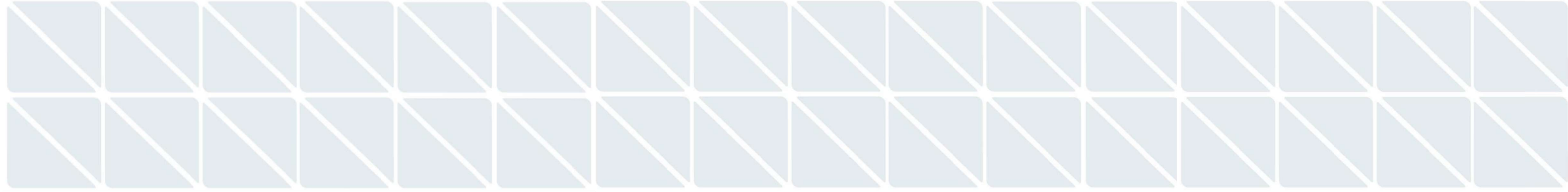




A-squared Studio

Renaissance Manchester

Supplementary Geo-environmental Assessment Report





Project Name	Renaissance Manchester
Project Number	3199
Client	Property Alliance Group Ltd
Document Name	Supplementary Geo-environmental Assessment Report

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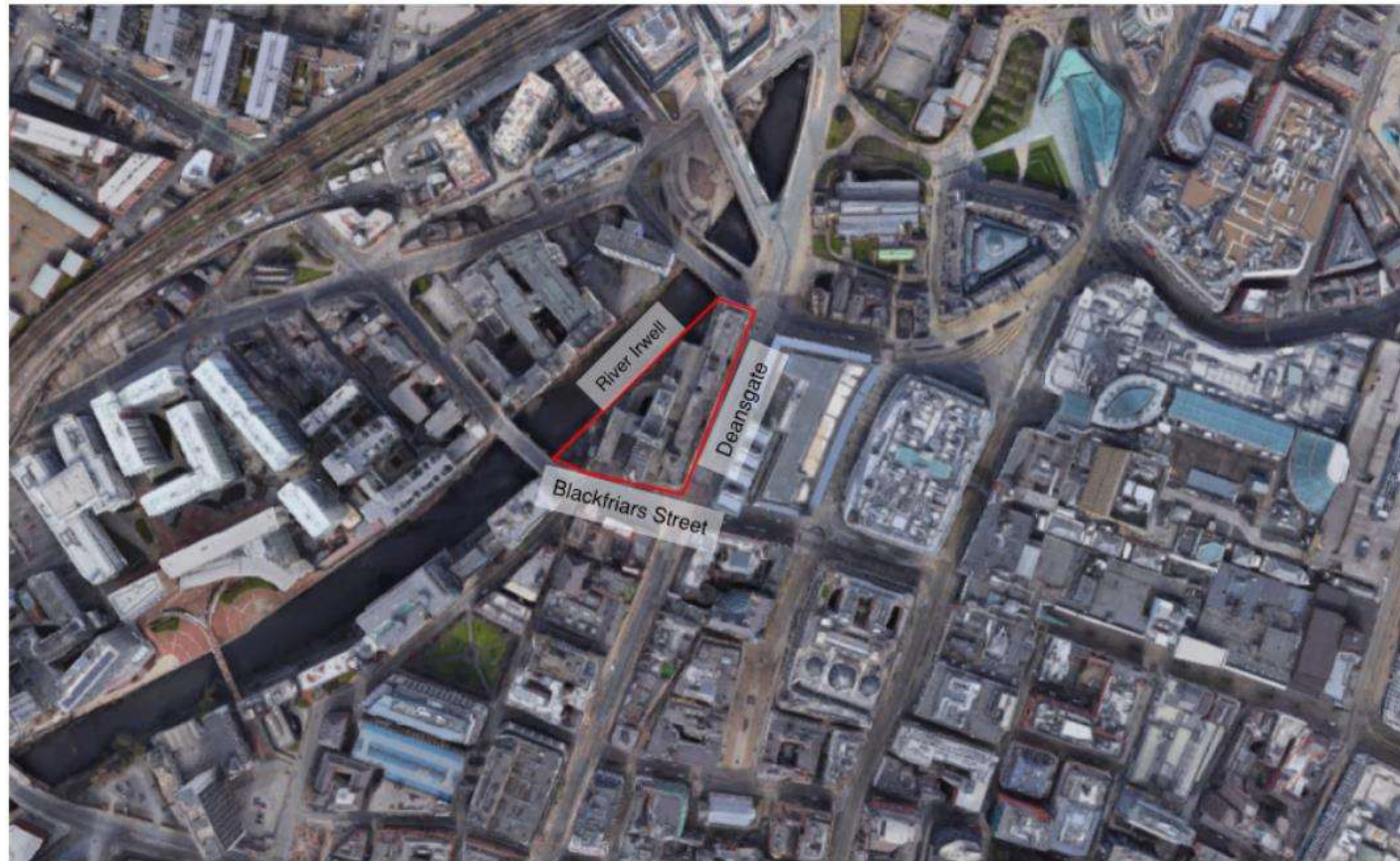
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1. Introduction

A-squared Studio Engineers Ltd (A-squared) has been appointed by Property Alliance Group Ltd to take forward the geo-environmental assessments (land contamination assessments) for the proposed redevelopment at Blackfriars Street, Manchester (herein called the 'site' – see Figure 1.1). The geo-environmental assessments included herein are to support discharge of planning conditions related to land contamination for the specific area of the site known as Land To The North Of Renaissance Hotel, Blackfriars Street, Manchester, M3 2EQ (herein called the 'application boundary'). The application boundary is shown on Figure 2.3 as per planning application number 132088/FO/2021.

This Supplementary Geo-environmental Assessment Report is based on the findings of site investigations undertaken specifically for the proposed development, including recent supplementary ground investigation undertaken by A2 Site Investigation Ltd (A2SI) and previous investigations by E3P. An updated generic quantitative risk assessment (GQRA) and conceptual site model (CSM) for the proposed development are presented herein. Foundation Works Risk Assessment (FWRA) is also presented.



Approximate site boundary (red line)
Image source: Google Maps [accessed June 2021]

Figure 1.1 Site location plan

This report has been prepared in accordance with the principles set out in *Land Contamination Risk Management* (LCRM) guidance, published by the Environment Agency on the UK Government website, and in the context of the *National Planning Policy Framework* (NPPF) and *The Building Regulations 2010, Approved Document C - Site preparation and resistance to contaminants and moisture (2004 Edition incorporating 2010 and 2013 amendments)*. The objective is to identify whether there are unacceptable risks (ref. *LCRM*) which require further assessment or remediation to enable the proposed development.

Previous geo-environmental studies for the proposed development undertaken by E3P include:

- *E3P, Phase 1 Geoenvironmental Site Assessment, Renaissance, Manchester, Reference: 14-261-R1-1, dated September 2020* (the 'E3P Desk Study')
- *E3P, Phase II Geoenvironmental Site Assessment, Renaissance, Manchester, Reference: 14-261-R2-1, dated 21st May 2021* (the 'E3P Phase 2 Assessment').

This report addresses the recommendations in the E3P reporting. The content of all previous E3P interpretive studies is not fully reproduced herein, so the E3P reports should be read in conjunction with this report. However, the E3P Phase 2 Assessment is provided as Appendix A for easy reference. The A2SI Factual Report (2022) for the supplementary ground investigation is included as Appendix B.

The FWRA is presented in two parts, one for the Deansgate level and one for other areas of the site.

This report does not include any geotechnical interpretation or assessment.



2. The Site and Proposed Development

2.1. Site Location and Setting

The application boundary forms part of a wider site redevelopment associated with an existing hotel. The wider site is located within the Central Retail District of Manchester City Centre. The site is roughly triangular in shape with Deansgate to the east, River Irwell to the west, Victoria Bridge Street to the north and Blackfriars Street to the south.

The site is currently occupied by a 13-storey hotel, four-storey office building and multi-storey car park. There is an approximately 9.5 m difference in level across the site between Deansgate and the River Irwell, with an existing retaining wall along the Deansgate side.

The River Irwell is situated within man-made river walls.

2.2. Proposed Development for the Application Boundary

The current office building and hotel are proposed to be partially demolished to enable the construction of a part ground and 26 storey, part ground and 13 storey building to form 300 no. residential apartments and ground floor retail/leisure floorspace, together with private amenity space for residents, new public realm to include riverside walkway and leisure/food and beverage space, new landscaping, parking, cycle parking spaces, servicing, supporting infrastructure and associated works. Further details are available on the local authority planning portal under reference number *132088/FO/2021*.

Architectural drawings for the proposed development are shown in Figure 2.1 and Figure 2.2.



Figure 2.1 Proposed development scheme image 1



Figure 2.2 Proposed development scheme image 2



Figure 2.3 Application boundary (in red) and site boundary (in blue)



3. E3P (2021) Summary

3.1. General

The initial site specific ground investigation works for this scheme were undertaken between 19th and 26th February 2021. The works were undertaken by E3P.

The fieldwork, factual ground investigation information and interpretive findings are presented in the E3P Phase 2 Assessment, provided in Appendix A.

The exploratory hole location plan is presented in Figure 3.1.

The scope of works for the ground investigation relevant to geo-environmental assessment comprised the following:

- 4no. mechanically excavated trial pits (TP101 to TP104) to depths ranging between 0.70m and 0.80m.
- 6no. rotary boreholes (RB101 to RB106) to approximately 10m below existing carpark level.
- Installation of 6no. combined groundwater and ground gas monitoring standpipes within the rotary boreholes (RB101 to RB106).
- Engineer logging of the soils encountered.
- Collection of soil samples for laboratory analysis.
- Collection of groundwater samples for laboratory analysis.
- Monitoring and sampling of the well installations.

GQRA was undertaken by E3P based on the results of the investigative works.

The E3P ground investigation results are summarised below in Section 3.2 – 3.4. Section 3.5 summarises the findings of the GQRA and CSM presented by E3P.

3.2. Intrusive Works

Table 3.1 and 3.2 summarise the depths of all the E3P borehole and trial pit investigation locations. All the works were carried out within the site boundary. It is to note that all the boreholes were conducted from the existing public car park level of +25.25mOD, and therefore the ground directly beneath the Deansgate level where a new contiguous pile wall is proposed in the north-east of the site was not investigated.



Figure 3.1 E3P (2021) Exploratory Hole Location Plan

Table 3.1 Summary of E3P (2021) borehole locations

Borehole ID	Ground Level (mOD)	Depth (mbgl)	Location Relevant to Proposed Buildings
RBH101	25.25	10.0	Residential Block
RBH102	25.25	10.0	Residential Block
RBH103	25.25	10.0	Residential Block
RBH104	25.25	10.0	Premier House
RBH105	25.25	10.0	Premier House
RBH106	25.25	10.0	Premier House



Table 3.2 Summary of E3P (2021) trial pit locations

Borehole ID	Ground Level (mOD)	Depth (mbgl)	Location Relevant to Proposed Buildings
TP101	25.25	0.80	Premier House
TP102	25.25	0.70	Premier House
TP103	25.25	0.80	Premier House
TP104	25.25	0.80	Premier House

3.3. Return Monitoring

Six groundwater and ground gas monitoring standpipes (RBH101 – RBH106) were installed as part of the ground investigation works. Return monitoring visits were completed on the 9th March and 23rd March 2021.

Table 3.3 summarises the boreholes and depths of installations of groundwater and ground gas standpipes. A total of 6 no. of standpipes were installed on the site. The standpipes were installed with response zones targeting the Made Ground and Chester Formation.

Groundwater level monitoring was undertaken using an electronic dip meter and interface probe to record the depth to groundwater and the thickness of any free-phase hydrocarbon product if present. The most elevated shallow groundwater level recorded was 23.85mOD, with an average shallow groundwater elevation of 23.08mOD calculated. No free-phase product was recorded.

Table 3.3 Summary of E3P (2021) groundwater monitoring

Well ID	Response Zone (mbgl)	Screened Stratum	Groundwater depth range (mbgl)	Groundwater level range (mOD)
RBH101	2.0 to 10.0	Chester Formation	2.20 to 2.85	23.05 to 22.40
RBH102	0.5 to 1.5	Made Ground	1.40 to 1.40	23.85 to 23.85
RBH103	2.0 to 10.0	Chester Formation	3.20 to 3.68	22.05 to 21.57
RBH104	2.0 to 10.0	Chester Formation	2.00 to 2.15	23.25 to 23.10
RBH105	2.0 to 10.0	Chester Formation	1.75 to 1.80	23.50 to 23.45
RBH106	2.0 to 10.0	Chester Formation	1.75 to 1.81	23.50 to 23.44

The return monitoring visits included ground gas monitoring at the six installed boreholes (RBH101 through to RBH106). Concentrations of methane (CH4), carbon dioxide (CO2) and oxygen (O2) were measured using a calibrated infra-red gas analyser (GFM435) with gas flow rates measured using an integrated flow meter. A summary of the ground gas monitoring results taken from E3P Phase 2 Assessment is reproduced as Table 3.4.

Table 3.4 Summary of E3P (2021) ground gas monitoring results

WELL	DATE	CH ₄ INITIAL (%V/V)	CH ₄ STEADY (%V/V)	CH ₄ GSV (l/hr)	CO ₂ INITIAL (%V/V)	CO ₂ STEADY (%V/V)	CO ₂ GSV (l/hr)	O ₂ (%V/V)	ATMOS (mb)	ATMOS. DYNAMIC	FLOW (l/hr)	RESPONSE ZONE (m bgl)	DEPTH TO BASE (m bgl)	DEPTH TO WATER (m bgl)
RBH101	09/03/21	0.1	0.1	0.0001	0.1	0.1	0.0001	20.5	1013	Falling	0.1	2.0–10.0	6.70	2.20
	23/03/21	0.1	0.1	0.0001	0.1	0.1	0.0001	20.1	1017	Falling	0.1		6.40	2.85
RBH102	09/03/21	0.1	0.1	0.0001	0.1	0.1	0.0001	19.3	1013	Falling	0.1	0.5–1.5	1.40	1.40
	23/03/21	0.1	0.1	0.0001	0.1	0.1	0.0001	20.3	1017	Falling	0.1		1.40	1.40
RBH103	09/03/21	-0.1	-0.1	-0.0031	-0.1	-0.1	-0.0031	19.8	1013	Falling	3.1	2.0–10.0	7.45	3.20
	23/03/21	0.1	0.1	0.0001	0.1	0.1	0.0001	19.9	1017	Falling	0.1		7.45	3.68
RBH104	09/03/21	-0.2	-0.2	-0.0044	-0.1	-0.1	-0.0022	16.8	1013	Falling	2.2	2.0–10.0	5.62	2.00
	23/03/21	0.1	0.1	0.0001	0.1	0.1	0.0001	19.5	1017	Falling	0.1		5.62	2.15
RBH105	09/03/21	-0.1	-0.1	-0.0001	-0.1	-0.1	-0.0001	20.3	1013	Falling	0.1	2.0–10.0	5.40	1.75
	23/03/21	0.1	0.1	0.0001	0.1	0.1	0.0001	20.1	1017	Falling	0.1		5.40	1.80
RBH106	09/03/21	-0.1	-0.1	-0.0001	-0.1	-0.1	-0.0001	19.6	1010	Falling	0.1	2.0–10.0	4.90	1.75
	23/03/21	0.1	0.1	0.0001	0.1	0.1	0.0001	20.6	1017	Falling	0.1		4.90	1.81

3.4. Geo-environmental Sampling and Testing

A series laboratory geo-environmental tests were performed on soil and groundwater as part of the previous E3P investigative efforts, including the following:

Geo-environmental Laboratory Testing (Soil):

- 13no. Asbestos ID (with quantification of asbestos if detected).
- 13no. Heavy metals and metalloids suite (including hexavalent chromium).
- 13no. Speciated Polycyclic Aromatic Hydrocarbons (PAH).
- 13no. Speciated Total Petroleum Hydrocarbons (TPH).
- 13no. Water soluble sulphate.
- 13no. Total sulphur.
- 13no. Acid soluble sulphate (SO4).
- 13no. pH.
- 13no. Total Cyanide.
- 13no. Total Phenols.
- 4no. Heavy metals and metalloids leachate suite.
- 12no. Water soluble sulphate leachate suite.

Geo-environmental Laboratory Testing (Groundwater):

- 3no. pH.
- 3no. Total phenols.
- 3no. Total cyanides.
- 3no. Dissolved organic carbon (DOC).
- 3no. Heavy metals and metalloids.
- 3no. Speciated Total Petroleum Hydrocarbons (TPH).
- 3no. Speciated Volatile Organic Compounds (VOC).
- 3no. Speciated Semi Volatile Organic Compounds (SVOC).



3.5. E3P GQRA and CSM

This Section 3.5 summarises the GQRA and CSM presented by E3P, based on the results of the investigative works summarised above.

3.5.1. CSM Summary

POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
PL1 PL2	Heavy Metals, non-volatile PAH (Made Ground, Former Works and Mills, Infilled Quarry)	Dermal contact.	Future site users.	Low Likelihood	Low	LOW
		Dermal contact and ingestion.	Off-site receptors.			
Assessment: No exceedances have been identified in the chemical testing completed.						
Recommendation: Due to the presence of Made Ground, construction works should be completed with PPE and provision of welfare. A clean cover system should be installed in areas of soft landscaping to prevent direct exposure to the underlying Made Ground.						
PL3	ACM in Made Ground	Inhalation of dust.	Future site users. Buildings. Off-site land users.	Likely	High	LOW
Assessment: Asbestos in the form of loose chrysotile fibres has been identified in the granular Made Ground in TP104 at <0.001 %.						
Recommendation: Asbestos impacted soils should be managed in accordance with the asbestos CSM, A cover system to landscaped areas will prevent exposure to future site users. Construction works completed with PPE and provision of welfare.						

POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
PL4	Volatile contaminants such as hydrocarbons, (Made Ground, Former Works and Mills)	Inhalation of vapours. Migration through permeable strata and preferential pathways.	Future site users. Off-site receptors.	Low Likelihood	Low	LOW
Assessment: No exceedances have been identified in the chemical testing completed.						
Recommendation: Due to the presence of Made Ground, construction works should be completed with PPE and provision of welfare. If any unidentified contamination is uncovered during remediation and enabling works, the soils may require localised excavation and validation.						
PL4	Methane, carbon dioxide (Made Ground, Infilled Quarry, Former Works and Mills)	Inhalation of gas. Migration through permeable strata and preferential pathways. Explosion in confined spaces.	Future site users. Buildings. Off-site land users.	Low likelihood	Low	LOW
Assessment: Monitoring completed to date suggests CS1.						
Recommendation: Completion of ground gas monitoring.						

POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
PL5	Mobile contaminants such as metals, PAHs, hydrocarbons, volatile compounds (Made Ground, Infilled Quarry, Former Works and Mills)	Surface runoff. Migration through permeable strata and preferential pathways. Perched waters migration.	Groundwater (Principal aquifer in bedrock). Surface water (River Irwell).	Low Likelihood	Low	TBC
Assessment: Leachate and groundwater analysis has identified exceedances of the EQS for chromium, copper, mercury, trichloromethane and pH. Historically, the site has been occupied by a Cotton Finishing Works, Copper Roller Works and Mills. The initial soil analysis has not identified a risk to controlled waters. The site is underlain by shallow sandstone bedrock which is classified as a principal aquifer. However, the majority of the identified inorganic compounds are of low solubility. The sensitivity of the principal aquifer in the bedrock is reduced given the closest potable groundwater abstraction is located 507 m north. Tricholormethane has been recorded above the limit of detection in all three groundwater samples from the rotary boreholes which have monitoring wells set within the sandstone bedrock. All other VOCs are less than the limit of detection. It is unlikely that this relates to residual contamination from the former works and mills located on site as these land uses were historical and the compounds would have degraded. It is considered possible that this compound may have migrated from commercial sites further afield. The site is topographically lower than the land to the east, therefore it is likely that groundwater will flow towards the site and towards the River Irwell. The results of the groundwater analysis indicate a higher concentration of trichloromethane at RBH101 in the north east as opposed to RBH105 located in the south west. The site is encapsulated in hardstanding, therefore infiltration will be limited. Recommendation: An additional round of groundwater sampling and surface water analysis is recommended to further assess the risk to controlled waters. The results will be issued in an addendum report						

POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
PL6	Sulphate (potential ash within Made Ground)	Sulphate attack on concrete.	Building structure.	Low likelihood	Low	LOW
Assessment: The soils at the site meet class DS-1, AC-1s.						
Recommendation: Concrete should be designed in accordance with the chemical testing results.						
PL7	Organic contaminants such as hydrocarbons, solvents (Made Ground, Former Works and Mills)	Ingestion of tainted water supply.	Future site users. Water pipes.	Low likelihood	Low	LOW
Assessment: Low likelihood as no significant contamination anticipated at pipeline depth across the site (0.75–1.35 m). Current chemical analysis indicates that PE pipe will be suitable for the site.						
Recommendation: A pipeline risk assessment should be completed following a process of remediation and enabling works. Post-remediation and enabling works ground conditions may be different from those identified during this site investigation.						
PL8	Phytotoxic contaminants (Made Ground, Former Works and Mills)	Direct Contact (plant uptake).	Flora.	Low Likelihood	Low	LOW
Assessment: No exceedances have been identified in the chemical testing completed.						
Recommendation Due to the presence of Made Ground impacted by asbestos, a clean cover system should be installed in areas of proposed planting/soft landscaping.						



3.5.2. E3P GQRA Summary

Human Health	The Tier I assessment identified a single exceedance for asbestos. Loose chrysotile fibres were identified in the granular Made Ground in TP104 at <0.001 %. No visual signs of ACM were encountered during the ground investigation; it is therefore likely that only trace fibres are present. Impacted soils should be managed according to the asbestos risk mitigation conceptual site model. The installation of a suitable cover system in all landscaping and public open space will remove any potential for direct exposure to impacted soils. The specific design and installation process for the appropriate cover systems should be defined within a site remediation and enabling works strategy. Chemical analysis of the natural granular deposits has identified these soils to be acceptable for use as subsoil within the proposed landscaped areas; however, further chemical validation samples will be required to confirm this. There are no suitable sources of topsoil available on the site. Further post-demolition investigations are required to confirm the findings of this initial assessment as and when full and unrestricted access is available.
Controlled Waters	Leachate and groundwater analysis has identified exceedances of the EQS for chromium, copper, mercury, trichloromethane and pH. Historically, the site has been occupied by a Cotton Finishing Works, Copper Roller Works and Mills which are potential sources of mobile contamination. However, the initial soil analysis has not identified a risk to controlled waters. The site is underlain by shallow sandstone bedrock which is classified as a principal aquifer. However, the majority of the identified inorganic compounds are of low solubility. The sensitivity of the principal aquifer in the bedrock is reduced given the closest potable groundwater abstraction is located 507 m north. Trichloromethane has been recorded above the limit of detection in all three groundwater samples from the rotary boreholes which have monitoring wells set within the sandstone bedrock. All other VOCs are less than the limit of detection. It is unlikely that this relates to residual contamination from the former works and mills located on site as these land uses were historical and the compounds would have degraded. It is considered possible that this compound may have migrated from commercial sites further afield. The site is topographically lower than the land to the east, therefore it is likely that groundwater will flow towards the site and towards the River Irwell. The results of the groundwater analysis indicate a higher concentration of trichloromethane at RBH101 in the north east as opposed to RBH105 located in the south west.

Controlled Waters	The site is encapsulated in hardstanding, therefore infiltration will be limited. An additional round of groundwater sampling and surface water analysis is recommended to further assess the risk to controlled waters. The results will be issued in an addendum report.
Ground Gas	Characteristic Situation 1 (pending completion of gas monitoring).
Potable Water	This will need to be confirmed following the completion of a UKWIR risk assessment. Post-remediation and enabling works ground conditions may be different from those identified during this site investigation. Current indications suggest that PE pipe may be suitable.



4. A2SI (2022) Summary

4.1. General

Supplementary site specific ground investigation works were undertaken by A2SI on 22-23rd February 2022. The works were supervised by A-squared.

The fieldwork and factual ground investigation information are presented in the A2SI Factual Report (2022), provided in Appendix B, referred to therein as ground investigation phase 2.

The exploratory hole location plan for ground investigation phase 2 is presented in Figure 3.1.

The scope of works comprised the following:

- Window sampler holes (WS08 - WS13) to a maximum depth of approximately 6m bgl.
- Engineer logging and photographing of the soils encountered.
- Installation of 2no. combined groundwater and ground gas monitoring standpipes within WS09A and WS13.
- Collection of soil samples for laboratory analysis.
- Collection of groundwater samples for laboratory analysis.
- Monitoring and sampling of the well installations.
- In-situ testing including soil sample head-space testing using a PID.

Note – Locations for WS07 and WS08 are presented in the A2SI Factual Report but these were not actually advanced.

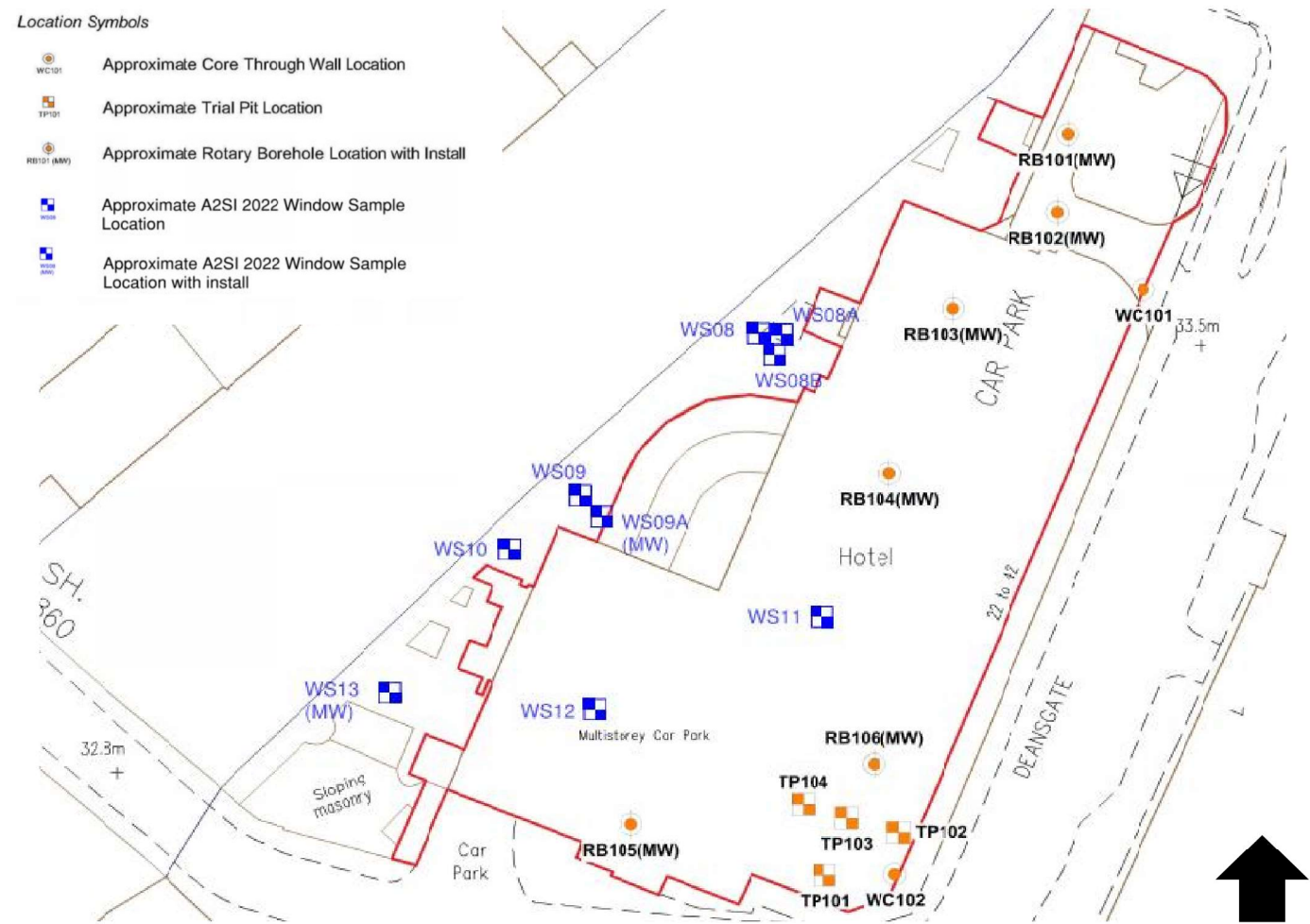


Figure 4.1 Exploratory hole location plan for A2SI (2022) and E3P (2021)

4.2. Intrusive Works

Table 3.1 summarises the depths of all the investigation locations undertaken during the works. All the works were carried out within the site boundary.

Table 4.1 Summary of A2SI (2022) exploratory locations

Borehole ID	Ground Level (mOD)	Depth (mbgl)
WS08	25.16	0.95
WS08A	25.16	0.70
WS08B	25.16	1.20
WS09	25.06	0.80
WS09A	25.16	4.00
WS10	25.11	6.00
WS11	25.26	0.80
WS12	25.26	0.80
WS13	25.80	6.00

4.3. Return Monitoring

Two groundwater and ground gas monitoring standpipes (WS09A and WS13) were installed as part of the ground investigation works. A single return monitoring visit was undertaken on the 14th and 15th March 2022. The return monitoring visit included use of the newly installed wells by A2SI and also the previously installed wells by E3P, although RB102 and RB101 were not accessible due to other works being carried out on-site at the time.

Groundwater level monitoring was undertaken using an electronic dip meter and interface probe to record the depth to groundwater and the thickness of any free-phase hydrocarbon product if present.

Table 4.2 summarises the exploratory locations and installation details for the wells installed by A2SI.

Table 4.2 Summary of A2SI (2022) monitoring well installations

Location Ref.	Base of Borehole (m bgl)	Standpipe Internal Diameter (m bgl)	Top of Response Zone (m bgl)	Base of Response Zone (m bgl)	Screened Stratum
WS09A	4.00	50mm	3.5	2.0	Made Ground
WS13	6.00	50mm	4.0	2.0	Made Ground

Table 4.3 summarises the groundwater levels measured in each of the monitoring wells on the return monitoring visit. The most elevated shallow groundwater level recorded was 23.15mOD, with an average shallow groundwater level of 22.45mOD calculated. No free-phase product was recorded.



Table 4.3 Summary of A2SI (2022) groundwater monitoring

Borehole ID	Response Zone (mbgl)	Screened Stratum	Groundwater depth (mbgl)	Groundwater level (mOD)
RBH103	2.0 to 10.0	Chester Formation	3.32	21.93
RBH104	2.0 to 10.0	Chester Formation	2.12	23.13
RBH105	2.0 to 10.0	Chester Formation	2.17	23.08
RBH106	2.0 to 10.0	Chester Formation	2.10	23.15
WS09A	2.0 to 3.5	Made Ground	3.41	21.75
WS13	2.0 to 4.0	Made Ground	3.41	21.67

The return monitoring visits included ground gas and soil vapour monitoring. Concentrations of methane (CH₄), carbon dioxide (CO₂) and oxygen (O₂) were measured using a calibrated infra-red gas analyser (GFM435) with gas flow rates measured using an integrated flow meter. Soil vapour concentrations were measured using a calibrated photoionisation detector (PGM6208)

A summary of the ground gas and soil vapour monitoring results recorded by A2SI is provided as Table 4.4.

Table 4.4 Summary of A2SI (2022) ground gas and soil vapour monitoring results

Exploratory Hole Reference	Date	Minimum O ₂ (%)	Maximum CO ₂ (%l)	Maximum CH ₄ (%)	Maximum H ₂ S (ppm)	Maximum CO (ppm)	Maximum PID (ppm)	Steady-state Flow Rate (l/hr)	Barometric Pressure (mb)
RBH03	14/03/22	19.3	0.7	<0.1	<1	<1	<1	0.0	1016
RBH04	14/03/22	18.1	1.7	<0.1	<1	<1	<1	0.0	1016
RBH05	14/03/22	19.7	<0.1	<0.1	<1	<1	<1	0.0	1016
RBH06	14/03/22	20.3	<0.1	<0.1	<1	<1	<1	0.0	1014
WS09A	14/03/22	20.2	0.5	<0.1	<1	<1	<1	0.0	1016
WS13	14/03/22	19.7	0.6	<0.1	<1	<1	<1	0.0	1016

4.4. Geo-environmental Sampling and Testing

A series laboratory geo-environmental tests were performed on soil and groundwater as part of the A2SI investigative efforts, including those detailed below. The following determinants for analysis were selected based on the findings of the previous E3P reporting:

Geo-environmental Laboratory Testing (Soil) -

- 9 no. Asbestos.
- 6no. Speciated Polycyclic Aromatic Hydrocarbons (PAH).
- 6no. Speciate Total Petroleum Hydrocarbons (TPH).
- 2no. Speciated Volatile Organic Compounds (VOC).

Geo-environmental Laboratory Testing (Groundwater) -

- 6no. pH.
- 6no. Total phenols.
- 6no. Total cyanides.
- 6no. Dissolved organic carbon (DOC).
- 6no. Heavy metals and metalloids.
- 6no. Speciated Polycyclic Aromatic Hydrocarbons (PAH).
- 6no. Speciate Total Petroleum Hydrocarbons (TPH).
- 6no. Speciated Volatile Organic Compounds (VOC).
- 6no. Semi Volatile Organic Compounds (SVOC).



5.1. Introduction

The information reviewed in this chapter includes stratigraphy (i.e. the absolute position of each unit within the soil column and their relationship relative to one another) in conjunction with basic physical characteristics and records of visual / olfactory evidence of contamination (if present).

5.2. Summary of Encountered Geology

The geological sequence encountered at the site can be summarised as follows:

- Made Ground (of variable thickness).
- Glaciofluvial Sheet Deposits (localised – not encountered across the whole site).
- Chester Formation.

The location of the site within the context of a regional geological map is illustrated in Figure 5.1.

The Made Ground material encountered was of variable thickness and is anticipated to be mainly backfill material placed during the construction of the original building, including car park subgrade material.

Glaciofluvial Sheet Deposits are mapped across the site footprint but were only encountered at one exploratory location (WS09A).

Sandstone (Chester Formation) was encountered between 0.35mbql and 10mbql (maximum depth of investigation).

Table 5.1 provides a summary of the indicative levels and thicknesses of the geological units encountered.

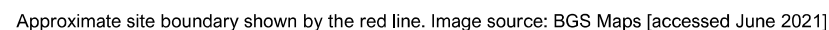


Figure 5.1 Geological context of the site

Table 5.1 **Indicative ground model**

GL (mOD)	Stratum	Depth Top (mbgl)	Elevation Top (mOD)	Thickness (m)
+25.25	Made Ground	0.00	+25.25	0.35 to >6.00
	Glaciofluvial Sheet Deposits (only encountered at WS09A)	3.00	+22.25	>1.00
	Chester Formation	0.35 - >6.00	+24.90 to +19.45	>9.30

5.3. Made Ground

Made Ground comprises an initial layer of concrete, approximately 0.3m thick, overlaying a mixture of materials with different properties.

The visual description of this soil generally varies between:

- Reddish brown medium SAND (possibly weathered bedrock).
- Grey slightly sandy GRAVEL.

A Made Ground thickness plan is included as Figure 5.2.





5.4. Glaciofluvial Sheet Deposits

Glaciofluvial Sheet Deposits were found to underlie the Made Ground at WS09A only. The deposits are described as:

- Medium dense reddish brown slightly gravelly fine to coarse SAND. With the gravel being angular, fine to coarse of sandstone.

Due to the description presented on the engineer logs, A-squared consider that it is possible that this strata was actually weathered sandstone bedrock of the Chester Formation.

5.5. Chester Formation

The Chester Formation sandstone underlies the Made Ground. The visual description of the sandstone generally varies between:

- Very weak medium bedded reddish brown fine SANDSTONE with occasional lenses of extremely weak sandstone.
- Medium strong (becoming very strong) medium bedded reddish brown coarse SANDSTONE with occasional interbeds of weak sandstone. Bedding 0-10 degrees, widely to medium spaced, planar rough.

The thickness of the sandstone was not proven by the exploratory locations. The depth to the top of the sandstone may have been altered immediately beneath the site during the original construction of the buildings currently present on site.

5.6. Groundwater

Groundwater level gauging was carried out on three occasions; on the 9th and 23rd March 2021 (by E3P) and on the 14th March 2022 (by A2SI). A summary of the groundwater level monitoring results is shown below in Table 5.2.

Table 5.2 Groundwater levels recorded

Location	Screened Strata	Well base (mgl)	Groundwater Reading - mbgl		
			15/09/2021	06/10/2021	13/10/2021
RBH01	Chester Formation	4.00	6.70	6.40	-
RBH02	Chester Formation	2.85	1.40	1.40	-
RBH03	Chester Formation	4.50	7.45	7.45	3.33
RBH04	Chester Formation	3.00	5.62	5.62	2.13
RBH05	Chester Formation	3.50	5.40	5.40	2.21
RBH06	Chester Formation	5.00	4.90	4.90	2.10
WS09A	Made Ground	3.50	-	-	3.41
WS13	Made Ground	6.50	-	-	3.41

Groundwater strikes water strikes were recorded during the intrusive investigation at WS09A and WS13, at depths of 2.9 m bgl and 3.5 m bgl respectively.

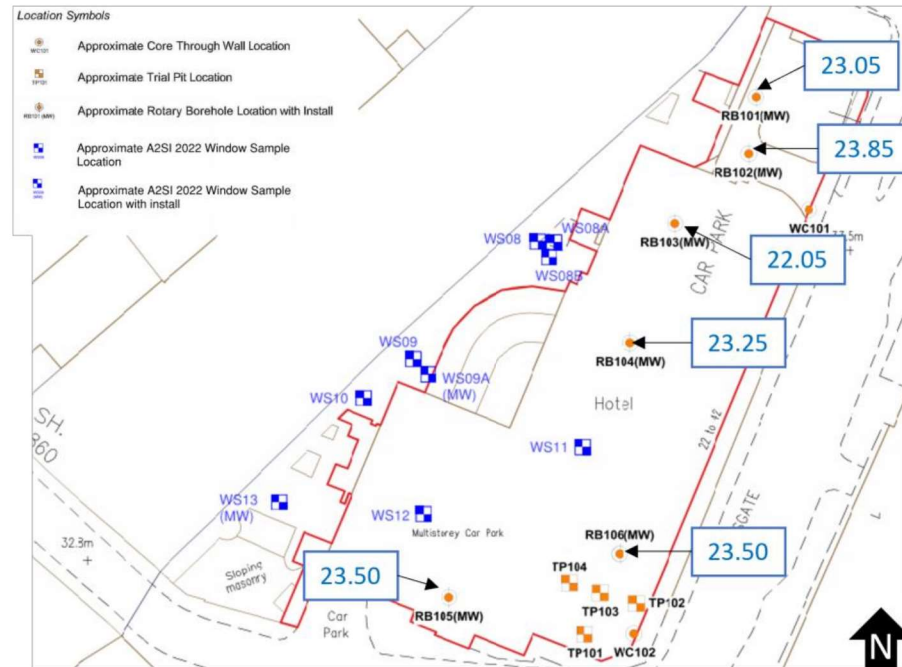
The highest groundwater level recorded over the three return monitoring rounds was 23.85mOD, with an average level of 22.77mOD within the strata.

Shallow groundwater elevation plots are included as Figure 5.3. The plots do not show a clear shallow groundwater flow direction.



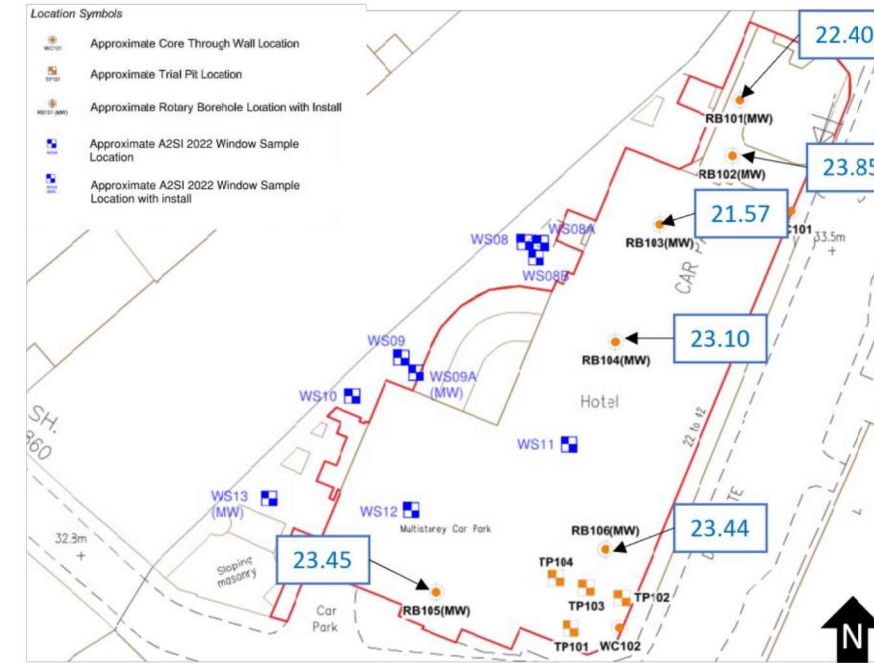
Monitoring round one
09/03/2021

- X.XX Groundwater level within the Chester Formation (mAOD)
- X.XX Groundwater level within the Made Ground (mAOD)



Monitoring round two
23/03/2021

- X.XX Groundwater level within the Chester Formation (mAOD)
- X.XX Groundwater level within the Made Ground (mAOD)



Monitoring round three
14/03/2022

- X.XX Groundwater level within the Chester Formation (mAOD)
- X.XX Groundwater level within the Made Ground (mAOD)

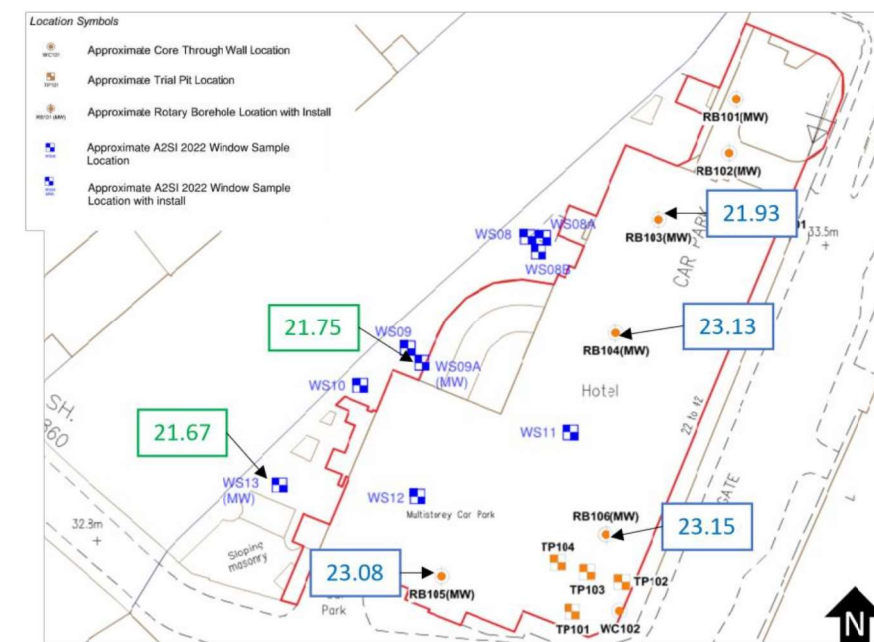


Figure 5.3 Shallow groundwater elevation plots



5.7. Visual / Olfactory Evidence of Contamination

Visual / olfactory evidences of contamination was not identified in soil during the multiple phases of intrusive investigation undertaken. In addition, no evidence of contamination was found during the return monitoring visits (such as evidence of groundwater contamination).

Within the Made Ground widespread inert materials were found to be present. Brick and concrete were encountered across much of the site as well as glass and ceramic identified in WS10.

In-situ soil sample VOC head-space testing using a PID returned no values over <0.1ppm.



6. Supplementary Generic Quantitative Risk Assessment

6.1. Introduction

Section 6 provides a supplementary geo-environmental assessment using the available information, including data gathered from the recent E3P (2021) and A2SI (2022) ground investigations, as summarised in Section 3 and Section 4 respectively. GQRA is presented and screening tables are included as Appendix C. Based on the results, the CSM and geo-environmental risk assessment for the proposed development is updated from what is presented in the E3P Phase 2 Assessment.

The E3P Phase 2 Assessment recommends that the following be undertaken to enable the GQRA for the proposed development to be finalised:

- Post-demolition site investigation to provide additional coverage;
- A further round of groundwater sampling to enable further assessment of controlled waters risks;
- Further ground gas monitoring to enable further assessment of human health risks and proposed buildings and structures risks; and
- Assessment of the available information in the form of a water supply pipes risk assessment.

The supplementary GQRA presented in this report addresses the E3P recommendations using the additional ground investigation data collected by A2SI. The supplementary GQRA includes:

- Water supply pipes risk assessment (see Section 6.3).
- Ground gas and soil vapour risk assessment with regards to human health and proposed buildings and structures (see Section 6.4).
- Controlled waters risk assessment based on an additional round of groundwater sampling (see Section 6.5).
- Comment on human health risks associated with the presence of asbestos in soils (see Section 6.2).

Note - Although the A2SI (2022) ground investigation was undertaken prior to completion of all demolition, it is assessed that the coverage which has been achieved is generally suitable to satisfy the recommendations of the E3P Phase 2 Assessment.

Please be aware that the GQRA relates to the wider site boundary including the application boundary. The site boundary extends beyond the application boundary.

Risks to site workers and the environment during the construction phase of the proposed redevelopment can be appropriately managed by successful implementation of construction phase risk assessments and method statements (RAMS). Therefore, the associated construction phase land contamination risks are not considered further in this document but should be appropriately considered and mitigated by the Principal Contractor in their preparation and implementation of construction phase RAMS and Construction Phase Plan (CPP).

6.2. Human Health Risk Assessment (Asbestos)

Asbestos has previously been identified by E3P in the form of loose chrysotile fibres in Made Ground at TP104 (at concentration of <0.001% w/w).

There is no published human health GAC with respect to asbestos or asbestos containing materials (ACMs) in soil. Industry best practice document 'Asbestos in soil and made ground: a guide to understanding and managing risks', CIRIA C733, 2014, identifies that soils containing asbestos concentrations of 0.001 % w/w may be able to liberate airborne fibre concentrations that exceed the contemporary occupational exposure limit for nuisance dust. However, as detailed in other research, including publications such as the CAR-SOIL Industry Guidance (2016), in circumstances where very low concentrations of asbestos are identified in soils, the associated risks are

considered low. In this study A-squared adopt an asbestos human health GAC of <0.001 % w/w i.e. mitigation or further assessment is required if asbestos in soil is detected at or above <0.001 % w/w.

A further nine soil samples were analysed for asbestos as part of the A2SI (2022) investigation. No asbestos was identified in any of the nine soil samples. Figure 6.1 shows an asbestos detection plan for the site, including the results from both the E3P (2021) investigation and the A2SI (2022) supplementary investigation. Based on all available site investigation results, the presence of asbestos in Made Ground is indicated to be limited to an area of Made Ground in the vicinity of TP104. The available data following the A2SI (2022) investigation provides additional delineation for the asbestos in Made Ground in the vicinity of TP104.

Laboratory certificates of analyses are presented within the respective appendices herein. Screening tables comparing the laboratory analytical results for soils to the selected human health GAC are provided in Appendix C.

The status of the E3P human health risk assessment for soil particle inhalation, ingestion and dermal contact pathways indicates that a clean cover layer is required for soft-landscaping areas constructed as part of the proposed development. A-squared maintain this recommendation. A-squared recommend that a detailed specification for an appropriate clean cover layer is provided in a Remediation Strategy for the proposed development. Suitable verification protocols should also be specified. This will suitably mitigate risks to future site users.

A-squared also recommend that if new underground services are installed in the impacted area of Made Ground surrounding TP104 then they should be installed in oversize clean service corridors. This will mitigate the risk to future site maintenance workers who may need to excavate soils around underground services. A suitable specification for the oversize clean service corridors should be included in a Remediation Strategy for the site along with appropriate verification protocols.

Should the aforementioned mitigation measures be suitably implemented as part of a Remediation Strategy then the risks to proposed site users will be low. The presence of localised asbestos in Made Ground should also be suitably considered by the Principal Contractor in their preparation and implementation of construction phase RAMS and CPP.

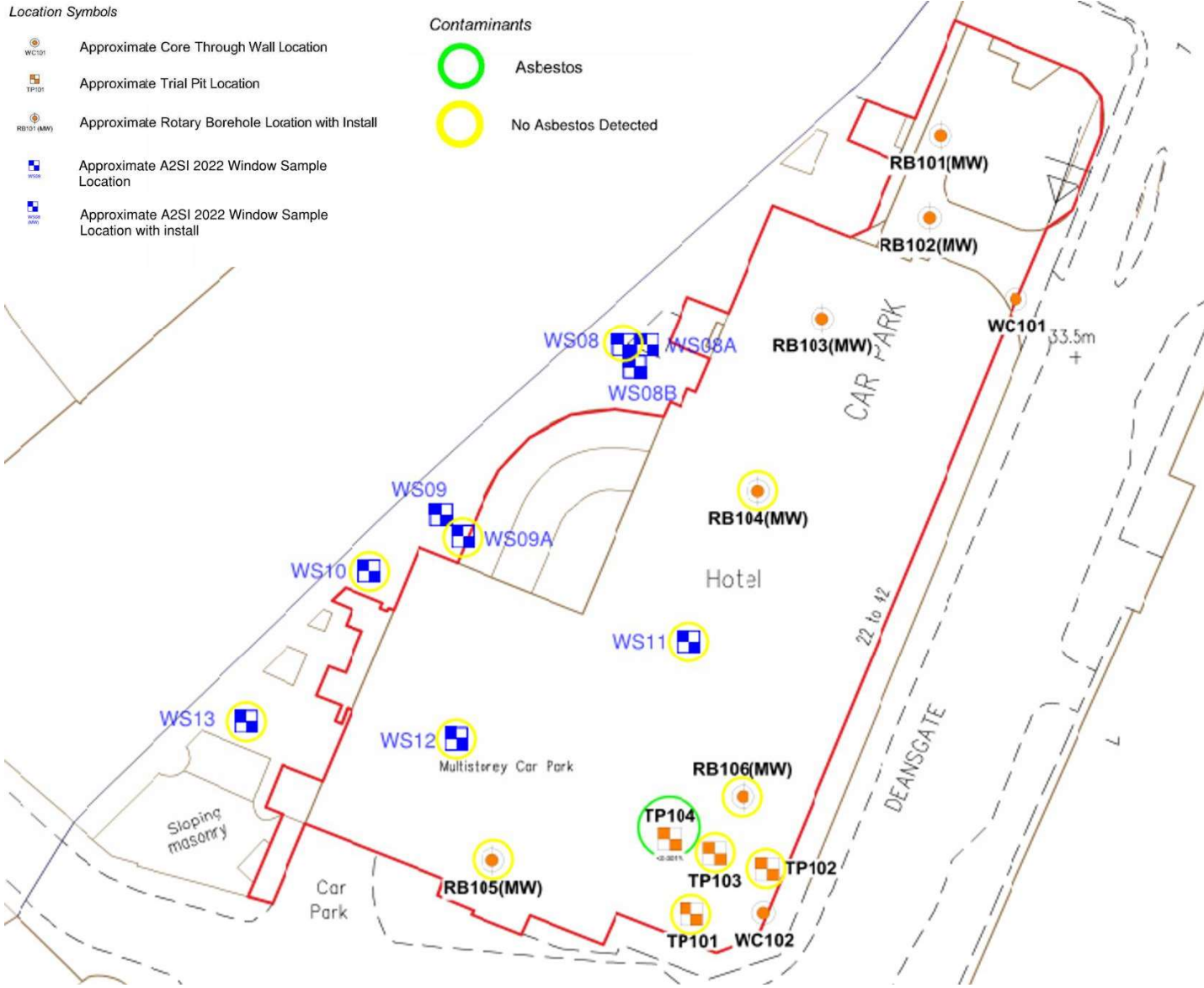


Figure 6.1 Asbestos detection plan for Made Ground

6.3. Human Health Risk Assessment (Drinking Water Supply Pipes)

The soil sample geo-environmental laboratory results have been compared to assessment criteria presented in *UKWIR Guidance for the selection of Water Supply Pipes to be used in Brownfield Sites (Ref. 10/WM/03/21)*. Only relevant assessment criteria for the potential contaminants of concern identified in the E3P Desk Study have been used. The results are summarised in Table 6.1.

Table 6.1 Water Supply Pipes Assessment Summary

Determinant	Polyethylene (PE) Pipe Assessment Criteria (mg / kg)	Polyvinylchloride (PVC) Pipe Assessment Criteria (mg / kg)	Maximum Concentration Detected in Soil (mg / kg)
Total VOCs	0.5	0.125	0.066 (WS10 at 0.5m bgl)
Total BTEX and MTBE	0.1	0.03	<0.01
Total Phenols	2	0.4	<0.1

Determinant	Polyethylene (PE) Pipe Assessment Criteria (mg / kg)	Polyvinylchloride (PVC) Pipe Assessment Criteria (mg / kg)	Maximum Concentration Detected in Soil (mg / kg)
Total C5-10 aliphatic / aromatic hydrocarbons	2	1.4	<1.00
Total C11-20 aliphatic / aromatic hydrocarbons	10	Pass	<4.00
Total C21-40 aliphatic / aromatic hydrocarbons	500	Pass	51 (RH102 at 0.6 m bgl)

No exceedances of either the PVC or the PE assessment criteria for water supply pipes have been identified. Therefore, either PE or PVC specification pipe may be suitable for the proposed development.

The final pipe specification to be installed at the site should be agreed with the utility provider.

The identified contamination does not appear to be in a form which will continue migrating through the ground at shallow depth on completion of the proposed development, so it is assessed that there is low risk to off-site drinking water supply pipes, including those at premises immediately adjacent to the site.

6.4. Human Health and Buildings and Structures Risk Assessment (Ground Gas / Soil Vapour)

6.4.1. Ground Gas

The primary potential on-site ground gas source is Made Ground. No notable potential off-site sources of ground gas are identified in the E3P Desk Study. Where Made Ground has been encountered at the site it is typically less than 1.0 m thick. The thickest Made Ground has been encountered in the southwest of the site immediately adjacent to the River Irwell river wall where it is locally greater than 1.0 m thick; WS10 (>6m thick) and WS13 (5.8m thick).

A Made Ground thickness summary plan is provided as Figure 6.2.

On-site Made Ground has generally been found to be of low thickness so that a typical ground gas assessment using monitoring wells is not possible as described in *CIRIA 665, 'Assessing risks posed by hazardous ground gases to buildings'* and *BS8485:2015+A1:2019 Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings*. *BS8576 Guidance on investigations for ground gas – permanent gases and volatile organic compounds (VOCs)* indicates that typical ground gas monitoring wells have a screened section commencing at least 1mbgl, which is not possible to achieve across most of the site.

Therefore, A-squared has taken a qualitative approach to ground gas risk assessment in view of; the measured Made Ground thicknesses, the ground conditions recorded, and the specifics of the proposed development. A particularly pertinent detail is that construction of the new residential building in the north of the site will require shallow excavation (to circa 1 m bgl) of shallow soils including Made Ground down to top of bedrock level to enable construction of a raft foundation. The excavated Made Ground is proposed for off-site disposal.

The engineering logs do not indicate the presence of degradable organic materials in Made Ground with elevated potential for ground gas generation. Indeed, much of the Made Ground is logged as comprising mainly inert materials and non-degradable natural clasts such as brick and ceramic. No visual or olfactory evidence of contamination was identified within the Made Ground. These details indicate low risk with respect to ground gas. Furthermore, the excavation of Made Ground from across the proposed building footprint in the north of the site effectively removes the potential source of ground gas from this area. Therefore, the risks from ground gas are assessed as low (i.e. no unacceptable risk) and not requiring of ground gas monitoring or remediation.

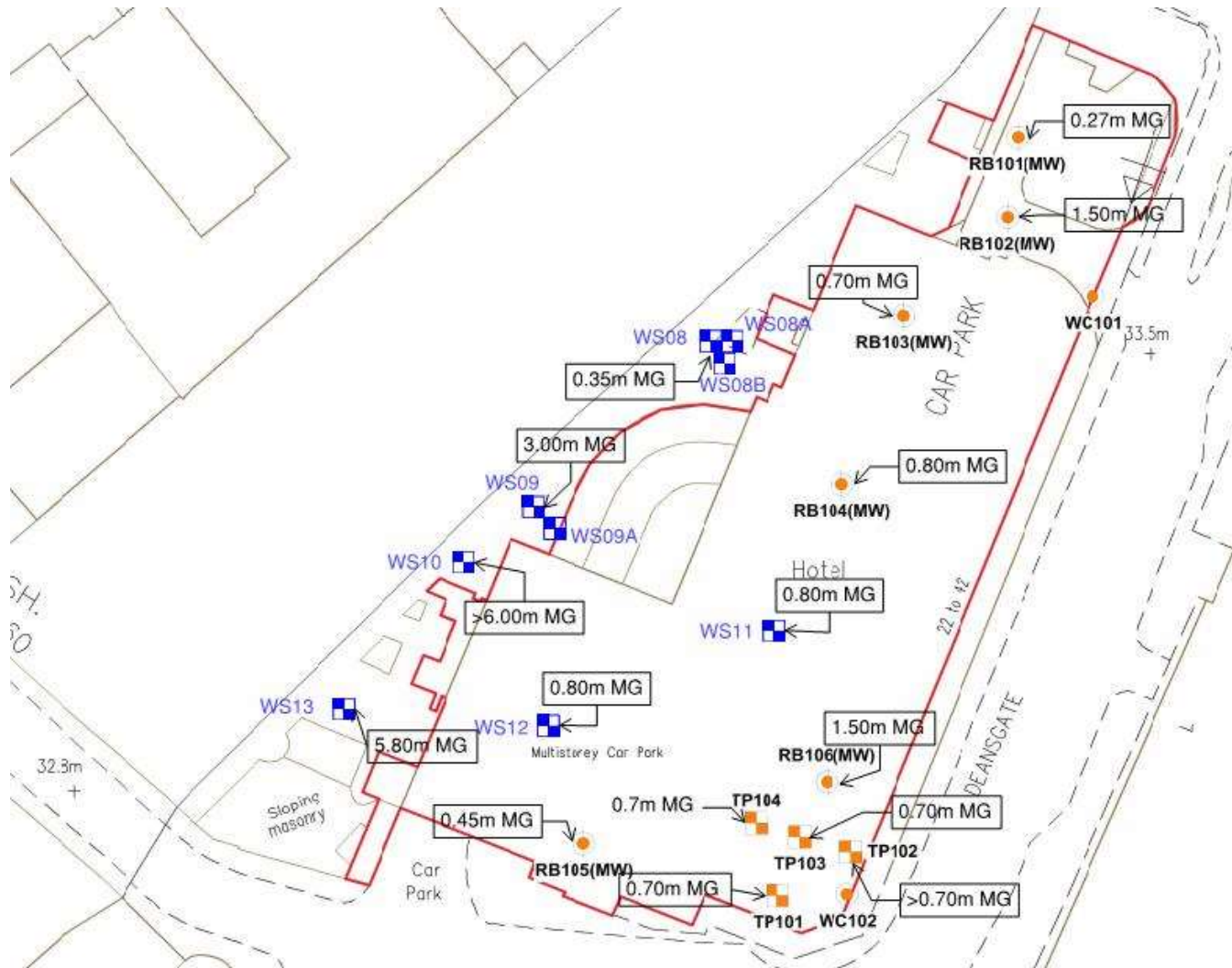


Figure 6.2 Made Ground thickness plan

The deeper Made Ground encountered in the southwest of the site at WS09, WS10 and WS13 does require some further consideration however. The thicker Made Ground is considered to be localised fill behind the existing river wall. The fill has been identified as not extensive. The fill is not present across a widespread area which may represent an elevated ground gas risk. The area is also located where soft-landscaping is proposed with no building footprint directly above, so the potential of any ground gas generated to impact buildings is reduced by the preferential migration of ground gas to atmosphere via open ground.

The deeper Made Ground encountered in the southwest of the site at WS09, WS10 and WS13 should also be considered in view of *Ciria C795 Retrofitting hazardous ground gas protection measures in existing or refurbished buildings, 2020*. The proposed redevelopment in this area of the site includes a refurbishment of the existing building structure rather than construction of new buildings. There will be very limited and possibly no groundworks undertaken in this area of the site. It is understood that there is no existing ground gas protection system and there are no known issues of gas ingress to the existing building or nearby buildings. The proposed development also maintains the current human health end-use in this area of the site (i.e. commercial end-use) and does not introduce a more sensitive receptor. This being the case, *Ciria C795 (2020)* indicates that the proposed refurbishment works in the southwest of the site would not require fitting of ground gas protection.

On the basis of the above further considerations, the deeper Made Ground encountered in the southwest of the site at WS09, WS10 and WS13 represents a low risk to the proposed development (i.e. no unacceptable risk) and not requiring of ground gas monitoring or remediation.

Despite the ground gas assessments above, A-squared has taken a precautionary approach and supplemented the assessment with a limited scope of ground gas monitoring to verify the conclusions. Ground gas monitoring data is available from three return monitoring visits undertaken at the site. Assessment of the available data has been undertaken in general accordance with guidance contained within *CIRIA 665, 'Assessing risks posed by hazardous ground gases to buildings'* and *BS8485:2015+A1:2019 Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings*. The method requires use of both gas concentrations and ground gas well flow rates to calculate a gas screening value (GSV). The GSV is calculated as follows:

$$GSV = \frac{\text{Analyte Concentration (\%)} \times \text{Flow rate (L/hr)}}{100}$$

The calculation is carried out for methane (CH₄) and carbon dioxide (CO₂).

The results of the ground gas monitoring from the E3P investigation are presented in Table 3.4 and the results of the ground gas monitoring from the A2SI investigation are presented in Table 4.4. The results are summarised in Table 6.2.

Table 6.2 Ground Gas Monitoring Summary Data

Exploratory Hole Reference	Date	Minimum O ₂ (%)	Maximum CO ₂ (%)	Maximum CH ₄ (%)	Maximum H ₂ S (ppm)	Maximum CO (ppm)	Maximum PID (ppm)	Steady-state Flow Rate (l/hr)	Barometric Pressure (mb)
RBH01	09/03/21	20.5	0.1	0.1	-	-	-	0.1	1013
	23/03/21	20.1	0.1	0.1	-	-	-	0.1	1017
RBH02	09/03/21	19.3	0.1	0.1	-	-	-	0.1	1013
	23/03/21	20.3	0.1	0.1	-	-	-	0.1	1017
RBH03	09/03/21	19.8	0.1	-0.1	-	-	-	3.1	1013
	23/03/21	19.9	0.1	0.1	-	-	-	0.1	1017
	14/03/22	19.3	0.7	<0.1	<1	<1	<1	0.0	1016
RBH04	09/03/21	16.8	0.1	-0.2	-	-	-	2.2	1013
	23/03/21	19.5	0.1	0.1	-	-	-	0.1	1017
	14/03/22	18.1	1.7	<0.1	<1	<1	<1	0.0	1016
RBH05	09/03/21	20.3	0.1	-0.1	-	-	-	0.1	1013
	23/03/21	20.1	0.1	0.1	-	-	-	0.1	1017
	14/03/22	19.7	<0.1	<0.1	<1	<1	<1	0.0	1016
RBH06	09/03/21	19.6	0.1	-0.1	-	-	-	0.1	1013
	23/03/21	20.6	0.1	0.1	-	-	-	0.1	1017
	14/03/22	20.3	<0.1	<0.1	<1	<1	<1	0.0	1014
WS09A	14/03/22	20.2	0.5	<0.1	<1	<1	<1	0.0	1016



Exploratory Hole Reference	Date	Minimum O ₂ (%)	Maximum CO ₂ (%)	Maximum CH ₄ (%)	Maximum H ₂ S (ppm)	Maximum CO (ppm)	Maximum PID (ppm)	Steady-state Flow Rate (l/hr)	Barometric Pressure (mb)
WS13	14/03/22	19.7	0.6	<0.1	<1	<1	<1	0.0	1016

BS8485 utilises the GSV and categorises the ground gas risk into 6 no. different hazard potentials, referred to as Characteristic Situations (CS1 – CS6). These are summarised in Figure 6.3.

CS	Hazard potential	Site characteristic GSV ^{A)} L/h	Additional factors
CS1	Very low	<0.07	Typically <1% methane concentration and <5% carbon dioxide concentration (otherwise consider an increase to CS2)
CS2	Low	0.07 to <0.7	Typical measured flow rate <70 L/h (otherwise consider an increase to CS3)
CS3	Moderate	0.7 to <3.5	–
CS4	Moderate to high	3.5 to <15	–
CS5	High	15 to <70	–
CS6	Very high	>70	–

^{A)} The figures used in this column are empirical.

NOTE The CS is equivalent to the characteristic GSV in CIRIA C665 [6].

Figure 6.3 CS vs. GSV (ref. BS8485)

GSV have been calculated to define the gas regime at the site as per BS8485. The measured worst-case parameters across all wells have been adopted for the calculation on a conservative basis. The GSV for carbon dioxide and methane have been calculated using the maximum concentrations of carbon dioxide (1.7%) and methane (0.1%) detected during the return monitoring visits. The maximum detected steady gas flow rate (3.1 l/hr) has also been used in the calculation. Where parameter values are recorded below the equipment detection limit then the limit of detection has been assumed for the calculation. The calculated GSV for CO₂ and CH₄ are:

- Carbon dioxide: 0.0527 l/hr
- Methane: 0.0031 l/hr

On the basis of the calculated GSV the site could be classified as characteristic situation 1 (CS1) – ‘very low risk’.

The results of the ground gas monitoring provide verification for the qualitative assessments presented earlier. It is therefore considered that no further ground gas monitoring is required. Ground gas represents low risk (i.e. no unacceptable risk) to the proposed development. No ground gas protection is required for the proposed development.

6.4.2. Soil Vapour

The soil sample laboratory analytical results have been compared to human health generic assessment criteria (GAC) appropriate for assessing risks for the specifically proposed development. The selected human health GAC include the LQM/CIEH ‘Suitable 4 Use Levels’ (S4ULs). The S4ULs are based on Health Criteria Values that represent minimal or tolerable levels of risks to health as described in the Environment Agency’s SR2 guidance, ensuring that the resulting assessment criteria are ‘suitable for use’ under Planning.

For each chemical substance, S4ULs include individual GAC for 6 no. generic land-uses (residential with home grown produce, residential without home grown produce, allotments, commercial and 2 no. public open space land uses) and a range of Soil Organic Matter (SOM) contents. All toxicological and physical-chemical parameters used in the derivation of the S4ULs are presented and discussed in the source publication.

In some instances, selected human health GAC used in this report have been applied from the DEFRA ‘Category 4 Screening Levels’ (C4SLs), CL:AIRE GAC, Environment Agency (EA) Soil Guideline Values (SGVs) and Atkins AtRisk Soil Screening Values (SSVs). The human health GAC source reference used for each chemical determinant is presented in the GQRA screening tables included as Appendix C. C4SLs have been used preferentially where available.

The proposed development includes two areas of the site with differing end uses, a residential premises without gardens in the north of the site and commercial development in the south including Premier House. Therefore, a human health GAC has been applied to each chemical determinant based on the ‘residential without home grown produce’ generic land-use scenario and the ‘commercial’ generic land-use scenario. The human health GAC for mercury assumes the presence of methyl mercury as a reasonable conservative worst case assumption based on the site history.

The chemical laboratory results for soils indicate that there are no exceedances of the selected human health GAC for volatile contaminants. This is consistent with the soil sample in-situ VOC head space readings which are all recorded as <0.1 ppm (see Section 5.7). The results indicate low risk to the proposed development due to potential soil vapour sourced from the unsaturated zone.

Groundwater samples have been collected from the on-site monitoring wells on two occasions. Dissolved phase VOC concentrations in groundwater have been tested via laboratory analysis and the results have been screened against ‘residential’ and ‘commercial’ assessment criteria presented in SoBRA document ‘Development of generic assessment criteria for assessing vapour risks to human health from volatile contaminants in groundwater’ produced in 2017. A screening table is included as Appendix C. No exceedances of the ‘commercial’ criteria have been identified. Where exceedance of the SoBRA assessment criteria for ‘residential’ end use have been identified these are summarised in Table 6.3 and Figure 6.4. Exceedances were identified from the second round of groundwater sampling only. The SoBRA assessment criteria for mercury has not been used given that the worst-case form has been assumed to be methyl mercury rather than elemental mercury.

Table 6.3 Exceedances of the SoBRA GAC for residential end use

Determinant	Maximum Concentration Detected (ug/l)	Location of Maximum Concentration	Number of exceedances	SoBRA Residential GAC (ug/l)
Trichloroethylene	27	RB103	1 of 6	5.7
Tetrachloroethylene	79	RB103	1 of 6	34

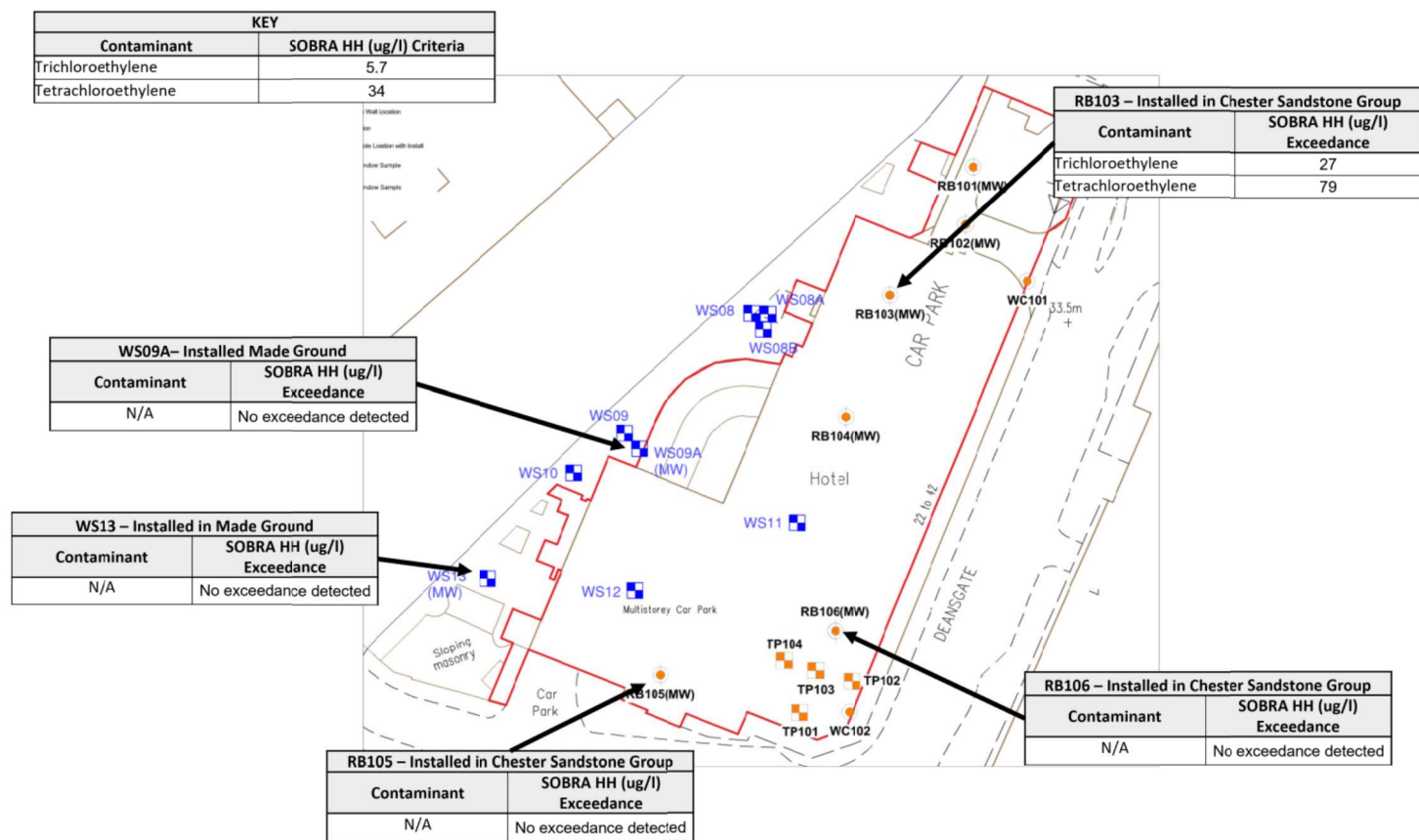


Figure 6.4 Human health exceedances plan for volatile determintns in groundwater (SOBRA ‘residential’ criteria)

Monitoring well RB103 (where exceedances of the SOBRA assessment criteria have been identified) is located in the northern area of the site proposed for residential use. The exceedances of the SoBRA assessment criteria therefore require further consideration, as provided below.

In the northern areas of the site, where residential development is proposed and where exceedances of the SoBRA ‘residential’ assessment criteria have been detected, residential apartments are located at proposed level -01 and upwards. Level -01 is effectively the first floor. The proposed floor to be constructed at the ground level across most of the site is called level -02. The level numbers are negative as they are in relation to the ground level at Deansgate which is higher than ground levels across most of the site.

Proposed level -02 (i.e. the ground floor) comprises car parking space, plant rooms, stairwells and lift pits. The car parking is open to the river side and is also assumed to be afforded ventilation appropriate to modern car park standards. Proposed floor plans for levels -02 and -01 are included as Appendix E.

The proposed land uses at the ground floor level (level -02) are low sensitivity since there is no residential accommodation or communal space located at this level, and since the car park is open to the river side so there will be a high level of natural ventilation. These characteristics mean that the ground floor level is not characteristic of typical residential use and the level of natural ventilation is also much greater than considered in the derivation of the SoBRA ‘residential’ assessment criteria. For both these reasons, the minor exceedances of the SoBRA ‘residential’ criteria identified for trichloroethylene and tetrachloroethylene detected in groundwater at RB103 are not considered significant for level -02. The ventilation provided at ground floor level (level -02) also provides appropriate mitigation for residential apartments on the levels above. An exception where lift shafts and stairwells are proposed at level -02 and these structures should be provided with appropriate soil vapour protection for trichloroethylene and tetrachloroethylene, and also for the breakdown products cis-1,2-dichloroethylene, trans-1,2-dichloroethylene, 1,1-dichloroethylene and vinyl chloride. A soil vapour protection

specification for the proposed lift shafts and stairwells should be provided in a Remediation Strategy for the proposed development. The Remediation Strategy should also include appropriate verification protocols.

Should the aforementioned soil vapour mitigation measures be suitably implemented as part of a Remediation Strategy then the risks to proposed site users will be low.

The soil vapour risks to proposed buildings and structures are low regardless of the soil vapour protection recommended for human health purposes since trichloroethylene and tetrachloroethylene have very low flashpoint values.

6.5. Controlled Waters Risk Assessment

Groundwater laboratory analytical results have been compared to generic assessment criteria (GAC) considered appropriate for assessing controlled waters risks. Controlled waters GAC have been selected to assess risks to drinking water quality and the aquatic environment in surface waters.

The selected drinking water GAC are based on Drinking Water Standards (DWS) published by the UK and EU, as well as Guidance Values (GVs) published by the World Health Organisation (WHO). The DWS and GVs are used as values indicative of low risk to drinking water quality and have been selected given the aquifer status of the Chester Formation sandstone beneath the site (Principal Aquifer).

The selected environmental quality GAC are based on freshwater Environmental Quality Standards (EQS) published by the UK and EU, and also operational targets published by the Environment Agency (EA). The EQS and operational targets are used as values indicative of low risk to the aquatic environment and have been selected given the proximity of the River Irwell to the site.

The environmental quality GAC and drinking water GAC used in this assessment are generally considered to be highly conservative for the manner used in this report, but technically robust for a GQRA.

The River Irwell is situated with a man-made river wall between the river and the site. The river wall will likely limit connectivity between the river and shallow groundwater beneath the site. Therefore, the reduced availability of a viable pathway between shallow groundwater beneath the site and the River Irwell is accounted for in the controlled waters risk assessment presented below. The controlled waters risk assessment also takes into account that the majority of the redeveloped site will be covered by building footprint and external hardstanding so infiltration of water through shallow soils will be greatly restricted.

The groundwater laboratory analytical results are presented in a screening table comparing the detected chemical concentrations to the selected GAC in Appendix C. The results generally indicate low risk to controlled waters with concentrations not exceeding the selected GAC. Where exceedance of the GAC are identified they are summarised in Table 6.4 - 6.7 and spatially orientated on Figure 6.5 and 6.6.

Table 6.4 Exceedances of the drinking water GAC (A2SI 2022 investigation)

Determinant	Maximum Concentration Detected (ug/l)	Location of Maximum Concentration	Number of exceedances	Drinking Water GAC (ug/l)
Trichloroethylene	27	RB103	2 of 6	10 (sum)
Tetrachloroethylene	79	RB103	2 of 6	
Benzo (b) fluoranthene	0.33	RB104	3 of 6	0.1 (sum)
Benzo (k) fluoranthene	0.42	WS13	3 of 6	
Benzo(ghi)perylene	0.08	RB103	3 of 6	
Indeno (1,2,3-cd) pyrene	0.08	RB103	3 of 6	



Determinant	Maximum Concentration Detected (ug/l)	Location of Maximum Concentration	Number of exceedances	Drinking Water GAC (ug/l)
Benzo (a) pyrene	0.09	WS13	3 of 6	0.01

Table 6.5 Exceedances of the environmental quality GAC (A2SI 2022 investigation)

Determinant	Maximum Concentration Detected (ug/l)	Location of Maximum Concentration	Number of exceedances	Environmental Quality GAC (ug/l)
Trichloroethylene	27	RB103	1 of 6	5.7
Tetrachloroethylene	79	RB103	2 of 6	34
Trichloromethane (chloroform)	8.0	RB101	1 of 6	2.5
>C21-C35 Aromatic	69.8	RB104	1 of 6	20
Fluoranthene	0.12	WS13	4 of 6	0.0063
Benzo (a) pyrene	0.09	WS13	4 of 6	0.0002
Copper	7.4	RB104	3 of 6	1
Nickel	8.3	RB104	1 of 6	4
Zinc	23.3	RB104	3 of 6	10.9
Lead	2.1	WS13	1 of 6	1.2
Sulphate	416	RB103	1 of 6	400

Table 6.6 Exceedances of the environmental quality GAC (E3P 2021 investigation)

Determinant	Maximum Concentration Detected (ug/l)	Location of Maximum Concentration	Number of exceedances	Environmental Quality GAC (ug/l)
Copper	8.4	RB103	3 of 3	1
Trichloromethane (chloroform)	18.8	RB101	3 of 3	2.5

Table 6.7 Exceedances of the drinking water GAC (E3P 2021 investigation)

Determinant	Maximum Concentration Detected (ug/l)	Location of Maximum Concentration	Number of exceedances	Drinking Water GAC (ug/l)
Mercury	1.22	RB104	1 of 3	1

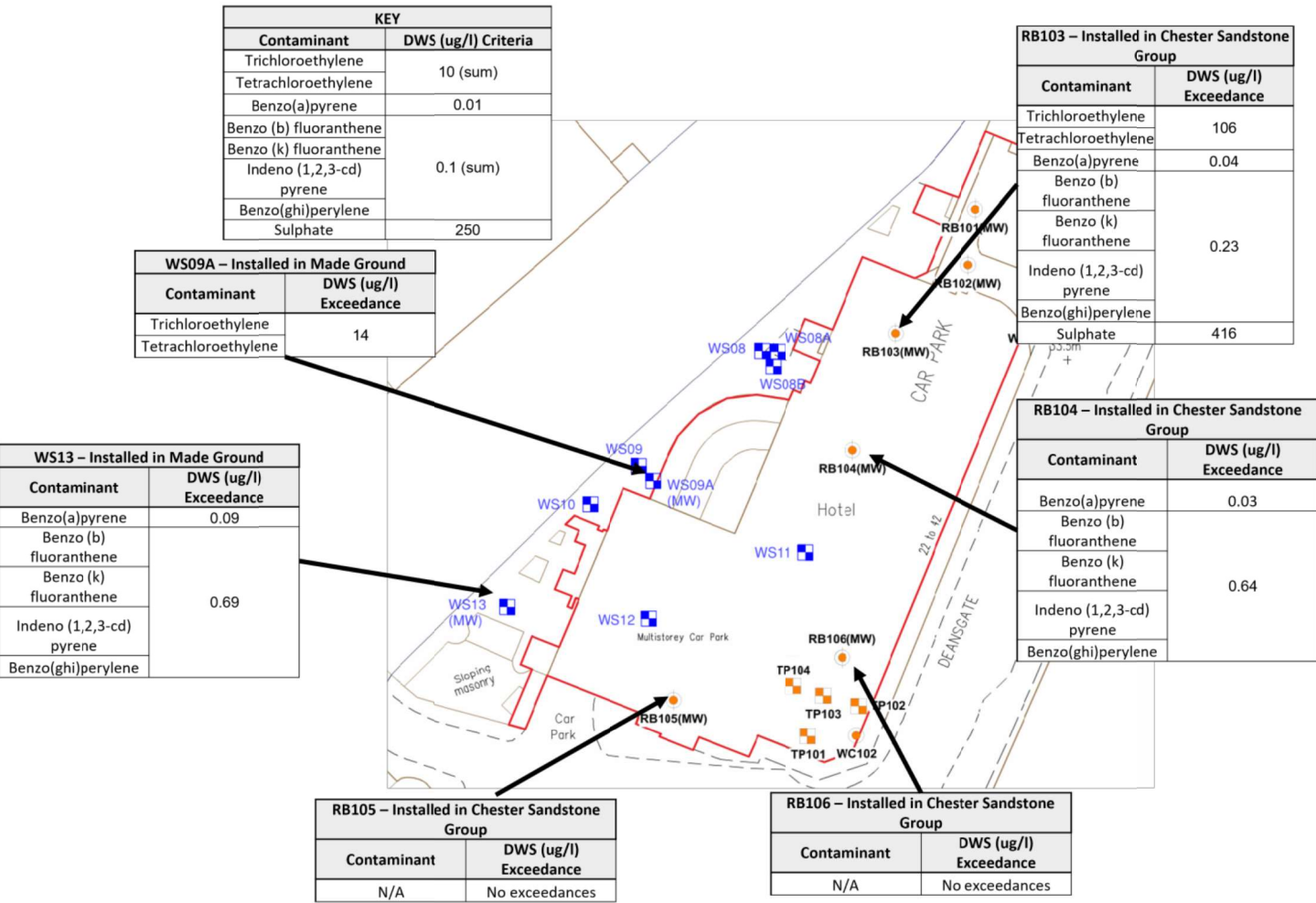


Figure 6.5 Drinking water GAC exceedances plan (A2SI 2022)

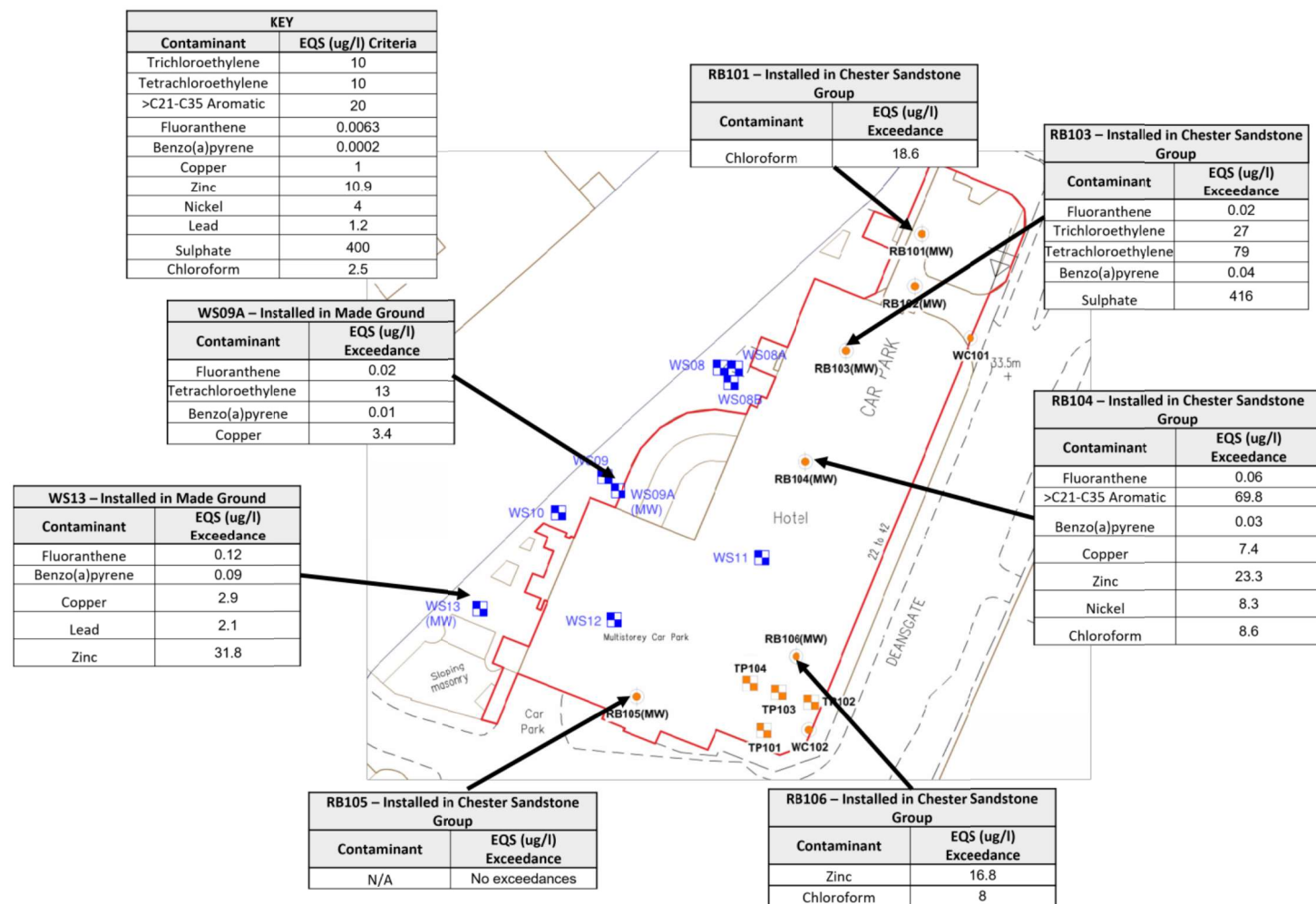


Figure 6.6 Environmental quality GAC exceedances plan (A2SI 2022)

6.5.1. VOCs

No visual / olfactory evidence of VOC contamination has been identified over the multiple phases of ground investigation undertaken. Also, the soil sample VOC head-space tests include no readings greater than instrument detection limit. Laboratory soil sample VOC analysis has been undertaken to provide an additional line of evidence and the results indicate VOC concentrations below laboratory method detection limit except 0.066 mg/kg tetrachloroethylene at WS10 (0.5mbgl) i.e. very low concentrations which indicate a viable active source of contamination in the unsaturated zone is not present.

VOC laboratory analysis has also been undertaken on shallow groundwater samples collected from the site over 2 no. monitoring rounds. Similar to soils, the majority of VOC concentrations detected in groundwater are below laboratory method detection limits. The exceptions are tetrachloroethylene, trichloroethylene and trichloromethane (chloroform) which have been detected at localised monitoring wells at concentrations slightly exceeding the selected environmental quality GAC and drinking water GAC. E3P have previously indicated that the nature of the VOC impacts in groundwater suggest an off-site source of contamination (see E3P Phase 2 Assessment) and, based on the additional data now available, this supplementary assessment concludes the same. This is because no free-phase product which would represent an ongoing source has been identified in the saturated zone, and as discussed, the soil data indicates that a viable active source in the unsaturated zone is also not present. Therefore, although there are localised VOC exceedances in groundwater the impacts do not appear to reflect a broad plume of contamination resulting from a significant on-site VOC source. On this basis, the ground investigation results indicate low risk (i.e. no unacceptable risk) to controlled waters and no remediation is required with respect to VOCs.

6.5.2. TPHs

C21-C35 aromatic TPH has been detected above the selected environmental quality GAC in shallow groundwater collected at RB104 during one of the two groundwater sampling rounds undertaken. The exceedance of the GAC is mild and on the other groundwater sampling round C21-C35 aromatic TPH was not detected above laboratory method detection limit at the same location. The absence of a repeat elevated readings indicates that there is not a coherent plume of TPH contamination in the vicinity of RB104. Furthermore, the TPH concentrations detected in the soil samples are all low and do not indicate a significant viable source of TPH contamination at the site. In consideration of these aspects, and given the relatively low mobility of this heavier end TPH fraction, the identified exceedance of the environmental quality GAC for C21-C35 aromatic TPH reflects a low risk (i.e. no unacceptable risk) to controlled waters.

6.5.3. PAHs

PAH concentrations above the selected controlled waters GAC have only been detected in the groundwater samples collected from the second groundwater sampling round:

- Fluoranthene exceedances have been identified in four of the six groundwater water samples collected on this site visit. The greatest groundwater concentration was detected at WS13 (0.12 ug/l).
- Benzo(a)pyrene was exceedances of the environmental quality GAC have been identified in four of the six groundwater samples collected on this site visit. The range of benzo(a)pyrene exceeding concentrations is from 0.01 ug/l (WS09A) to 0.09 ug/l (WS13).
- The drinking water GAC was exceeded by the sum of the following PAH concentrations: Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(ghi)perylene and Indeno(1,2,3-cd)pyrene. These exceedances were recorded for water samples from RB103, RB104 and WS13, with a maximum concentration of 0.69 ug/l recorded at WS13.

A-squared has undertaken some further assessment of the PAH concentrations particularly in relation to the possibility that particulates in the water samples are impacting the reported laboratory results. PAHs can adsorb to sediment which then becomes entrained in the water during sampling. The laboratory analytical methods used for detecting PAHs in water cannot always differentiate between dissolved phase PAHs and those adsorbed to sediment. A graph plotting Total Suspended Solid (TSS) concentration vs. Total PAH concentration for all groundwater samples collected during the second groundwater sampling round is presented as Figure 6.7. TSS is shown on the x-axis in mg/l and Total PAH is shown on the y-axis in ug/l. There is a clear linear relationship between the two parameters indicating that the detected PAH concentrations in shallow groundwater are due to PAHs adsorbed to sediment rather than actual dissolved phase contamination. Figure 6.7 indicates that as TSS trends towards zero so does Total PAH. On this basis, the identified exceedances of the controlled waters GAC for PAHs are not considered to reflect dissolved phase contamination and therefore the risk to controlled waters is low (i.e. no unacceptable risk).

6.5.4. Sulphate

Sulphate has been found to exceed the controlled waters GAC only in the groundwater sample taken from RB103. No other exceedances have been registered across all other water samples. It is likely that the exceedance for sulphate is not indicative of widespread contamination within shallow groundwater and that the elevated sulphate concentration is localised in the vicinity of RB103. Therefore, sulphate represents a low risk (i.e. no unacceptable risk) to controlled waters.

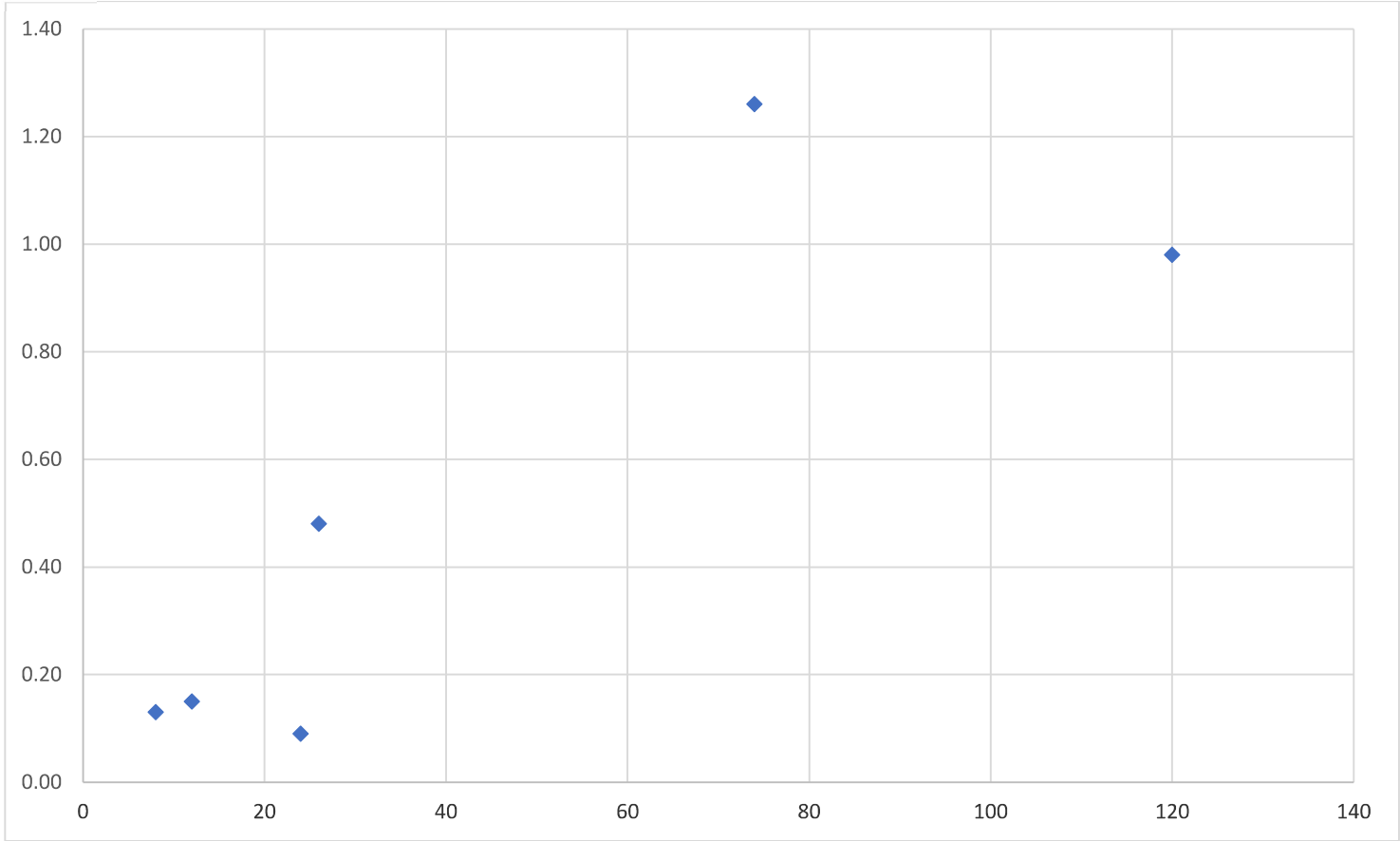


Figure 6.7 TSS vs. Total PAH for groundwater samples collected on the second sampling round

6.5.5. Heavy Metals

The heavy metal concentrations detected in shallow groundwater are generally low and where there are exceedances of the controlled waters GAC they are very mild. The soil sample laboratory analytical results do not indicate a viable source of heavy metals present in the unsaturated zone at the site. The concentrations of heavy metals detected in shallow groundwater are fairly typical of an urban setting such as where the site is located. The detected concentrations are likely reflective of ambient background water quality within the vicinity of the site. Therefore, heavy metals at the site represent a low risk (i.e. no unacceptable risk) to controlled waters.

6.5.6. Piling Risk

If piling or other deep foundation solution is selected for the proposed development then preferential pathways are unlikely to be formed between shallow soils and the Chester Formation aquifer. The Chester Formation is encountered at shallow depth beneath the site and soils in the thin unsaturated zone (including Made Ground) are typically granular. No cohesive layers which may be punctured by piling have been identified. It is considered that water, and potentially contamination (if present), can freely percolate towards the shallow groundwater table via the unsaturated zone in the absence of piling and installation of piles will not change this.

A FWRA for the Deansgate level is included as Section 7 and for other areas of the site as Section 8.



7. Foundation Works Risk Assessment for the Deansgate Level

7.1. Introduction

Section 7 presents a FWRA specifically for the contiguous pile wall to be constructed along the eastern boundary of the site from the Deansgate level. The FWRA has been informed by specific site investigation targeted at this area which is additional to what has been discussed in the earlier sections of this report.

The approximate location of the proposed contiguous pile wall is shown on Figure 7.1.

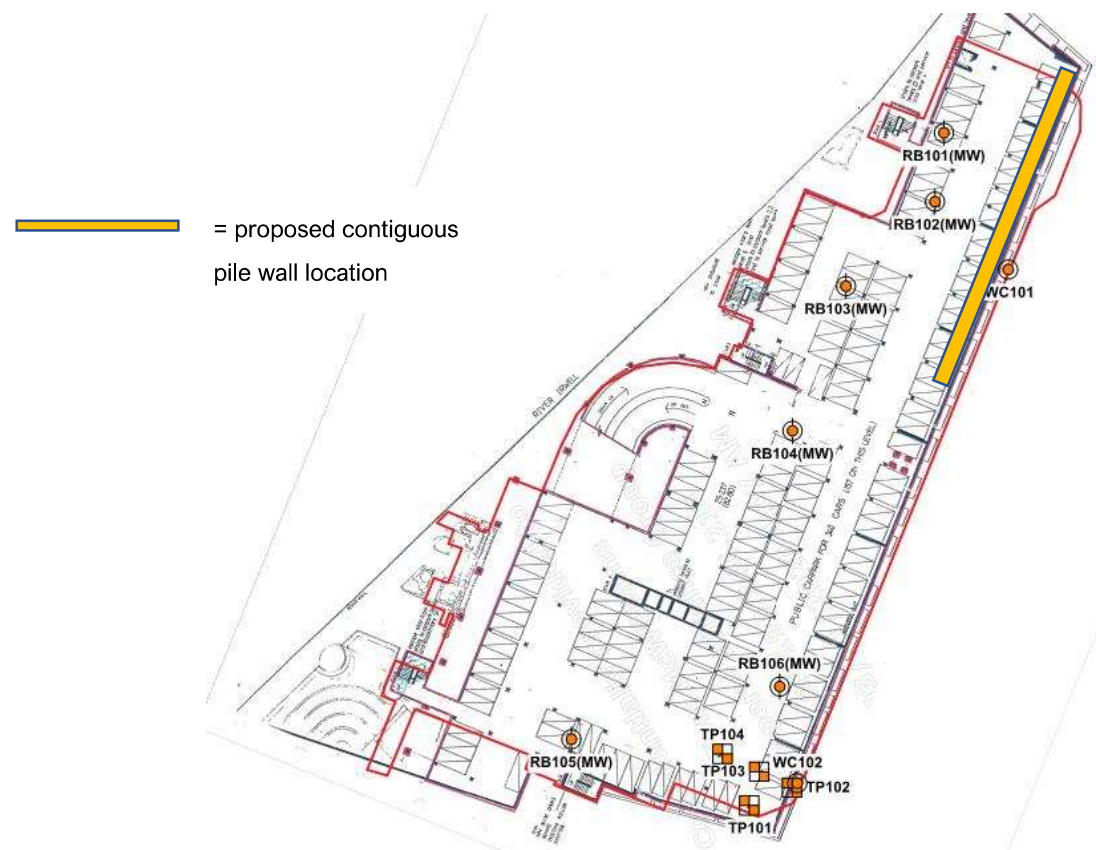


Figure 7.1 Approximate location of the proposed contiguous pile wall

The targeted site investigation to inform the FWRA for contiguous piling was undertaken by A2SI in December 2021. The A2SI Factual Report is included as Appendix B and therein refers to the works as ground investigation phase 1. Ground investigation phase 1 is summarised below and is described in detail in Appendix B. Ground investigation phase 1 is not relevant to other parts of the geo-environmental assessment for the proposed development.

Proposed pile wall drawings are included as Appendix G. In summary, piling for the wall will be undertaken from Deansgate road level along the eastern boundary of the site. Deansgate is at an elevated level compared to the site levels in this area. The piles will extend down from Deansgate level behind the existing gravity retaining wall along the eastern boundary of the site. The piles will extend past the current site ground level and terminate within the sandstone bedrock, likely below shallow groundwater level. On completion of piling, the existing retaining wall will be removed so that the new contiguous pile wall forms the operational boundary of the site. A summary of the proposed finished construction is shown in Figure 7.2.

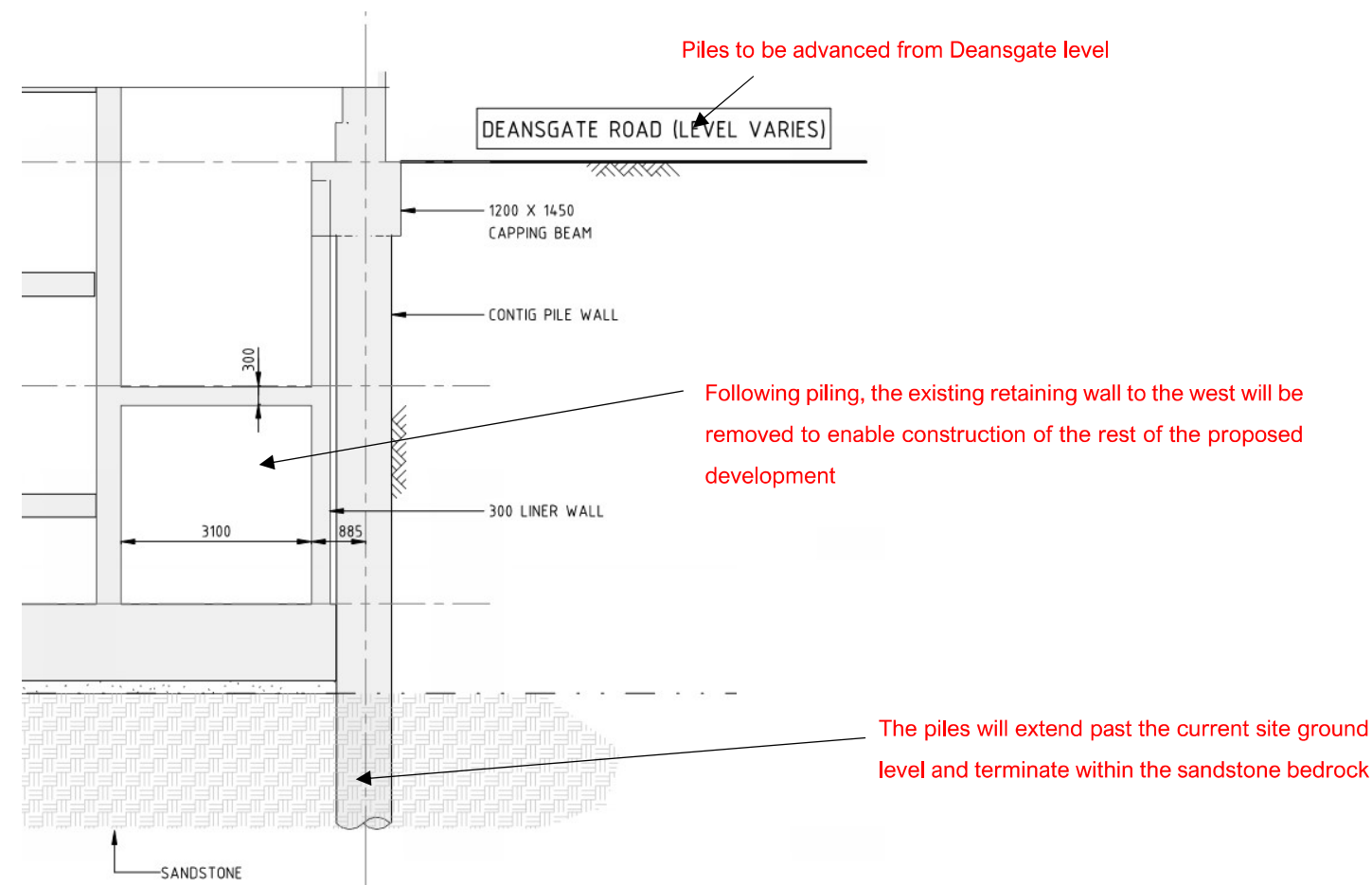


Figure 7.2 Summary contiguous pile wall details

7.2. Site Investigation Summary

In summary, the targeted site investigation to inform the Deansgate level FWRA for contiguous piling comprised the following:

- 5 no. window sampler holes to 6 m bgl (or earlier termination if impenetrable ground conditions encountered) (WS01-05);
- 1 no. deeper borehole location to approximately 10 m bgl (BH01);
- Logging of soils in accordance with BS5930;
- In-situ soil sample VOC head-space testing using a PID;
- Soil sampling for chemical laboratory analysis for speciated heavy metals, asbestos (quantified if encountered), speciated PAHs (EPA16), TPHCWG, phenolics and speciated VOCs. 7 no. soil samples were selected for each suite of analysis except the phenolics and VOCs suites for which 3 no. soil samples underwent analysis;
- Chemical laboratory analysis of soil leachate samples in accordance with BS12457-1 (single stage 2:1 liquids / solids ratio) for speciated heavy metals and speciated PAHs (EPA16). 7 no. soil leachate samples were selected for each suite of analysis.
- Chemical laboratory analysis was undertaken at a laboratory accredited to ISO17025 by UKAS.

The exploratory holes were advanced from Deansgate level from where the contiguous pile wall will be constructed. An exploratory hole plan is included in Appendix B along with other factual data from the investigation.

Where relevant, data from the E3P Phase 2 Assessment and A2SI ground investigation phase 2 has also been considered in the Deansgate level FWRA as well.