10.2 Requirements for remediation verification/validation

10.2.1 Frequency and records

The remedial strategy will set out detailed provisions for verification of the remedial works, these being provided in a verification plan.

It is envisaged at this stage that verification/validation of the remediation will require:

- analytical testing at the limits of remedial excavations at appropriate frequencies which will be set out within an agreed remedial verification plan
- analytical testing of soils excavated from general excavations and stockpiled for re-use or in situ soils to be used to form cover systems
- for imported materials, certification and/or chemical testing depending on the source of the material to be carried out at agreed frequencies set out in the verification plan
- confirmation of suitability of materials intended for any cover system
- confirmation any soil cover system has been correctly installed at an agreed frequency set out in the verification plan
- a remedial verification report.

10.2.2 Chemical criteria

Appropriate criteria for chemical compliance will be developed and agreed within the remedial strategy document. These are likely to be based on the results of risk assessments, but taking into account other factors such as sustainability, practicality, and reasonableness. It is inappropriate to consider actual values at this stage until the remedial strategy is fully developed and all relevant contaminant linkages which require mitigation have been defined, this is particularly relevant to assessment of the potential for risk to controlled waters.

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