

Phase 2 Site Investigation

Plots NT02, NT03 & NT04
Dantzic Street

Far East Consortium International Ltd



15/12/23 (Rev 5)



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Phase 2 Site Investigation

Plots NT02, NT03 & NT04 Dantzic Street

Far East Consortium International Ltd

TITLE	NAME	SIGNATURE	DATE
Report Author	REECE MCGUINNESS		21/10/2022
Reviewed By	LINDEN RICHARDSON		21/10/2022
Approved By	ALEX SMILES		21/10/2022
Issue No.	05		
Report Reference	4328-ROC-ZZ-XX-RP-ES-P2-101		
Report Status	FINAL		

REVISIONS ONLY	DESCRIPTION	SIGNATURE	DATE
02	UPDATE FOLLOWING COMPLETION OF SUPPLEMENTARY SI WORKS		23/06/2023
03	UPDATE FOLLOWING COMPLETION OF DQRA MODEL		17/07/2023





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04	UPDATE FOLLOWING COMPLETION OF NETWORK RAIL MOUND INVESTIGATION WORKS		23/11/2023
05	UPDATE FOLLOWING COMPLETION OF PHASE 2F WORKS		15/12/2023



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1.0 Introduction

1.1 Background

- 1.1.1 RoC Consulting has been appointed by Far East Consortium International Ltd to conduct a Phase 2 Site Investigation across plots NT02, NT03 and NT04 (the site).
- 1.1.2 The site is divided into three development plots termed NT02, NT03 and NT04. These boundaries are indicated on Drawing 4328-ROC-ZZ-XX-DR-ES-ES200 presented in Appendix A. The site is also divided into three distinct areas based on current land uses: Plot NT02 (comprising two warehouse / light industrial type buildings with associated service yards and hardstanding), central plot NT03 (comprising a former yard, topsoil mound and a concrete batching plant in the northwest corner) and Plot NT04 (comprising a derelict plot of land partially covered in gravel and partially overgrown with trees and bushes). In this report 'the site' refers to all of the above areas.
- 1.1.3 It is understood that the site is to be developed with a mixture of high and medium rise residential buildings to heights of between 20 and 35 stories with smaller buildings varying in heights of between 4 and 8 storeys. The development is also anticipated to include small areas of soft landscaping, and a new access road passing between NT02 and NT03 and continuing to the east along the southern site boundary. The current proposed layout is presented in drawing RDB-MLA-2D-XX-DR-A-00110XXX presented in Appendix A. In the short-term Plot NT02 is also being used as a temporary event space.
- 1.1.4 The following Phase 2 Site Investigation assessment has been completed to support design and planning requirements for the site's redevelopment (Manchester City Council Planning app ref: ref: 136814/FO/2023). This updated report has been compiled to include additional phases of site investigation work undertaken in April and May 2023 (Phase 2e), September 2023 (Network Rail Mound) and October to November 2023 (Phase 2f). The scope of the Phase 2e works was approved by the Environment Agency following consultation on the findings of the Phase 2a investigation in their letter of 9th March 2023, presented in Appendix H. The scope of works of the Phase 2f works was discussed with the Environment Agency following consultation on the findings of the Phase 2e investigation completed by RoC Consulting and Outline Phase 3a Remediation Strategy completed by RSK Geosciences.
- 1.1.5 This report has been updated from a previous version (dated June 2023, Revision R4) to reflect the Phase 2f aspect of works and subsequent update of the Detailed Quantitative Risk Assessment (DQRA) for the site.
- 1.1.6 A number of previous studies and ground investigations have been completed at the site, as detailed below:
- 1) RoC Consulting, January 2023. Technical Note on Plot NT03 Network Rail Mound (ref. 4328-ROC-ZZ-XX-TN-ES-TN2)
 - 2) RoC Consulting, January 2023. Phase 1 Desktop Study (ref: 4328-ROC-ZZ-XX-RP-ES-PH1DTS)
 - 3) Phase 2 site investigation report, completed by RoC Consulting in October 2022 (ref. 4328-ROC-ZZ-XX-RP-ES-P2-101 Rev01). This report is superseded by the current document.
 - 4) LK, March 2020. Phase 2 Geo-Environmental Investigation, Risk Assessment and Remediation Strategy, at Plot NT02 only (ref: CL-602-LKC 20 1060-01)

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- 5) Allied Exploration & Geotechnics Ltd, March 2019. Northern Gateway Final Factual Report (Contract Number: NW1580)
 - 6) Hydrock, December 2015. Ground Conditions Desk Study (ref: R/151819/G001)
- 1.1.7 In addition to the above ground investigation reports, the following supporting assessments have been completed in relation to ground contamination risks across the site.
- 1) RSK Geosciences, July 2023, Controlled Waters Detailed Quantitative Risk Assessment (ref: 11847 R01 (01)).
 - 2) RSK Geosciences, August 2023, Outline Phase 3a Remediation Strategy (ref: 11834 R01 (00)).
 - 3) RSK Geosciences, November 2023, Detailed Phase 3a Remediation Strategy, Plots NT02, NT03 & NT04 (ref: 11834 R02 (01)).
- 1.1.8 It is recommended reference be made to the abovementioned reports when reviewing the current assessment.
- 1.1.9 The scope of the report and its assessment has been based around the site redevelopment proposals as outlined in the aforementioned Architect's plans. It should be noted that any subsequent revision of the proposed redevelopment or site boundary away from the above-mentioned drawing may result in the full or partial re-interpretation of this report and assessment.

1.2 Terms of Reference

- 1.2.1 The Phase 2 Site Investigations contained within this report were carried out following receipt of an instruction from Far East Consortium International Ltd.

1.3 Limitations of Study Assessment

- 1.3.1 The report has been produced by RoC Consulting for the client solely for the purposes of a review (update) of information for the above-mentioned site. It may not be used by any person for any other purpose other than that specified without the express written permission of RoC Consulting. Any liability arising out of its use by a third party for purposes not wholly connected with the above shall be the responsibility of that party who shall indemnify RoC Consulting against all claims, costs, damages and losses arising out of such use.
- 1.3.2 This report is written in the context of an agreed scope of work (as described in the Section 4) and should not be used in a different context. The report should be read in its entirety, in conjunction with the previous works undertaken at the site. Furthermore, new information, improved practices and changes in legislation may require re-interpretation of this report in whole or in part after its original issue. RoC Consulting reserve the right to alter their conclusions and recommendations in the light of further information that may become available.
- 1.3.3 Ground conditions can change rapidly, especially in areas of made ground, however, it is assumed that the ground conditions observed are typical and representative of the site as a whole. The ground conditions have been determined from a limited number of exploratory holes formed across the property, therefore, only a small percentage of the total area of the property has been investigated. Interpolation



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between exploratory holes has enabled a general interpretative picture of the subsurface conditions to be produced.

- 1.3.4 Conclusions drawn from the ground investigation findings should be read in this context. RoC Consulting cannot accept responsibility for any situations resulting from locally unforeseen ground conditions occurring between exploratory holes.
- 1.3.5 RoC Consulting has exercised all reasonable due skill, care and diligence when collating the design and subsequent execution of ground investigation works. It should be noted we cannot anticipate the requirements and actions of the regulatory authorities when designing and implementing ground investigation works and, whilst thorough consideration has been given to all geo-environmental and geotechnical concerns; further additional fieldworks or assessments may be required at their request.
- 1.3.6 RoC Consulting cannot confirm that all ground conditions which may be uncovered during the works have been identified, rather this report is intended as an informative for use by experienced professionals and contractors.
- 1.3.7 Whilst the investigation and report has been scoped in accordance with our understanding of typical regulatory authority requirements, we cannot confirm that on submission regulators may require additional in-situ testing or investigation.

1.4 Objectives and Scope of Works of the Phase 2 investigations

Objectives

- 1.4.1 The RoC Consulting (January 2022) Phase 1 Desktop Study recommended that a programme of intrusive ground investigation be undertaken at the site; the main objectives of these works were to establish site wide ground conditions to support new building foundation and road design, as well as identify and delineate any sources of contamination that may be present on site.
- 1.4.2 A number of rounds of ground investigation works were completed across the site between April 2022 and November 2023 as outlined below:
- **“Phase 2a” investigations** - Completed across Plots NT02,03 and 04 during July and August 2022 to establish baseline conditions across the site, support new building foundation design; and target potential sources of ground contamination (as revealed during the Phase 1 Desktop Study).
 - **“Phase 2e investigations”** – Comprising supplementary ground investigations across Plot NT02, completed during April and May 2023 to further assess the spatial extent of a suspected plume of Trichlorethylene contamination noted during the initial site investigation works.
 - **“Network Rail mound investigations”** – Comprising the investigation of ground conditions across a mound feature partially forming the southern boundary of the Plot NT03 site to support the design of a new retaining structure during September 2023.
 - **“Phase 2f investigation”** – Comprising the formation of deep targeted groundwater sampling wells across the Plot NT02 portion of the site during October and November 2023 to support the refinement of chlorinated solvent characterisation and remediation design.
- 1.4.3 An overview to the scope of works for each of these phases of ground investigation works is provided below. The current Phase 2 Site Investigation report captures and describes the results for all phases of ground investigation works completed across the site to date.

Phase 2a (initial) GI Scope of Work

- 1) Design a programme of site investigation works to establish ground conditions beneath the site and target known or suspected sources of contamination (as revealed by the Phase 1 desktop study).
- 2) Completion of site investigation field works including the formation of 10 rotary open hole and rotary cored boreholes to establish ground conditions, complete in situ strength tests and facilitate the installation of groundwater monitoring wells.
- 3) Completion of approximately 11 window sampler boreholes to support information obtained from rotary boreholes and target the investigation of potential sources of soil and groundwater contamination.
- 4) Completion of 16 machine excavated trial pits to further assess the quality of soils across the site, presence of obstructions and former structures, and infill information obtained from the aforementioned boreholes.

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- 5) Completion of hand pitting and foundation exposures to investigate the Network Rail viaduct and retaining wall structures and foundations.
- 6) Completion of geo-environmental and geotechnical laboratory analysis of soil, water, and rock samples to determine physical and chemical characteristics.
- 7) Completion of a ground gas risk assessment to establish site conditions and, as required, the scope of any remedial measures required to control gas ingress.
- 8) Completion of a geotechnical assessment to support new building foundation design requirements.
- 9) Completion of a geo-environmental assessment utilising information provided by both the current and previous phases of site investigation works sufficient in its scope for submission to the relevant statutory authorities as well as identify the initial scope of any remedial works necessary to support the site redevelopment.

Phase 2e (supplementary) GI Scope of Work

- 1) Design a programme of supplementary site investigation works to assess concerns and data gaps during the Phase 2a GI works and engage with the Environment Agency to discuss scope of additional works. Of particular interest during these additional works was the further assessment of the nature and extent of the chlorinated solvent plume, identified during the Phase 2a works, and determination of the risks to affected receptors (primarily the principal aquifer but also the nearby watercourse).
- 2) Formation of 7 Rotary cored boreholes across the site to determine the structure and physical properties of the underlying Triassic Sandstone bedrock (Principal Aquifer) and formations that exist beneath the site. The purpose of these boreholes was twofold, namely, to permit the installation of additional groundwater monitoring wells to permit further assessment of the site's hydrogeological regime; and to obtain specimens of rock core to permit physical strength testing as well as undertake in-situ SPT tests to support future foundation and engineering design requirements.
- 3) Formation of 11 targeted window sampler boreholes to complement information obtained from rotary bores and target / further delineate previously identified sources of contamination beneath the site.
- 4) Excavation of 9 machine excavated trial pits across Plots NT03 and 04 to increase spatial coverage of GI data in this area.
- 5) Investigate the foundation construction of the existing live railway viaduct that forms the sites southern boundary.
- 6) Complete contaminated land and ground gas investigations of un-investigated site areas, primarily Plot NT03 and further investigate the composition and quality of material stored within existing stockpile mounds present across this portion of the site.
- 7) Completion of additional groundwater and ground gas monitoring and testing to further assist with the characterisation of conditions beneath the site.



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- 8) Investigation of site soils for waste assessment and earthworks design purposes.
 - 9) Further geotechnical investigations of bedrock across Plots NT02-04 to further investigate the identified poor rock quality and incorporate further testing requests from piling contractors.
 - 10) Completion of Detailed Quantitative Risk Assessment associated with a Chlorinated Solvent Plume identified beneath the southern and western portion of the site.
 - 11) Review of all additional data from site works and subsequent laboratory analysis and update the associated geo-environmental and geotechnical assessments postulated within the initial RoC Consulting Phase 2a GI report.
- 1.4.4 The scope of works of the Network Rail mound SI are listed below.

Network Rail Mound Boreholes

- 1) Design a programme of works to facilitate access to the summit of the Network Rail (NR) mound to form dynamic sampling boreholes to investigate and characterise mound materials and feed into proposed retaining wall design.
- 2) Completion of enabling works to facilitate access to the summit of the NR mound by a civil engineering contractor.
- 3) Completion of 3 dynamic sampling boreholes through mound materials, underlying natural soils and into the underlying bedrock formation with requisite in-situ testing to assess soil quality and characteristics for subsequent environmental and geotechnical assessment of the Network Rail mound material.
- 4) Installation of 2 groundwater monitoring installations to assess quality of groundwater bodies underlying the mound.
- 5) Laboratory analysis of soil and rock samples to determine physical properties for geotechnical assessment.
- 6) Laboratory analysis of soil samples to determine chemical properties and inform subsequent waste assessment and contaminated land assessment.
- 7) Completion of additional groundwater testing to further assist with the characterisation of conditions beneath the NR mound.
- 8) Completion of Geo-environmental and Geotechnical assessment of mound materials for inclusion with the current Phase 2 site investigation report.



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1.4.5 The scope of works of the Phase 2f site investigations are listed below.

Phase 2f site investigations

- 1) Design a programme of supplementary site investigation works to refine and increase the robustness of the Conceptual Site Model and hydrogeological model for the site.
- 2) Of particular interest during these additional works was the further assessment of the extent of the chlorinated solvent plume, in particular the presence of DNAPL at the base of the Chester Formation perched above the underlying lower permeability Manchester Marl Formation.
- 3) Formation of 5 rotary open hole and rotary cored boreholes across the site to the underlying Triassic Sandstone bedrock (Principal Aquifer) and Manchester Marls Formation (Secondary B Aquifer). The purpose of these boreholes was to permit the installation of additional groundwater monitoring wells into the Chester Formations. Two of the boreholes were installed with dual monitoring wells with deeper wells sealed into the top 2 to 3 metres of the Manchester Marls formation. This facilitated the collection of additional water samples to assess if any migration of chlorinated solvents into the Manchester Marl Formation had occurred.
- 4) Completion of additional groundwater monitoring and testing to further assist with the characterisation of conditions beneath the site.
- 5) Update of Detailed Quantitative Risk Assessment associated with the chlorinated solvent plume identified beneath the southern and western portion of the site.
- 6) Review of all additional data from site works and subsequent laboratory analysis and update the associated geo-environmental assessments postulated within initial RoC Consulting Phase 2 GI report.

2.0 Background Information

- 2.0.1 The overview below outlines the most salient points and considerations, and it is recommended reference be made to the complete findings of previous site investigation reports for additional information and/or clarification.

2.1 Site Description

- 2.1.1 The site comprises an area of approximately 2.3 hectares, located to the south of Dantzic Street in Manchester and is centred at National Grid Reference E384690, N399470.
- 2.1.2 The site can be divided into three areas based on proposed plot boundaries; the western land parcel referred to as "Plot NT02", the central parcel referred to as "Plot NT03" and the eastern parcel referred to as "Plot NT04". Drawing 4328-ROC-ZZ-XX-DR-ES-ES200 provided within Appendix A provides an indication of the site subdivision. In this report 'the site' refers to all of the above areas except where specifically describing conditions or characteristics specific to each area.

Plot NT02

- 2.1.3 Plot NT02 comprises two light industrial buildings, associated access roads and areas of hardstanding. The boundaries of the plot are formed by Dantzic Street to the north with a former caravan park beyond, the adjacent Victoria Riverside development to the west, a road and Network Rail viaduct to the south and Plot NT03 to the east. It is believed that the northern industrial building was occupied by Farlam Waste Management a skip hire and waste handling company whose operations extended onto Plot NT03. The southern light industrial building was operated by Astra Signs Ltd; a sign making company.
- 2.1.4 The topography of the Plot NT02 is relatively flat with levels varying between 31.20mAOD at the interface with Dantzic Street and 34.80mAOD in the southern portion of the site. Plot NT02 is accessed from the east through a gate leading from Dantzic Street onto Plot NT03.

Plot NT03

- 2.1.5 The west portion of Plot NT03 comprises largely of hardstanding with a gate providing vehicular access in the northwest from Dantzic Street. There is a central roadway oriented roughly north to south from Dantzic Street allowing an alternative access route. To the south-west of this central roadway is the former Farlam Waste Management Ltd facility; a skip hire and waste handling facility. The former Ryan Topsoil Ltd land is located to the east of this roadway with some smaller stockpiles of loose, topsoil-like material left in place from a former large soil mound which was removed from site in early 2023.
- 2.1.6 The south-eastern part of Plot NT03 is owned by Network Rail and is occupied by a soil mound built up against the Network Rail Viaduct (along the southern boundary of the site). The summit of the mound is covered with vegetation, and it is currently unclear if this slope provides support to the viaduct structure or what structures may be behind it.
- 2.1.7 A small portion of the north of this plot, also covered with hardstanding, is fenced off from the remainder of the plot and accessed separately, also from Dantzic Street. At the time of writing, this was occupied by a concrete batching plant.

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- 2.1.8 Levels on the Plot NT03 vary significantly due to the presence of the Network Rail mound in the southeast which rises to 45.65mAOD at its peak and sloping to 33.27mAOD at its base in the centre of the plot. The hardstanding working area to the west and extending from the base of the mound to the northern boundary, varies in elevation from 35.29 in the southwest to 31.42mAOD in the northwest.

Plot NT04

- 2.1.9 Plot NT04 is comprised of semi vegetated disused land. The southern boundary is formed by the Network Rail Viaduct. Dantzic Street and Dalton Street form the northern boundary with a disused warehouse and the River Irk beyond. The eastern boundary is formed by Dalton Street and residential housing. During the site walkover relic walls of a former structure were encountered in the northern portion of the plot, likely part of the historic Dalton Print Works. Parts of the south of the plot are covered with coarse limestone gravel, with areas in the southwest surface with concrete.
- 2.1.10 Levels in this plot fall from east (41.62mAOD) to west (31.56mAOD) with a slope separating the eastern and western portions of the site.
- 2.1.11 The lower level of Plot NT04 is accessed via a gate onto Dantzic Street which enters Plot NT03. The upper level of Plot NT04 is accessed via a gate onto Dalton Street in the east of the plot.

Adjacent Sites

- 2.1.12 The site is bound to the north by Dantzic Street and Dalton Street, to the west by the construction site for the Victoria Riverside development (currently under construction) and to the south and east by the Railway Viaduct, up to 10m above the site in some locations. This incorporates both track and areas of sidings. The viaduct wall is comprised primarily of brick where exposed, with different sections visibly constructed at different times.
- 2.1.13 Beyond Dantzic Street to the north is an area occupied by caravans and a brick commercial building formerly occupied by Theos Timber and currently in use by contractors associated with the Victoria Riverside development. Beyond this is the River Irk, a small river which is in a visibly poor condition with large amounts of rubbish present on the riverbank (located approximately 20m to the north of the site boundary).
- 2.1.14 Further land uses within the immediate vicinity include a mixture of railway land, scrapyards, construction sites, car parking and residential housing.

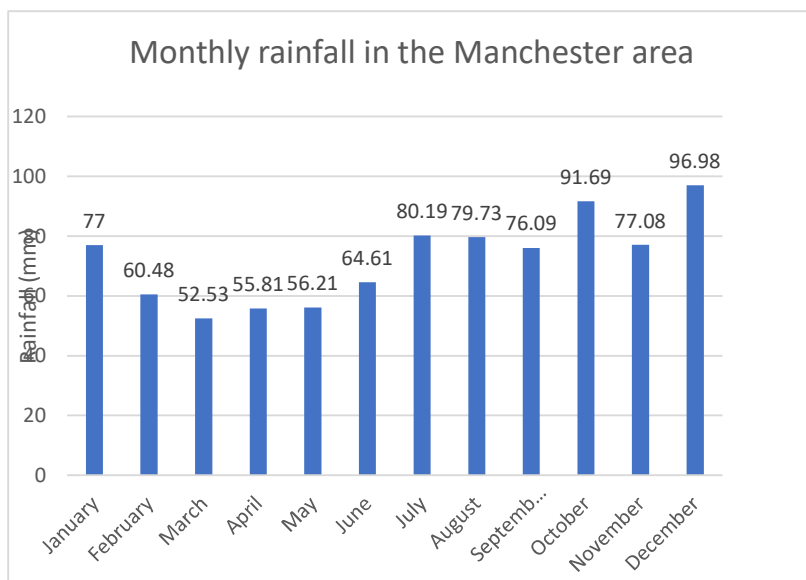
2.2 Published Geology, Hydrology and Hydrogeology

- 2.2.1 In the following, the review of publicly available climate, hydrology, geology and hydrogeology records are presented.

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2.2.2 For the climate period 1991-2000, the annual rainfall at the Woodford station is estimated 864.40mm/yr (<https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcqrqyr80>). The monthly rainfall data is summarised in the Table and chart below.

Month	Rainfall (mm)	Days of rainfall ≥ 1 mm (days)
January	77	14.73
February	60.48	12.21
March	52.53	11.81
April	55.81	10.96
May	56.21	10.84
June	64.61	11.96
July	80.19	13.17
August	79.73	13.6
September	76.09	11.96
October	91.69	14.51
November	77.08	15.04
December	96.98	15.7
Annual	868.4	156.49



2.2.3 The nearest surface water feature is indicated 21m to the north in the form of the River Irk. Water quality of this receptor indicates a GQA Grade of “E” (Poor) and a flow rate of less than 2.5 cumecs. There are no active surface water abstractions at the site or within 500m of the site boundary.

2.2.4 The BGS geological map indicate the site is underlain by the following Formations:

Drift Geology: Till, Devensian – Diamicton

Solid Geology: The western portion of the site is underlain by the Chester Formation (BGS Lexicon CHES, Sandstone, Lower Triassic) and the eastern portion of the site is underlain by the Manchester Marls Formation (Mudstone, Upper Permian). The Manchester Marls Formation (BGS Lexicon MM) underlies the Chester Formation where this is present on site. The Manchester Marls Formation is underlain by the Collyhurst Sandstone Formation (BGS Lexicon CS; Lower Permian) at depth, which is in turn underlain by the Pennine Middle Coal Measures (Carboniferous, Westphalian).

Structural Geology: the BGS bedrock map shows a fault on the eastern part of the site, with an NNW-SSE strike, putting into contact the Chester Fm (Lower Trias) with the Manchester Marls (Upper Permian). and the Collyhurst Fm (Lower Permian).

2.2.5 The Envirocheck Groundwater Vulnerability Map indicates the superficial deposits (Till) are classified as **Secondary Undifferentiated Aquifer** with the underlying Chester Formation bedrock designated as a **Principal Aquifer** and the Manchester Marls designated as a **Secondary B Aquifer**.

2.2.6 The site is not located within any Environment Agency Source Protection Zones or close proximity to any sensitive water abstraction points (e.g., potable water supply well). The nearest water abstraction point is indicated 533m to the west relating to Joseph Holt Ltd. Water is abstracted from groundwater for use in breweries/wine process water, it is not clear if the permit is still valid. Site specific hydrogeology is detailed in Section 6.3.

2.2.7 The Envirocheck report included within Appendix C of the RoC Consulting Phase 1 Desk Study, indicated that the site is located within an area which may be affected by historic Coal Mining, with bedrock of the Pennine Middle Coal Measures present at depth beneath the site. We anticipate these to be located at a depth of approximately 100m beneath the site with approximately 150m further depth of rock above any potentially viable coal seams. The coal seams beneath the site are also separated from any likely workings by faulting. As such, further investigation of mining related risks has not been undertaken.

2.2.8 According to the environmental database search, the site is located within a lower probability radon area (less than 1% of homes are estimated to be at or above the action level). Radon protection measures are not required for new dwellings.

2.3 Site History and Environmental Characteristics

- 2.3.1 The site has accommodated a number of industrial land uses in the past. The history of each individual plot is summarised below.

Plot NT02

- 2.3.1 The Victoria Screw and Bolt works was present in the southern portion of this plot on records dating from 1891 and was extended to incorporate the former Victoria Paint Works in 1908 covering the entirety of the southern portion of the Plot NT02. The Victoria Paint works itself is indicated as being present between 1891 and 1908. Records dated 1948 to 1952 shows the paint works to have been converted to the Collyhurst Foundry up until some point between 1958 to 1968 when much of the building was demolished and a Tripe Works was constructed within its general footprint.
- 2.3.2 Records from 1958 to 1989 shows the construction of a light industrial / warehousing buildings across the majority of the plot which became a part of the rubber works which had previously only operated adjacent the sites western boundary. Buildings in the north of Plot NT02 are no longer shown in an aerial photograph dated 2000. Mapping dating from 2006 indicates much of this structure to have been demolished and only the present-day light industrial building and a smaller building along the northern boundary of the Plot NT02 (now also demolished). The light industrial building is known to have previously been occupied by Astra Signs Ltd (a sign manufacturer) and is believed to have used solvents and paints although the previous Hydrock report states that the paints used on site were water based and therefore likely had low contaminative potential.

Plot NT03

- 2.3.3 The Victoria Screw and Bolt works was present in the southwest portion of the site (extending from Plot NT02 to the west) on records dating from 1891 until circa 1948-1952 when it became the Collyhurst Foundry up until some point between 1958 to 1968 when the building was demolished. A chimney was present in the southwest corner of the site, likely associated with the bolt works, from 1891 to circa 1970 when it was replaced with an Asphalt Works. An unspecified building is located in the central-east portion of the site recorded on maps dated 1891 to mid 1990's labelled as a scrap metal works and later a 'works'.
- 2.3.4 The site is largely vacant, is mostly occupied by derelict urban land with surfacing a mixture of concrete, hardcore and processed anthropogenic materials associated with the removal of the soil mound (which was removed from the site by Ryan Topsoil before the site was vacated and should not be confused with the Network Rail Mound which is still present in the south of the site).
- 2.3.5 A waste management company known as Farlam Waste Management is known to have operated in the north and eastern portion of this plot, only having ceased operation within the past decade; anecdotal evidence from discussions on site with excavator operatives indicate the southern portion of the Plot NT03 was also used as a yard for construction plant.
- 2.3.6 A small area of the southern boundary of the Plot NT03 was previously occupied by a signal box on an embankment adjacent the railway viaduct. It is not clear from historical records if there is a retaining wall which supports the viaduct in this location or if the viaduct is supported by the embankment which is visible on historic plans and aerial photography and still present today.

Plot NT04

- 2.3.7 Dalton Works (a print works) was present in this plot from 1891 until it was demolished on records dating from 2013. It occupied the southern area of the site and a small area adjacent Dalton Street sitting at a slightly elevated position to the rest of the site. Relic retaining walls appear to be present in the vicinity of the former works in the present day.

Adjacent Historical Land Uses

- 2.3.8 The site is located within an area of the city which has seen heavy industrial land use in the past. The most significant historic industrial land uses in close vicinity to the site are summarised below.
- 2.3.9 The Lancashire and Yorkshire Railway has been present adjacent the sites southern boundary from 1848 till the present day. In 1891 the Newtown sidings were added bringing the railway right up against the site's southern boundary.
- 2.3.10 The Rochdale Road Gasworks is visible as early as 1848, 50m to the south of the site comprising four large gasometers and significant associated infrastructure at its peak. Two gasometers associated with the gasworks were present 10m to the north of the site on the opposite side of Dantzic Street from the site. The extent of the gasworks declined during the mid-20th century before being converted to a depot in the late 20th century. The two gasometers to the north of the site were demolished in the mid to late 20th century and have since been occupied by caravans.
- 2.3.11 A garage / depot was located 10m to the north of the site from the mid-20th century and is believed to have most recently been used as a timber merchants.
- 2.3.12 Within 200m of the west of the site, a number of historic industrial activities were recorded including a rubber works, oil works, chemical works, print works, foundry, engineering works, glue works, timber yards, scrap yards and a large iron works. The vast majority of this industry is no longer present and has been replaced by alternative land uses such as car parking. It should be noted much of this industry is a considerable distance from the site and superficial ground conditions are relatively impermeable, furthermore a number of these industries were located on the other side of the River Irk which would also serve as a boundary to contaminants migration.
- 2.3.13 There is a single BGS recorded Landfill Site present 330m to the north of the site. There are three historic landfill sites located within 500m of the site with the closest being located 205m to the north of the site. There are three Registered Waste Transfer Sites located within 500m of the site. The closest of which is located 82m to the west of the site. The licence holder for this site is Placemix Ltd and is operational as far as is known. There are no further waste facilities located within 500m of the site.
- 2.3.14 There are two Licensed Waste Management Facility located on site. The first is located within the eastern portion of Plot NT02 the license for which expired in 2020 and was operated by Farlam Waste Management Ltd. The second facility is located on Plot NT03 and, the license is listed as transferred and it was operated by Ryan John. Both facilities are categorised as Household, Commercial and Industrial Transfer Stations. There are a further 3 Licensed Waste Management Facilities located within 500m of the site however all licenses are shown as expired. There are a further three waste management facilities within 500m of the site.



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- 2.3.15 A small area of the northern portion of the site is located in Flood Zone 2, the remainder of the site is located in Flood Zone 1. The risk of pluvial flooding is deemed as very low.

2.4 Previous Environmental Assessment

- 2.4.1 Findings of the site investigation work carried out to-date by RoC Consulting in 2022 and 2023 (Phase 2a, Network Rail Mound Investigation, Phase 2e and Phase 2f) are incorporated into this report. The findings of the LK Consult Phase II Site Investigation (2020), carried out in the Plot NT02 of the site are summarised below. The location of the exploratory holes is illustrated in Drawing 4328-ROC-ZZ-XX-DR-ES-ES201.
- 2.4.2 Results from chemical testing undertaken by LK Consult revealed the following issues in the Plot NT02 regarding contamination:
- Elevated levels of Heavy Metals (Lead) in soil at WS104, SP1 and SP2 (Likely associated with ash, clinker and coal noted within made ground deposits)
 - Trace amounts of asbestos in soil at TP105 and SP1 (Likely associated with the demolition of historic buildings)
 - Elevated levels of PAHs - Benzo(a)pyrene and Naphthalene in soil at WS102, WS103, WS105, TP103, TP105 SP1 and WS205 (Likely associated with ash, clinker and coal noted within made ground deposits)
 - Elevated levels of TPH – Aliphatic C12-C16, Aromatic C8-C10 and Aromatic C10-C12 in soil at WS205 (beneath the light industrial building and likely associated with the numerous historic industrial activities in this area of the site)
 - Elevated levels of VOCs/SVOCs – Benzene and Trichloroethene in made ground and superficial deposits at WS205, WS201, WS202 and WS204. PID readings in the southwest of the plot also indicate the presence of volatile contamination with readings between 4.3ppm and 207ppm (Likely associated with the historic industrial activity in this area of the site); and
 - Elevated concentrations of contaminants in groundwater including Vinyl chloride at RBH101 and Trichloroethene in RBH103. The report hypothesizes these may be linked to historic industrial activity on site or a result of historic industry across the wider area, such as the former gasworks.
- 2.4.3 Ground gas monitoring visits were undertaken on a total of seven wells. Slightly elevated levels of carbon dioxide were encountered with an absence of methane, carbon monoxide and hydrogen sulphide gases. Slightly depleted levels of oxygen were also encountered. The site was characterised as a Characteristic Situation 1 with no remedial measures envisaged.
- 2.4.4 On site soil and groundwater contamination encountered was believed to relate to previous industrial operations as well as the potential movement of gas works era contamination within the underlying principal aquifer beneath the site. A defined area of contamination was suspected in the southern and western portion of the plot beneath the existing building.
- 2.4.5 The report recommended that an area of contaminated soils, in the southwest of the Plot NT02, should be excavated and either treated onsite or disposed of offsite. The use of a soil cover system was



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recommended in soft landscaping areas. Although exceedances of contaminants in groundwater were recorded, groundwater remediation was not recommended.

3.0 Site Investigation Design

Phase 2a – Initial Ground Investigation Works

- 3.0.1 The first phase of intrusive investigation (Phase 2a) was designed and completed to further investigate geo-environmental issues identified during the Phase 1 Desktop Study and previous site investigations; as well as provide geotechnical information to facilitate new building design.
- 3.0.2 The site investigation works comprised the formation of nine rotary open hole and cored boreholes to a maximum depth of 25.00mbgl, 11 window sampler boreholes to a maximum depth of 5.00mbgl and 14 machine excavated trial pits to a maximum depth of 4.00mbgl.
- 3.0.3 Exploratory hole placement was dictated by the findings of the Phase 1 Desktop Study to zone-in on areas where current / previous industrial activity may have impacted soil quality. In addition, boreholes and trial pits were located within the footprint of the proposed new development to establish ground conditions and support foundation design.
- 3.0.4 Samples of soil collected during the investigation works were analysed for a variety of determinants associated with the pattern of current / historic industrial activity across the site, as outlined within the preliminary conceptual site model.
- 3.0.5 Table 3.0 provided below provides location justification for each exploratory hole formed during the site investigation fieldworks. The purposes of this table are to illustrate the targeting of potential sources of contamination during the Phase 2 site investigation works.

Table 3.0: Borehole Locations & Justification

BH/WS ID	Reason for selection
RBH201	Assess groundwater quality in north-western corner of Plot NT02.
RBH202	Provide geotechnical information in the vicinity of proposed building and assess groundwater quality on Plot NT02.
RBH203	Assess groundwater quality in area of previously identified groundwater contamination. Provide geotechnical information in the vicinity of proposed high-rise buildings.
RBH205	Assess groundwater quality in the northern portion of Plots NT03/NT04.
RBH206	Assess groundwater quality in the northern portion of Plot NT03 and provide geotechnical information in the vicinity of proposed building.
RBH207	Assess groundwater quality in the northern portion of Plot NT04.
RBH208	Assess groundwater quality in the western portion of Plot NT04 and provide geotechnical information in the vicinity of proposed building.
RBH209	Assess groundwater quality in the centre of Plot NT04 and provide geotechnical information in the vicinity of proposed hi-rise building.
RBH210	Assess groundwater quality in the eastern portion of Plot NT04 and provide geotechnical information in the vicinity of proposed hi-rise building.
WS201	Establish ground conditions and assess area of previously identified contamination.
WS202	Establish ground conditions and assess area of previously identified contamination. Install ground gas monitoring well.
WS203	Establish ground conditions and assess area of previously identified contamination. Install ground gas monitoring well.
WS204	Establish ground conditions and assess area of previously identified contamination. Install ground gas monitoring well.
WS205	Establish ground conditions and assess area of previously identified

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BH/WS ID	Reason for selection
	contamination.
WS208	Establish ground conditions and install ground gas monitoring well.
WS209	Establish ground conditions and install ground gas monitoring well.
WS210	Establish ground conditions.
WS211	Establish ground conditions and install ground gas monitoring well.
WS212	Establish ground conditions.
WS213	Establish ground conditions and install ground gas monitoring well.
TP201	Establish ground conditions and investigate area of historic tank.
TP202	Establish ground conditions and investigate area of previously identified contamination.
TP203	Establish ground conditions.
TP204	Establish ground conditions.
TP207	Establish ground conditions.
TP208	Establish ground conditions and foundation exposure along Network Rail viaduct.
TP213	Establish ground conditions.
TP214	Establish ground conditions.
TP215	Establish ground conditions.
TP216	Establish ground conditions.
TP217	Establish ground conditions.
TP218	Establish ground conditions.
TP219	Establish ground conditions.
TP220	Establish ground conditions and foundation exposure along Network Rail viaduct.

3.0.6 It should be noted that, at the time of the original RoC Consulting SI works, one of the major proposed buildings in Plot NT03 was located in a then inaccessible area of the site, beneath a topsoil mound and could not be directly investigated as part of this phase of the works.

3.0.7 Exploratory hole locations are shown on RoC Consulting drawing 4328-ROC-ZZ-XX-DR-ES-ES201B provided within Appendix A.

Phase 2e – Supplementary Ground Investigation Works

3.0.8 The second phase of intrusive investigation works (Phase 2e) was designed to achieve the objectives stated in Section 1.4 and address outstanding data gaps listed in section 3.0.10, following the works in August 2022.

3.0.9 These supplementary works comprised the following:

- Formation of 7 rotary boreholes across the site to a maximum depth of 30.00m
- Formation of 12 window sample boreholes across the site to a maximum depth of 5.00m
- Excavation of 9 trial pits in Plot NT03 and NT04
- Investigation of the viaduct foundation in Plot NT03 and acquisition of soil samples from earth mounds remaining onsite
- Groundwater, ground gas, and soil vapour monitoring and sampling

**COMPLEX CHALLENGES ...
MADE SIMPLE**

- 3.0.10 Exploratory hole placement was dictated by the findings of the previous Phase 1 and Phase 2 report to address outstanding data gaps. In particular these were:
- 1) Locate and delineate a potential plume of chlorinated solvent contamination in the southern warehouse of NT02.
 - 2) Install additional groundwater monitoring wells across plots NT02 and NT03 to obtain further samples of groundwater from the Principal Aquifer in the Chester Formation, for the purpose of environmental assessment.
 - 3) Complete Phase 2 contaminated land and ground gas investigations of un-investigated site areas, primarily Plot NT03.
 - 4) Obtain samples of soil from mounds and ground at the site for the purposes of waste assessment and earthworks design.
 - 5) Further geotechnical investigations of bedrock across Plots NT02-4 to further investigate the identified poor rock quality and incorporate further testing requests from piling contractors.
- 3.0.11 Access to portions of the site was limited during the supplementary phase of ground investigation works. These limitations relate to a “Meanwhile” use currently in operation across the central portion of Plot NT02 and Plot NT03, comprising a pop-up event space. The formation of boreholes within this portion of the site was impacted as a result as only limited works where possible in this area. This limitation has had an impact on further investigation and delineation of the aforementioned chlorinated solvent plume suspected to be present this area.
- 3.0.12 Samples of soil collected during the investigation works were to be analysed for a variety of determinants associated with the pattern of current / historic industrial activity across the site as outlined within the preliminary conceptual site model.
- 3.0.13 Investigation of the foundations of the Network Rail viaduct to the south of the site, including potential for the NR mound to the rear of NT03 to offer support to the railway.
- 3.0.14 The Table 3.1 provided below provides location justification for each exploratory hole formed during the Phase 2e site investigation fieldworks.

Table 3.1: Phase 2e GI: Borehole Locations & Justification

Location ID	Reason for selection
RBH301	Permit additional hydrogeological assessment & groundwater testing
RBH302	
RBH303	
RBH304	As RBH301-3 & to provide further geotechnical information (retaining wall and piling)
RBH305	
RBH306	
RBH307	Geotechnical (at request of piling contractor)
WS301	Plot NT02 VOC Soil plume contamination delineation, vapour monitoring

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Location ID	Reason for selection
WS302	Plot NT02 VOC Soil plume contamination delineation
WS303	Plot NT02 Soil contamination delineation, vapour monitoring
WS304	Plot NT02 VOC Soil plume contamination delineation
WS305	
WS306	
WS307	
WS308	
WS308a	Plot NT02 Soil contamination delineation (replacement for aborted WS308)
WS309	Plot NT02 Soil contamination delineation, vapour monitoring
WS310	NT03 site coverage and monitoring
WS311	NT03 site coverage and monitoring
WS312	NT03 site coverage and monitoring
TP301	NT03 site coverage
TP302	NT03 site coverage
TP304	NT04 sampling for waste and earthworks grading
TP305	NT03 site coverage
TP306	NT04 sampling for waste and earthworks grading
TP307	NT03 site coverage
TP308	NT03 site coverage
TP309	NT03 site coverage
TP310	NT03 site coverage
MP301	Mound sampling for waste and earthworks grading
MP302	Mound sampling for waste and earthworks grading
MP303	Mound sampling for waste and earthworks grading
MP304	Mound sampling for waste and earthworks grading
HP301	Network Rail Mound sampling for waste and earthworks grading

3.0.15 Phase 2e exploratory hole locations are shown on RoC Consulting drawing 4328-ROC-ZZ-XX-DR-ES-ES201C provided within Appendix A.

Network Rail (NR) Mound Investigation Works

3.0.16 Additional investigation works were designed to achieve the objectives stated in Section 1.4.5 The works comprised the following:

- 3 Dynamic sample boreholes and 2 rotary follow on boreholes to a maximum depth of 21.00mbgl.

3.0.17 Exploratory hole placement was dictated by the location of the proposed retaining wall and constraints present on the Network Rail mound. A new access ramp was created by civil engineering contractors Adana Construction at a gradient of 5:1 to allow the rotary drilling rig to traverse to the summit of the mound.

3.0.18 Samples of soil collected during the investigation works were analysed for a variety of determinants associated with the pattern of current / historic industrial activity across the site, as outlined within the preliminary conceptual site model.

3.0.19 NR mound borehole locations are shown on drawing 4328-ROC-ZZ-XX-DR-ES-ES201D.

Phase 2f – Additional TCE Investigation

- 3.0.20 Additional investigation works were designed to achieve the objectives stated in Section 1.4.5 The works comprised the following:
- 5 Dynamic sample boreholes with follow on rotary open hole and rotary coring boreholes to a maximum depth of 20.50mbgl.
- 3.0.21 Exploratory hole placement was dictated by the findings of the previous Phase 1 and Phase 2 report to address outstanding data gaps. In particular these were:
- 1) Install additional groundwater monitoring wells across plots NT02 and NT03 to obtain further samples of groundwater from the Principal Aquifer in the Chester Formation, for the purpose of environmental assessment.
 - 2) Establish the presence of any DNAPL at the base of the Chester Formation sitting above the underlying lower permeability Manchester Marl Formation.
 - 3) Establish the presence of any VOCs within the shallow Manchester Marls.
 - 4) Further refine the hydrogeological model of the site through additional groundwater monitoring works.
 - 5) Complete additional hydraulic conductivity testing within the Chester Formation to refine “k” values for use within the DQRA model.
- 3.0.22 Access to portions of the site were limited during this phase of ground investigation works. These limitations relate to a “Meanwhile” use currently in operation across the central portion of the Plot NT02 site, comprising a pop-up event space.
- 3.0.23 Samples of soil collected during the investigation works were analysed for a variety of determinants associated with the pattern of current / historic industrial activity across the site, as outlined within the preliminary conceptual site model.
- 3.0.24 The Table 3.2 provided below provides location justification for each exploratory hole formed during the Phase 2f site investigation fieldworks.

Table 3.2: Phase 2f GI: Borehole Locations & Justification

Location ID	Reason for selection
RBH501	Located within SE corner of the southern warehouse to assess presence of TCE plume in east of Plot NT02
RBH502	Located within NW corner of the southern warehouse to assess presence of TCE plume on western boundary of Plot NT02.
RBH503	To infill deep ground model data and hydrogeological conditions in the Chester Formation
RBH504	To delineate eastern extent of TCE plume within Plot NT03
RBH505	To replace lost monitoring well at RBH201

- 3.0.25 Phase 2f borehole locations are shown on RoC Consulting Drawing 4328-ROC-ZZ-XX-DR-ES-ES201C.

4.0 Site Investigation Fieldworks and Laboratory Testing

General

- 4.0.1 The first phase of site investigation fieldworks (Phase 2a) was completed between the 11th July and the 15th August 2022 with the Phase 2e supplementary investigation undertaken between the 2nd April and 25th April 2023. The NR mound boreholes and associated enabling works were completed between the 11th and 21st September 2023 and Phase 2f works were completed between the 30th October and 9th November 2023.
- 4.0.2 In the first phase of work drilling was completed by contractors DMW Drilling Ltd. Rotary open hole and cored boreholes were formed using a Massenza MI3 and window sample boreholes were formed with a Competitor 150. In Phase 2e, rotary boreholes were completed by MT Geoservices using a Beretta T44 and window sample boreholes were formed with a Premier 110. The NR mound boreholes were completed by MT Geoservices using a Beretta T44. The Phase 2f works were completed by Central Alliance using a Comacchio 300 and a Fraste PLC.
- 4.0.3 Prior to excavation, RoC Consulting methodology for service avoidance, G5.15, was applied. This methodology includes:
- Consultation of existing statutory undertakers plans of services
 - Consultation of service drawings provided to us by the client or site operator
 - Completion of location specific GPR clearance where applicable
 - Opening of nearby service covers
 - CAT and Genny scanning
 - Excavation of 1.20m hand dug service avoidance pit in advance of borehole drilling
 - Recording of these checks through location specific Permits To Dig.
- 4.0.4 Records of equipment calibration are presented in Appendix F. RoC Consulting operatives all hold current qualifications for the use of such equipment.
- 4.0.5 To ensure that no new sources of contamination were introduced or mobilised to underlying soils / bedrock during the formation of each borehole, we have adopted safe drilling techniques for ground investigation in all instances. These methods include but are not limited to:
- Use of steel casing and vegetable oil as a lubrication medium
 - Formation of impermeable bentonite seals in borehole wells during drilling
 - Formation of impermeable bentonite seals to the tops and bottoms of response zones in installed monitoring wells
 - Reinstatement of boreholes without monitoring wells with bentonite
 - Cleaning of sampling equipment to reduce cross contamination
 - Dual pipe monitoring wells have not been installed
- 4.0.6 We consider that the employment of these above methods keeps the likelihood of contamination disturbance as low as reasonably practicable, although it is not possible to wholly remove the possibility of such occurrences.

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- 4.0.7 Soil and rock core samples were collected for subsequent chemical and geotechnical laboratory analysis. Soil samples used for geotechnical analysis were collected in 1kg plastic sample tubs. Samples collected for chemical testing were collected in 1kg plastic sample tubs, 258g glass jars and 60g glass jars.
- 4.0.8 Samples were obtained from both made ground and natural strata to assess the overall quality of underlying soils. In-situ soil strength was calculated using Standard Penetration Tests (SPT) within superficial deposits; SPTs also allowed to confirm rockhead had been reached by refusal.
- 4.0.9 The soils and rocks encountered during construction of the boreholes were described and logged by a suitably qualified engineer in accordance with BS 5930: Code of Practice for Site Investigations (the log sheets for which have been provided within Appendix B).
- 4.0.10 Ground gas and groundwater monitoring wells were installed within rotary and window sampler boreholes. Monitoring wells from LK and RoC previous site investigations were also monitored. Installation details are provided within Table 5.0 below, copies of ground water and gas monitoring records are provided within Appendix E. Drawing 4328-ROC-ZZ-XX-DR-ES-ES202 shows the locations of all boreholes installed with gas and groundwater monitoring wells.

Table 4.0: Monitoring Well Installations

BH ID	Monitoring Well Depth (mbgl)	Response Zone (mbgl)	Response Zone Strata
Recommissioned and used from previous LK Site investigations			
LK RBH1	15.00	5.00 to 15.00	Chester Formation
LK RBH3	20.00	5.00 to 20.00	Chester Formation / Manchester Marls
LK WS103	3.00	1.00 to 3.00	Made Ground / Devensian Till
LK WS105b	3.00	1.00 to 3.00	Made Ground / Devensian Till / Chester Formation
LK WS201	3.00	1.00 to 3.00	Devensian Till
Phase 2a - 2022 RoC Site Investigation			
RBH201	25.00	21.00 to 25.00	Manchester Marls Formation
RBH202	25.00	21.00 to 25.00	Manchester Marls Formation
RBH203	15.00	10.00 to 15.00	Chester Formation
RBH205	25.00	20.00 to 25.00	Manchester Marls Formation
RBH206	25.00	21.00 to 25.00	Manchester Marls Formation
RBH207	25.00	20.00 to 25.00	Manchester Marls Formation
RBH208	24.00	19.00 to 24.00	Manchester Marls Formation
RBH209	17.00	12.00 to 17.00	Manchester Marls Formation
RBH210	25.00	20.00 to 25.00	Manchester Marls Formation
WS202	1.50	1.00 to 1.50	Made Ground

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BH ID	Monitoring Well Depth (mbgl)	Response Zone (mbgl)	Response Zone Strata
WS203	1.00	0.50 to 1.00	
WS204	1.50	0.50 to 1.50	
WS208	1.00	0.50 to 1.00	
WS209	1.50	0.50 to 1.50	
WS211	1.00	0.50 to 1.00	
WS213	1.00	0.50 to 1.00	
Phase 2e - 2023 RoC Site Investigation			
RBH301	10.00	4.00 to 10.00	Chester Formation
RBH302	12.00	5.00 to 12.00	Chester Formation
RBH303	10.00	5.00 to 10.00	Chester Formation
RBH304	9.00	5.00 to 9.00	River Terrace Deposits
RBH305	9.00	5.00 to 9.00	Chester Formation
RBH306	11.00	9.00 to 11.00	Manchester Marls Formation
RBH307	20.00	9.00 to 20.00	Manchester Marls Formation
NR Mound Boreholes – 2023 RoC Site Investigation			
RBH401	16.50	11.50 to 16.50	River Terrace Deposits
RBH403	16.50	11.50 to 16.50	River Terrace Deposits
Phase 2f – 2023 RoC Site Investigation			
RBH501	11.80	4.50 to 15.00	Chester Formation
RBH502 (P1)	18.30	5.50 to 18.30	Chester Formation
RBH502 (P2)	20.30	19.30 to 20.30	Manchester Marls Formation
RBH503	10.00	5.00 to 10.00	Chester Formation
RBH504	11.95	4.50 to 11.95	Chester Formation
RBH505 (P1)	11.80	4.50 to 11.80	Chester Formation
RBH505 (P2)	14.50	13.00 to 14.50	Manchester Marls Formation

4.1 Below Ground Obstructions

- 4.1.1 A number of obstructions and constraints were encountered during the site investigation works on Plots NT02, NT03 and NT04 and are detailed in the tables below. The results indicate that, as typical for a brownfield site of this type, numerous buried obstructions and structures should be anticipated.

**COMPLEX CHALLENGES ...
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Table 4.1: Below Ground Obstructions, Plot NT02

BH ID	Depth		Notes and observations
	mbgl	mAOD	
RBH203	1.20	32.39	Concrete obstruction.
TP202	0.25 to 1.50	33.35 to 32.10	Concrete structure in northern face of trial pit.
WS201	0.30	31.14	Cobblestone block likely associated with historic street / yard.
WS307	0.50	33.10	Borehole aborted on unknown concrete obstruction.
WS308	0.40	33.20	Borehole aborted on unknown concrete obstruction.
RBH501	0.25 to 0.60	33.34 to 32.99	Red brick structure, suspected remnant historic structural feature.
RBH502	1.80 to 2.50	31.79 to 31.09	Concrete obstruction, suspected relic slab / footing.
RBH503	0.60 to 0.80	31.05 to 30.85	Asphalt, suspected historic roadway / car park
RBH505	0.40 to 0.55	31.01 to 30.86	Asphalt, suspected historic roadway / car park

Table 4.2: Below Ground Obstructions, Plot NT03

BH ID	Depth		Notes and observations
	mbgl	mAOD	
TP207	0.80	32.50	Small diameter Alkathene water supply pipe Clay Drainage Pipe
	1.00	32.30	
WS205	0.60	33.81	Metal pipe encountered within handpit likely associated with historic building.
TP308	0.40	32.84	Brick structure across base of trial pit
TP309	0.30	33.03	Brick wall in northern face of trial pit

Table 4.3: Below Ground Obstruction, Plot NT04

BH ID	Depth		Notes and observations
	mbgl	mAOD	
TP218	0.40 to 1.70	40.82 to 39.52	Masonry wall likely associated with former Dalton Works
	0.40 to 2.80	40.82 to 38.42	Masonry wall likely associated with former Dalton Works
	0.60	40.62	Arch structure likely associated with former Dalton Works
	1.20	40.02	Masonry floor likely associated with former Dalton Works
WS208	1.00 to 1.18	40.72 to 40.54	Asphalt infill
WS212	0.50	40.85	Relic brick wall likely associated with former Dalton Works
TP305	0.60	32.37	Brick structure in western face
TP307	0.50	34.32	Concrete boulders

4.2 Laboratory Testing

4.2.1 To establish the physical and chemical properties of underlying soils, a programme of laboratory analysis was completed utilising samples obtained during both phases of site investigation works. This analysis comprised the testing of soil samples to assist with the estimation of risks posed by contaminated land related concerns.

Chemical Testing

4.2.2 RoC Consulting submitted the following soil and water samples to a UKAS accredited testing facility for analysis against a range of determinants synonymous with the site's former industrial activity and to further assess contamination issues identified during the initial phase of works.

Table 4.4: Chemical Testing Breakdown

Determinands	No. of Tests (Phase 2a)	No. of Tests (Phase 2e)	No. of Tests (NR Mound)	No. of Tests (Phase 2f)
Soil - Toxic and phytotoxic metals and metalloids	27	60	12	10
Soil - Total & Speciated Polycyclic Aromatic Hydrocarbons (PAH)	27	60	12	10
Soil - Other inorganic substances (e.g. Sulphate, Cyanide etc)	27	60	12	10
Soil - TPH UKCWG	15	51	12	10
Soil - Asbestos ID	26	32	7	5
Soil - Asbestos Quantification	5	13	0	0
Soil - SVOC's	11	37	9	10
Soil - VOC's	11	37	9	10
Soil - Speciated Phenols	12	37	0	0
Soil - Leachate Analysis (Heavy Metals, PAHs etc)	5	7	3	0
Soil - Leachate Analysis (TPH UKCWG)	6	7	3	0
Soil - Leachate Analysis (VOC)	0	7	0	0
Soil - Water Soluble Sulfate & pH	27	17	12	10
Soil - Waste Acceptance Criteria	2	14	2	0
Soil - UKWIR	1	0	0	0
Water - Toxic and phytotoxic metals and metalloids	19	17	1	11

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Water - Total & Speciated Polycyclic Aromatic Hydrocarbons (PAH)	19	17	1	11
Water - TPH UKCWG	19	17	1	11
Water - SVOC's	19	17	1	1
Water - VOC's	19	17	1	11
Water - Speciated Phenols	15	17	1	1

4.2.3 Copies of chemical testing results have been provided within Appendix C.

Geotechnical Testing

4.2.4 A programme of geotechnical laboratory analysis was also completed on soil samples and rock cores obtained during site investigation works. A summary is presented in the table below. Results from geotechnical laboratory testing have been provided within Appendix D.

Table 4.5: Geotechnical Testing Breakdown

Test	Total (Phase 2)	Total (Phase 2e)	NR Mound	Total	Remarks
Unconfined Compressive Strength	15	10	1	26	Detail in Section 10
Point Load Testing	41	22	0	63	Detail in Section 10
PI	5	7	4	16	Detail in Section 10
Moisture Content	13	18	4	35	Earthworks assessment
Particle Size Distribution	2	5	6	13	Earthworks, generally confirms field observations
Sedimentation	0	5	1	6	Earthworks, generally confirms field observations
2.5kg Compaction	0	5	0	5	Earthworks assessment
Consolidation (Oedometer)	0	1	0	1	Detail in Section 10
Triaxial Shear Strength	0	1	0	1	Detail in Section 10

4.3 Investigated Structures

- 4.3.1 The scope of the works also included the investigation of existing structural elements.
- 4.3.2 In NT02 TP08 was undertaken to establish the foundation arrangement to the existing viaduct structure. The trial pit encountered a large footing beneath a relic steel column which sits in front of the viaduct this feature prevented further excavation to reveal the retaining wall foundations.
- 4.3.3 In NT03 MP301 was undertaken to establish the foundation arrangement to the existing viaduct structure. The trial pit encountered a large strip footing extending approximately 900mm from the viaduct.
- 4.3.4 In NT04 TP220 was undertaken to establish the foundation arrangement to the existing viaduct structure. This has shown the structure to be sat on a foundation located 1.40mbgl and founded within underlying stiff clay of the Devensian Till.
- 4.3.5 Sketch drawings of the structural investigations are presented in Drawing 4328-ROC-ZZ-XX-SK-ES-ESK110 and 4328-ROC-ZZ-XX-SK-ESK111 contained within Appendix A. The locations of the works and photographic records are presented on Drawing 4328-ROC-ZZ-XX-DR-ES206.
- 4.3.6 Several investigation and excavations have been undertaken in the Network Rail Mound in NT03, to determine the potential existence of a retaining structure behind the mound. The findings of these works are summarised in a separate report, completed by RoC Consulting in January 2023 (ref. 4328-ROC-ZZ-XX-TN-ES-TN2) enclosed in Appendix J.

5.0 Ground and Groundwater Conditions

- 5.0.1 In the following Sections, the encountered ground and groundwater are described for plots NT02, NT03 and NT04, based on the factual findings of the exploratory holes formed during the LK (2020) and RoC Consulting (2022 and 2023) site investigations and subsequent geological and hydrogeological interpretation. Borehole and trial pit log sheets are provided within Appendix B for a detailed strata description.

5.1 Ground Conditions

Plot NT02

- 5.1.1 In the following, the superficial deposits and the bedrock underneath the Plot NT02 is described; the ground profile is summarised below.

Made Ground

- 5.1.2 Made Ground soils have been encountered across the plot at all exploratory hole locations.
- 5.1.3 In Plot NT02 there is a surface covering of concrete and tarmac within and outside of buildings which is typically underlain by Made Ground of demolition fill type material. Typically, this is a gravelly sand or sandy gravel containing whole and half bricks and chunks of concrete. The gravel fraction of the made ground was predominantly made up of a mixture of brick fragments, slate, clinker, and slag. Other anthropogenic inclusions included wire, metal, glass, plastic, metal pipes and beams, clay pipes, fabric, rubber, and timber. The density of Made Ground was generally reported as medium dense according to SPT N Values and the level of difficulty experienced during hand excavation.

Superficial Deposits: Devensian Till

- 5.1.4 Devensian Till has been encountered in a slight majority of location in NT02, although it is often thin and sometimes comprises granular soils. Most typically Devensian Till was encountered as brown sandy gravelly clay ranging in consistency from very soft to stiff but generally becoming stiff with depth where encountered.

Bedrock Formations: Chester Formation

- 5.1.5 Bedrock of the Chester Formation (CHES) was encountered beneath Devensian Till deposits in all locations in NT02. The upper horizons of the Chester Formation were encountered to be significantly weathered and are effectively sand for up to the first 8m. Deeper horizons of the bedrock also show weaknesses and may be affected by faulting (Section 2.2). Bedrock contour plots displaying the level in mAOD at which weathered bedrock was encountered across the site are presented on 4328-ROC-ZZ-XX-DR-ES-ES204A in Appendix A. The depth of weathered bedrock was determined by a combination of physical description and SPT N values.

Bedrock Formations: Manchester Marls

- 5.1.6 Bedrock of the Manchester Marls (MM) formation was encountered beneath the Chester Formation in all locations where the Chester Formation was penetrated. The MM also shows weaknesses and may be affected by faulting (Section 2.2). 4328-ROC-ZZ-XX-DR-ES-ES204B depicts the surface levels of the MM formation based on borehole logs from across the site. It is evident from the contours on this drawing that

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the MM formation generally dips to the west beneath the site (with some small variations in levels in the western portion of Plot NT04) in line with BGS mapping with the lowest recorded point on site being in the vicinity of RBH502 in the south western portion of Plot NT02 (15.29mAOD).

Table 5.0: Plot NT02 Ground Profile Summary Table – Made Ground and Superficial

	Min. depth to base		Max. depth to base		Av. depth to base		Notes
	m BGL	m AOD	m BGL	m AOD	m BGL	m AOD	
Made Ground	0.30	33.33	3.20	29.41	1.40	31.64	
Devensian Till	2.00	31.29	4.70	27.17	2.98	30.02	Not consistently present

Table 5.1: Plot NT02 Ground Profile Summary Table – Bedrock

Bedrock	Min. depth to top		Max. depth to top		Av. depth to top		Notes
	m BGL	m AOD	m BGL	m AOD	m BGL	m AOD	
Weathered Chester Formation	2.00	31.29	4.50	28.71	2.75	30.19	Predominantly dense sand of Chester Formation
Competent Bedrock – Chester Formation or Manchester Marl	6.00	27.60	15.00	18.20	11.40	21.46	Predominantly sandstone
Manchester Marl	8.06	27.17	18.30	15.29	13.56	19.92	Predominantly mudstone

Plot NT03

5.1.7 In the following, the superficial deposits, and the bedrock underneath the Plot NT03 is described; the ground profile is summarised below.

Made Ground

5.1.8 Made Ground soils were encountered in all exploratory locations in Plot NT03. In Plot NT03 there is a surface covering of concrete and tarmac within and outside of buildings which is typically underlain by Made Ground of demolition fill type material.

Superficial Deposits: River Terrace Deposits

5.1.9 In the location of RBH304, beneath Made Ground, rounded sandy gravel of sandstone, quartzite and siltstone was encountered, from a depth of 3.60m to termination at a depth of 9.45m. These soils are typically of River Terrace or Glaciofluvial Deposits and were not anticipated based on previous records or the published geological record. It is likely that these soils will be encountered during construction and be present at founding depths. Based on in-situ SPT testing, these are generally considered to be highly competent, but will exhibit differing geotechnical characteristics to the majority of the site and may contain groundwater.

5.1.10 The potential distribution of Glaciofluvial Deposits is indicated on Drawing 4328-ROC-ZZ-XX-DR-ES-ES210 in Appendix A. This has been inferred from other nearby borehole locations. It is also feasible these soils may extend into Plot NT04.

Superficial Deposits: Devensian Till

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- 5.1.11 Devensian Till has been encountered in the significant majority of excavations to sufficient depth in NT03. Most typically Devensian Till was encountered as a firm to stiff slightly gravelly slightly sandy clay.

Bedrock Formations: Chester Formation

- 5.1.12 Bedrock of the Chester Formation was encountered beneath Devensian Till deposits in all locations in NT03. As encountered in bedrock across the site, the upper horizons of the Chester Formation are significantly weathered and are effectively sand for up to the first 6m. Deeper horizons of the bedrock also show weaknesses and may be affected by faulting. Bedrock contour plots displaying the level in mAOD at which weathered bedrock was encountered across the site are presented on 4328-ROC-ZZ-XX-DR-ES-ES204 in Appendix A. The depth of weathered bedrock was determined by a combination of physical description and SPT N values.

Bedrock Formations: Manchester Marls Formation

- 5.1.13 Bedrock of the Manchester Marls was encountered beneath the Chester Formation in all locations where this was penetrated. The bedrock also shows weaknesses and may be affected by faulting. Drawing 4328-ROC-ZZ-XX-DR-ES-ES204B in Appendix A depicts the contours of the surface of the MM formation across the plot and levels generally fall to the west from circa 25 to 26m along the boundary with Plot NT04 to circa 20m along the boundary with Plot NT02.

Table 5.2: Plot NT03 Ground Profile – Summary Table - Made Ground and Superficial

	Min. depth to		Max. depth to		Av. depth to		Notes
	m BGL	m AOD	m BGL	m AOD	m BGL	m AOD	
Made Ground	0.20	34.92	3.30	29.05	1.89	31.44	
River Terrace Deposits	19.30	23.77	19.50	23.53	19.40	23.65	
Devensian Till	2.0	31.64	7.80	25.93	3.75	29.61	

Table 5.3: Plot NT03 Ground Profile – Summary Table - Bedrock

Bedrock	Min. depth to top		Max. depth to top		Av. depth to top		Notes
	m BGL	m AOD	m BGL	m AOD	m BGL	m AOD	
Weathered Chester Formation	2.00	30.76	7.80	25.93	3.80	29.36	Predominantly dense sand of Chester Formation
Competent Bedrock – Chester Formation or Manchester Marl	7.50	24.65	13.00	19.76	10.33	22.55	Predominantly sandstone
Manchester Marl	8.80	24.93	13	20.01	10.44	22.45	Predominantly mudstone

Network Rail Mound

- 5.1.14 In the following summary of ground conditions, the made ground, superficial and the bedrock deposits that underly the Network Rail mound located on Plot NT03 is described; the ground profile is summarised in the table overleaf with all depths indicated in meters below existing top of mound level, unless otherwise stated.

NR Mound Made Ground

- 5.1.15 Made Ground was encountered in all locations on top of the Network Rail mound. The mound was surfaced by 6F2 material laid down to create a working platform for the drilling rig during the works. Made ground directly beneath the 6F2 material was generally encountered as a black clayey organic material suspected to contain a large fraction of wood mulch. The gravel fraction included glass, slag, clinker, plastic and brick. Hydrocarbon odours were common throughout this material and pockets of ashy material were also encountered.
- 5.1.16 The mound was cut into circa 2-3m to create the working platform and the material forming the cut largely resembled that described above, in addition some large masonry inclusions were encountered possibly associated with the former signal station that once resided atop the mound.
- 5.1.17 At RBH401 and RBH402 the organic material described above was underlain by a firm gravelly clay containing brick, slate and ceramic with rare clinker and limited bands of granular made ground within the first one to two metres containing ash, slag and clinker. At RBH403 granular material was encountered beneath the organic material containing brick, plastic and glass with frequent metal and fibres, a hydrocarbon odour was also noted. The clay fraction of made ground encountered beneath the mound was generally of a very soft to firm consistency containing brick, slate, occasional glass fragments, ceramic, clinker, coal and various natural lithologies. At RBH403 a slight hydrocarbon odour was reported within the deep made ground between 9.00 and 10.50mbgl. At RBH401 from 7.80 to 9.20mbgl a firm slightly gravelly clay was reported, no anthropogenic inclusions were noted within the clay however it is believed to constitute a reworked clay owing to its low strength and occasional brick inclusions.

NR Mound Superficial Deposits: River Terrace Deposits

- 5.1.18 Natural soils were encountered underlying the cohesive made ground deposits at all 3 exploratory hole locations and were reported as a medium dense gravelly sand becoming silty and less gravelly in areas. The density of these deposits was found to increase with depth eventually becoming very dense. At 16.50 to 18.00mbgl in RBH403 a band of stiff slightly gravelly clay was encountered with granular deposits present both over and underlying.

NR Mound Bedrock Formations: Manchester Marls

- 5.1.19 Bedrock of the Manchester Marls formation was encountered at RBH401 and RBH403 at depths of 19.30 and 19.50mbgl respectively directly underlying the river terrace deposits and was described as an extremely weak reddish-brown mudstone completely weathered to a very stiff clay in places.

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Table 5.4: Network Rail Mound Ground Profile Summary

Superficial Soil	Min. depth to base		Max. depth to base		Av. Depth to base		Notes
	m BGL	m AOD	m BGL	m AOD	m BGL	m AOD	
Made Ground (6F2)	0.20	43.12	0.20	42.83	0.18	42.94	Placed during ramp and working platform formation
Made Ground (Organic Material)	1.00	42.28	3.50	39.52	2.33	40.79	Topsoil like material containing a large proportion of man-made material and suspected wood mulch
Made Ground (Cohesive Material)	9.20	33.87	10.50	32.53	9.97	33.16	Very soft to firm clay with significant gravel content primarily of anthropogenic origin including bricks, glass and slag. Some pockets of granular material in the upper several metres.
River Terrace Deposits	19.30	23.77	19.50	23.53	19.40	23.65	Predominantly sand, silty sand and sandy gravel a band of clay was encountered in RBH403.
Manchester Marls	N/A						Depth to base not proven encountered as stiff clay – extremely weak mudstone at the base of the River Terrace deposits.

Plot NT04

5.1.20 In the following, the superficial deposits and the bedrock underneath the Plot NT04 is described; the ground profile is summarised in the table overleaf.

Made Ground

- 5.1.21 Made Ground soils were encountered in all locations in NT04. The southern part of NT04 is surfaced with a concrete slab while the remainder comprises overgrown vegetation and weeds. Made ground was generally encountered as a gravelly sand or gravelly clay containing clinker, concrete, brick, slag, slate, coal, and ceramics.
- 5.1.22 At TP214 material suggestive of an informal domestic waste landfill was encountered with domestic products such as food containers, plastic, clothing, rubber, rebar, and sheet metal encountered. This material appears to be limited to the immediate vicinity of TP214 and no similar material was encountered in neighbouring exploratory holes.

Superficial Deposits: Devensian Till

- 5.1.23 Devensian Till has been encountered in the significant majority of excavations to sufficient depth in NT04. Most typically Devensian Till was encountered as a stiff brown or blueish grey clay, slightly gravelly in places.

Bedrock Formations: Chester Formation

- 5.1.24 Consistent with geological records, bedrock of the Chester Formation was encountered in only one location at the western edge of NT04, RBH206. As encountered in bedrock across the site, the upper horizons of the Chester Formation are significantly weathered. Bedrock contour plots displaying the level in mAOD at which weathered bedrock was encountered across the site are presented on 4328-ROC-ZZ-XX-DR-ES-ES204 in Appendix A. The depth of weathered bedrock was determined by a combination of physical description and SPT N values.

Bedrock Formations: Manchester Marls

- 5.1.25 Bedrock of the Manchester Marls was encountered in all locations underlying the Devensian Till Deposits and beneath the Chester Formation at RBH206.
- 5.1.26 As encountered in bedrock across the site, the upper horizons of the Manchester Marl are significantly weathered, and often comprise clay or sand in the first 3m and show poor recovery. The bedrock also shows weaknesses at depth and may be affected by faulting. The surface of the Manchester Marl on Plot NT04 is dipping from the east to the north and west. The dip is relatively shallow in the eastern portion of the plot and steepens to the boundary with Plot NT03, generally following the natural topography of the land.

Table 5.5: Plot NT04 Ground Profile Summary Table - Made Ground and Superficial

	Min. depth to base		Max. depth to base		Av. Depth to base		Notes
	m BGL	m AOD	m BGL	m AOD	m BGL	m AOD	
Made Ground	0.60	40.49	9.00	29.38	1.87	35.85	
Devensian Till	4.70	33.88	10.00	23.88	7.48	28.99	

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Table 5.6: Plot NT04 Ground Profile Summary Table - Bedrock

Bedrock	Min. depth to top		Max. depth to top		Av. Depth to top		Notes
	m BGL	m AOD	m BGL	m AOD	m BGL	m AOD	
Chester Formation	7.65	24.35	7.65	24.35	N/A	N/A	Only present at RBH206
Weathered Bedrock (Manchester Marl)	4.70	33.88	10.00	23.88	7.48	28.99	Predominantly clay or weak mudstone
Competent Bedrock (Manchester Marl)	10.20	30.00	15.00	17.88	12.17	25.43	Predominantly mudstone

5.2 Contamination Observations

Plot NT02 – Southern Warehouse

5.2.1 Evidence of a potential source of SVOC or VOC contamination was noted beneath and around the warehouse structure across the Plot NT02 portion of site, potentially relating to former metal fabrication / bolt works operations that were known to have been present in this area. The issue was initially identified during the first phase of RoC Consulting ground investigation works and was the subject of a more detailed targeted programme of investigations during the follow up Phase 2e and Phase 2f investigations. The contamination observations in this location, from across both phases of works, are summarised in the table below.

Table 5.7: Plot NT02 Southern Warehouse Visual and Olfactory Evidence of Contamination

BH ID	Depth		Notes and observations
	mbgl	mAOD	
WS202	1.00	31.05	Strong solvent odours within Devensian Till deposits. Likely associated with historic industry on plot and adjacent to site boundary (Rubber works, foundry, bolt works, signage works)
TP202	0.40	33.20	Hydrocarbon odours within made ground deposits. Likely associated with historic industry on plot and adjacent to site boundary (Rubber works, foundry, bolt works, signage works)
RBH203	2.30	31.29	Strong solvent odours within weathered Chester Formation (Reddish brown sand). Likely associated with historic industry on plot and adjacent to site boundary (Rubber works, foundry, bolt works, signage works)
WS303	0.28	33.32	Hydrocarbon odour likely associated with historic industry on plot and adjacent to site boundary (Rubber works, foundry, bolt works, signage works)
RBH502	1.20 to 1.80	32.59 to 31.79	Hydrocarbon odour likely associated with historic industry on plot and adjacent to site boundary (Rubber works, foundry, bolt works, signage works)

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- 5.2.2 A photoionisation detector (PID) has been used to assess potential volatile organic contamination in soils in this location across multiple stages of investigation and monitoring. While positive detections have been made, these are inconsistent, and are considered to be of lesser relevance for assessment than laboratory testing and subsequent vapour sampling.
- 5.2.3 In addition, as part of these works, a manhole in the centre of the southern warehouse was lifted to determine if this presented a potential source of contamination. A photograph of the chamber is presented below. The chamber has no contents or labelling, and its structure suggests it is a former drain. There was no visual or olfactory evidence of contamination.

Figure 5.0 – Southern warehouse manhole chamber



Plot NT03

- 5.2.5 Olfactory evidence of contamination in Plot NT03 as summarised in the table below.

Table 5.8: Plot NT03 Visual and Olfactory Evidence of Contamination

BH ID	Depth		Notes and observations
	mbgl	mAOD	
WS311	0.10	34.94	Hydrocarbon odour
TP203	0.05	32.19	Strong hydrocarbon odours within made ground deposits. Likely associated with historic industry on plot (foundry, bolt works, asphalt works)
TP309	0.30	33.03	Hydrocarbon odour, potentially associated with plastic jerry can found in soil.

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RBH504	1.40 to 1.90	32.64 to 32.14	Hydrocarbon odour likely associated with historic industry on plot (foundry, bolt works, asphalt works)
	1.90 to 2.40	32.14 to 31.64	Strong hydrocarbon odour and oily sheen likely associated with historic industry on plot (foundry, bolt works, asphalt works)
	2.40 to 2.90	31.64 to 31.14	Slight hydrocarbon odour likely associated with historic industry on plot (foundry, bolt works, asphalt works)
	3.10 to 3.30	30.54 to 30.74	Hydrocarbon odour, black bands and oily sheen likely associated with historic industry on plot (foundry, bolt works, asphalt works).

5.2.6 In addition, it should be noted that Plot NT03 contains aforementioned small mounds of material associated with the former site operator Ryan Topsoil, some of which has been left here for the purpose of maintaining slope integrity. This material is generally poor quality containing a fraction of household waste and plastic and occasional deposits of ash. Logs of these excavations are presented in Appendix B.

Network Rail Mound

5.2.7 Olfactory evidence of contamination within the Network Rail mound as summarised in the table below.

Table 5.9: Plot NT03 Visual and Olfactory Evidence of Contamination

BH ID	Depth		Notes and observations
	mbgl	mAOD	
RBH401	0.20 to 2.50	42.87 to 40.57	Hydrocarbon odour
	2.50 to 3.40	40.57 to 39.67	Hydrocarbon odour
RBH402	0.15 to 1.00	43.12 to 42.28	Hydrocarbon odour
RBH403	2.50 to 3.50	40.53 to 39.53	Hydrocarbon odour
	3.50 to 5.30	39.53 to 37.73	Hydrocarbon odour
	9.00 to 10.50	34.03 to 32.53	Slight hydrocarbon odour

Plot NT04

5.2.7 Olfactory evidence of contamination in Plot NT04 as summarised in the table below.

Table 5.10: Plot NT04 Visual and Olfactory Evidence of Contamination

BH ID	Depth		Notes and observations
	mbgl	mAOD	
TP307	0.50	34.32	Hydrocarbon odour

5.3 Groundwater Conditions

- 5.3.1 Groundwater strikes were observed throughout the site investigation works and records of these are presented in borehole logs in Appendix B. It should be noted that, due to the choice of drilling methods, it was not possible to accurately record the depth of groundwater strikes in rotary drilling locations. Assessment of deep groundwater levels is more accurately made based on the resting water levels recorded during monitoring (presented in Appendix E).

Made Ground (MG)

- 5.3.2 Made ground was encountered at all exploratory hole locations across the site. In **Plot NT02** there is a surface covering of concrete and tarmac within and outside of buildings (approximately 3,000 m²) which is typically underlain by Made Ground of demolition fill type material; mainly granular (gravelly sand or sandy gravel, containing bricks and concrete); gravel is a mixture of brick fragments, slate, clinker, and slag.
- 5.3.3 The density of Made Ground in Plot NT02 was generally reported as medium dense according to SPT N Values and the level of difficulty experienced during hand excavation. The average thickness of the MG is 1.40m (varies from 0.30 to 3.20m).
- 5.3.4 In **Plot NT03** there is a surface covering of concrete and tarmac within and outside of buildings (approximately 4,500 m²), within the former Ryan Topsoil Yard there is a surface covering of hardcore material. Surface coverings present on NT03 are typically underlain by Made Ground of demolition fill type material of similar composition to Plot NT02.
- 5.3.5 The density of Made Ground was generally reported as medium dense according to SPT N Values and the level of difficulty experienced during hand excavation. The average thickness of the MG is 1.89m (varies from 0.20 to 3.30 m).
- 5.3.6 The southern part of **Plot NT04** is surfaced with a limestone gravel (approximately 350m²), while the remainder comprises overgrown vegetation and weeds. Made ground was generally encountered as a gravelly sand or gravelly clay containing clinker, concrete, brick, slag, slate, coal, and ceramics.
- 5.3.7 The density of Made Ground was generally reported as medium dense according to SPT N Values and the level of difficulty experienced during hand excavation. The average thickness of the MG is 1.87m (varies from 0.60 to 9.00 m).

Superficial Deposits: River Terrace Deposits

- 5.3.8 These deposits (not anticipated based on published geology) were encountered beneath the MG in the south of Plot NT03 at four locations (RBH304 and RBH401 to RBH403)
- 5.3.9 At RBH304, River Terrace Deposits were encountered as rounded sandy gravel of sandstone, quartzite and siltstone, from a depth of 3.60m to termination at a depth of 9.45m, similar deposits were also encountered beneath the Network Rail mound from 19.30 to 19.50 mbgl.
- 5.3.10 It is likely that these soils will be encountered during construction and be present at founding depths. Based on in-situ SPT testing, these are generally considered to be highly competent, but will exhibit differing geotechnical characteristics to the majority of the site and may contain groundwater, likely in hydraulic contact with the River Irk. It is also feasible these soils may extend into Plot NT04.

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- 5.3.11 The estimated extents of the encountered River Terrace Deposits is indicated on Drawing 4328-ROC-ZZ-XX-DR-ES-ES210 in Appendix A.
- 5.3.12 Based on its lithology, the hydraulic conductivity of the River Terrace deposits is estimated to be quite variable, between 1×10^{-5} and 1×10^{-1} m/s (Ref. Freeze and Cherry, 1979).

Superficial Deposits: Devensian Till

- 5.3.13 On **Plot NT02** Devensian Till has been encountered in most locations, typically comprising brown sandy gravelly clay ranging in consistency from very soft to stiff but generally becoming stiff with depth. Till has also occasionally been reported as being granular in nature, but this was at a limited number of locations. The average depth to the base of the Till is 2.98m (varies from 2.00 to 4.70m). The density of Till was generally reported as medium dense according to SPT N Values. Based on its lithology, the Till hydraulic conductivity is estimated to be quite variable, between 1×10^{-12} and 1×10^{-6} m/s (Ref. Freeze and Cherry, 1979).
- 5.3.14 On **Plot NT03** Devensian Till has been encountered in the majority of boreholes to sufficient depth. Most typically Devensian Till was encountered as a firm to stiff slightly gravelly slightly sandy clay. Where bedrock was encountered, the average depth to the base of the Till is 3.75m (varies from 2.00 to 7.80m).
- 5.3.15 The density of Till was generally reported as medium dense according to SPT N Values. Based on its lithology, the Till hydraulic conductivity is estimated to be quite variable, between 1×10^{-12} and 1×10^{-6} m/s (Ref. Freeze and Cherry, 1979).
- 5.3.16 On **Plot NT04** Devensian Till has been encountered in the majority of boreholes to sufficient depth. Most typically Devensian Till was encountered as a stiff brown or blueish grey clay, slightly gravelly in places. The average depth to the base of the Till is 7.48m (varies from 4.70 to 10.00 m). The density of Till was generally reported as medium dense according to SPT N Values. Based on its lithology, the Till hydraulic conductivity is estimated to be quite variable, between 1×10^{-12} and 1×10^{-6} m/s (Ref. Freeze and Cherry, 1979).

Bedrock Formations: Chester Formation

- 5.3.17 The Bedrock of the Chester Formation was encountered beneath Devensian Till deposits in all locations in NT02 and NT03, thinning from west to east. In NT04 this formation was encountered only in two locations at the western edge of NT04, RBH206 and WS312.
- 5.3.18 The upper horizons of the CHES were encountered to be significantly weathered and are effectively sand for up to the first 8.00m in NT02 and 6.00m in NT03. Deeper horizons of the bedrock also show weaknesses and may be affected by faulting (Section 2.2). The CHES was proven to 18.30mbgl in Plot NT02 and 13.00m within Plot NT03 at its greatest extent before the bedrock transitions to the MM formation. The thickness of the CHES varies from 13.8m in the southwestern portion of the Plot NT02 to 1.00m in Plot NT03 with the average thickness being 8.69m. The strength of the CHES was generally reported as weak, locally very weak based on results from UCS and point load testing completed during the Phase 2f investigation.

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- 5.3.19 Hydraulic conductivity testing on site in the CHES at RBH203, RBH301, RBH302, RBH303, RBH503 and RBH505 P1 presented in the DQRA report in Appendix I, gave a range between 5.01E-06 to 1.76E-05 m/sec, with a geometric mean of 6.17x10E-06 m/sec or 0.82 m/day. These values lie between reported CONSIM literature values for a solid sandstone of 3x10E-10 and 6x10E-06 m/s and a sand of 1x10E-07 and 6x10E-03 consistent with groundwater flow within a weathered sandstone.

Bedrock Formations: Manchester Marls Formation

- 5.3.20 The Bedrock of the Manchester Marls (MM) was encountered beneath the CHES in all locations drilled to sufficient depth in the west of the site and beneath the River Terrace Deposits in Plot NT03 and Devensian Till in the eastern portion of the site; its full thickness within the site area was not proven by drilling. As encountered in bedrock across the site, the upper horizons of the MM are significantly weathered, and often comprise clay or sand in the first 3m and show poor recovery. The bedrock also shows weaknesses at depth and may be affected by faulting (Section 2.2). The strength of the MM was also found to be extremely weak to weak.
- 5.3.21 Based on its lithology, the hydraulic conductivity of the weathered MM (approximately comparable to a silty sand, thus mainly permeable by porosity) is estimated to be between 1x10E-07 and 1x10E-03 m/s, whilst the conductivity of the competent MM (mainly permeable by fracturing) is estimated to be between 1x10E-10 and 1x10E-07 m/s (Ref. Freeze and Cherry, 1979).

Groundwater Occurrence and Level Monitoring

- 5.3.22 Groundwater strikes were observed throughout the site investigation works and records of these are presented in borehole logs in Appendix B.
- 5.3.23 It should be noted that it was not possible to accurately record the depth of groundwater strikes in rotary drilling locations.
- 5.3.24 The assessment of groundwater levels is more accurately made based on the resting water levels recorded during monitoring events carried out in the period September 2022 to December 2023; these are reported in Appendix E and the hydrograph(s) in chart 5.0, 5.1, 5.2, 5.3 and 5.4 below.
- 5.3.25 Throughout the monitoring period, covering a full hydrological year, the following can be highlighted:
- A single well screened in the Made Ground deposits (WS311) was found to contain groundwater. Groundwater in this location had a hydraulic head varying between 34.64 and 34.51mAOD over a monitoring period from April to August 2023.
 - The hydraulic head of the well screened in RBH304 in the River Terrace Deposits located in the centre south of Plot NT03 ranges from 27.25 (April 2023) to 27.43 mAOD (June 2023), it should be noted however that this well was largely dry and these levels may be attributable to rainfall infiltrating into the well.
 - The hydraulic head of the subsequently installed RBH403 ranges from 29.23 to 29.11mAOD (November 2023). RBH401 which was also installed within the River Terrace Deposits at the same depth and with the same response zone as RBH403 was dry during all visits. The groundwater within RBH403 is therefore likely to be an isolated pocket of groundwater sitting above the low permeability clay encountered at 26.53mAOD in this location which was not encountered at RBH401.

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- The hydraulic head of the wells screened both in the CHES and the MM (only two holes have screens in both formations, LKBH01 and LKBH03) ranges from 26.63 mAOD (LKBH01 nearby the river in the northwest of site, in June 2023) to 27.13 mAOD (LKBH03 in the southwest of the site, in January 2023).
- The hydraulic head of the wells screened in the CHES ranges from 26.44 mAOD (RBH305 nearby the river in the centre-north of Plot NT03, in June 2023) to 27.60 mAOD (RBH302 in the southwest of Plot NT02, in November 2023).
- The hydraulic head of the wells screened in the MM ranges from 25.78 mAOD (RBH205 nearby the river in the north of Plot NT04, in September 2022) to 29.74 mAOD (RBH306 in the centre-east of Plot NT03, in April 2023).

5.3.26 The hydraulic head data have been assembled in five different periods, to represent different rainfall regimes during the year, namely: September 2022 (autumn), December 2022-February 2023 and November to December 2023 (winter) and April-June 2023 (spring) and July to August 2023 (summer); the hydraulic head distribution across the site and the groundwater flow field is described in the following paragraphs.

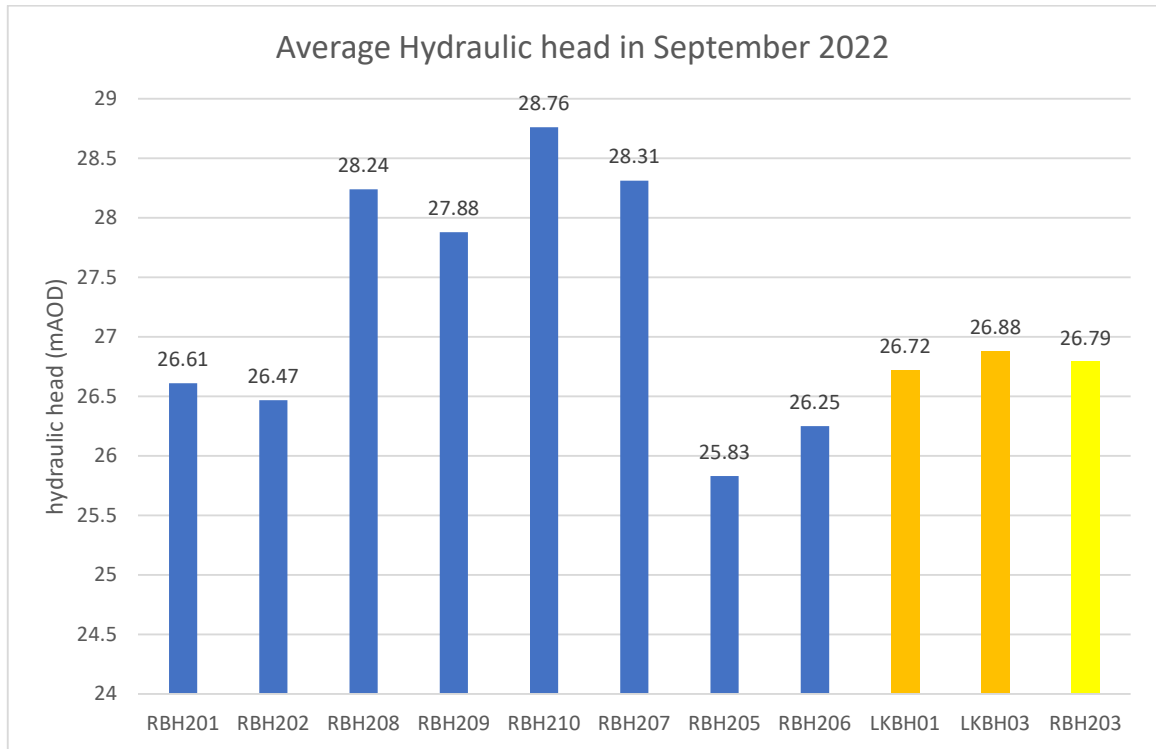
Autumn

5.3.27 The September 2022 monitoring round was carried out mostly in monitoring wells screened in the MM (with only two wells in the CHES & MM, and only one well screened in the CHES); as such, this monitoring round has been taken as representative of the MM average hydraulic head in Autumn. Chart 5.0 below shows the following:

- Boreholes screened in the MM (blue in the chart) located near the river (RBH201, RBH202, RBH205 and RBH206) have the lowest heads, indicating that the groundwater is in hydraulic contact with the river in this area of the site.
- Boreholes screened in the MM (blue in the chart) located in the eastern area of site (RBH207-210) have the highest heads, likely due to the effect of the thickening of the Till towards the east and that, albeit hydraulically connected, the CHES and the MM aquifers have a slightly different piezometry, due to the geological setting of the site and different hydraulic conductivities of the two formations.
- Boreholes screened in the CHES (RBH203, yellow in the chart) and the ones in the CHES & MM (orange in the chart) have heads in-between the two above sets of data, possibly indicating that, albeit hydraulically connected, the CHES and the MM aquifers have a slightly different piezometry, due to the geological setting of the site and different hydraulic conductivities of the two formations.

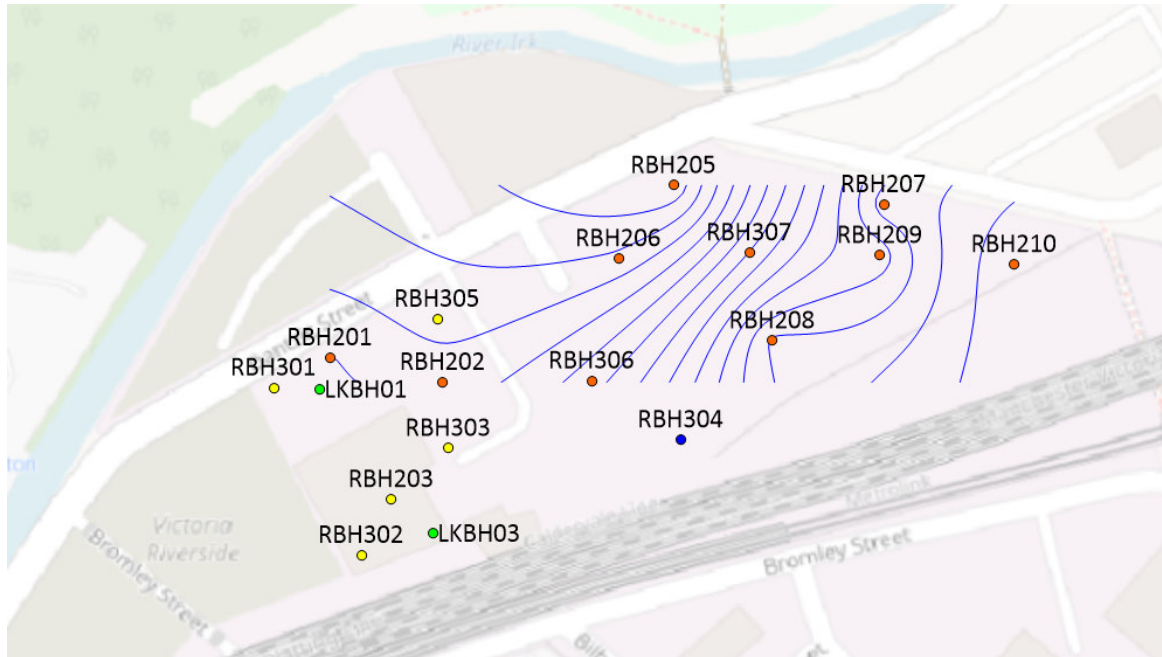
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Chart 5.0 – Average Hydraulic Head September 2022



5.3.28 The September 2022 MM groundwater contour map is presented in Figure 5.1; the piezometry in the MM shows hydraulic heads between 28.76 mAOD at RBH210 to 25.83 mAOD in RBH205 (near the river); the groundwater flow direction is SSE-NNW towards the river, showing a progressive change in direction in the centre of the site to SSW-NNE and a decrease in hydraulic gradient (increase of contours spacing). The groundwater flow field shows that the River Irk is a gaining river, i.e., the MM aquifer is providing baseflow to the river.

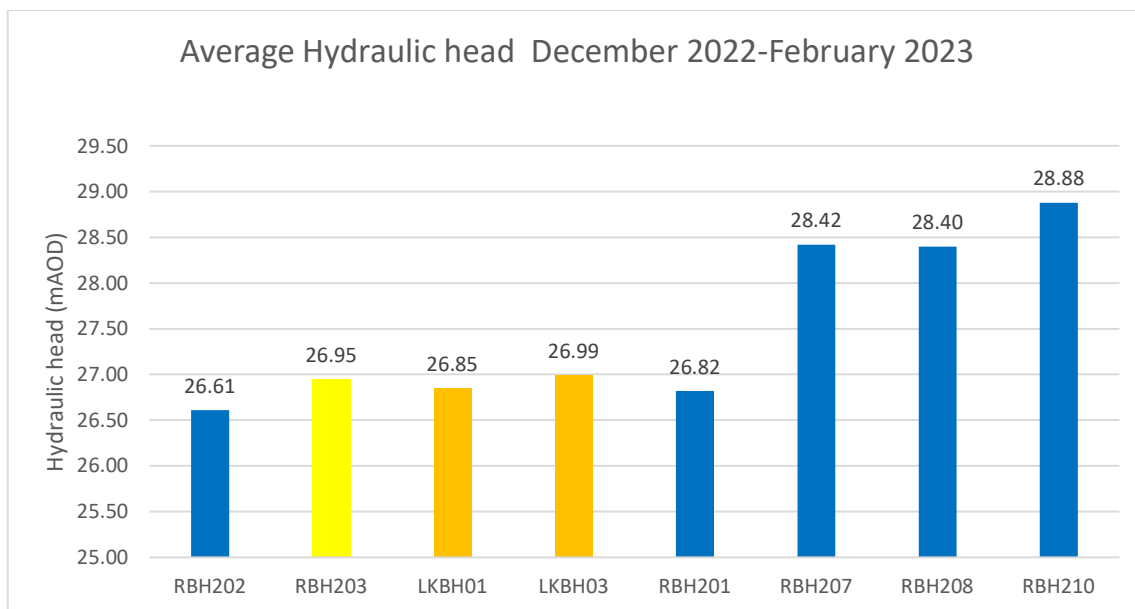
Figure 5.1 – Sept 2022 average hydraulic head in the MM aquifer



Winter

- 5.3.29 The winter (wet season) piezometry is considered to be represented by the average heads in December 2022 and the January and February 2023 monitoring rounds, (illustrated in Chart 5.1 and Figure 5.2) and November to December 2023 (illustrated in Chart 5.2 and Figure 4328-ROC-ZZ-XX-DR-ES-ES205 K) based on the fact that the hydraulic heads of the monitored wells do not show significant differences and that there is no clear relationship with the monthly rainfall, with the only exception of well LKBH03 showing the highest head (27.13mAOD) in January in comparison to those measured in December and February (26.97 and 26.89 mAOD, respectively). However, it should be noted that 1) December has the highest monthly rainfall (96.98mm) in the 30-year climate period 1991-2020, therefore the connection between the heads and the rainfall remains unclear, and 2) the relative differences in the levels are small and not deemed to have a significant impact on the groundwater flow field.

Chart 5.1 – Average Hydraulic Head December 2022 to February 2023

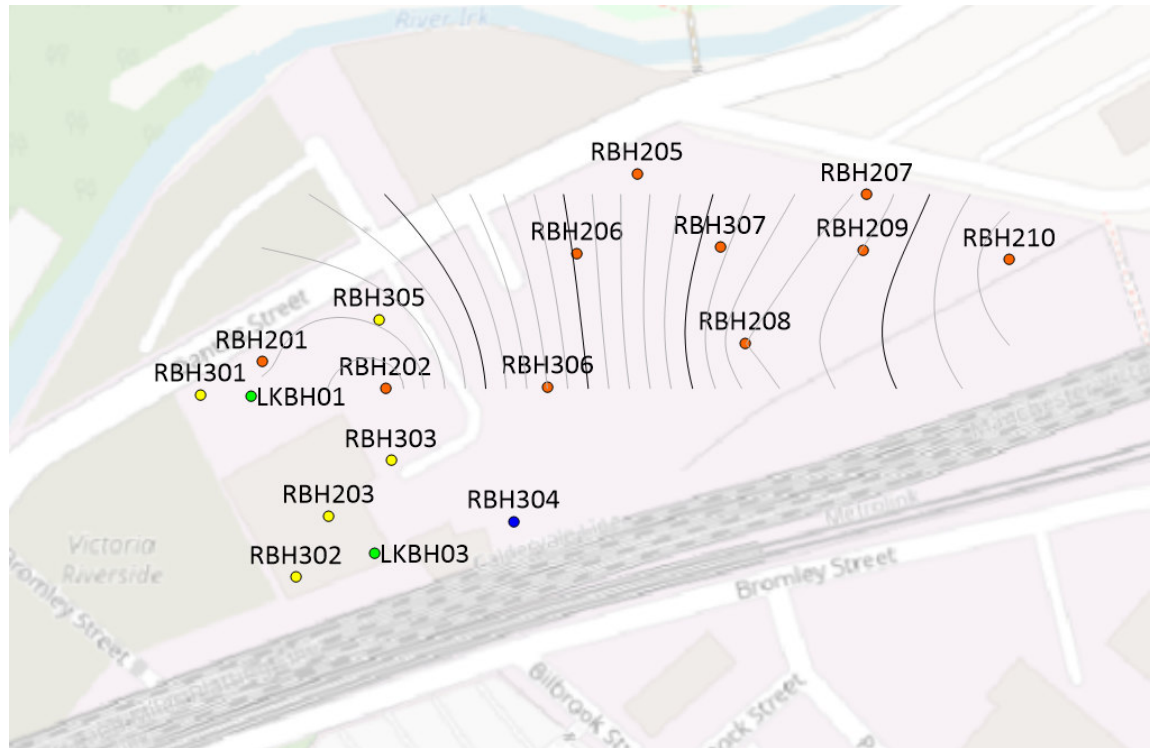


5.3.30 Similarly to September 2022, the December 2022 to February 2023 MM piezometry shows the following:

- RBH201 and RBH202 show the lowest heads, indicating hydraulic connectivity of the MM aquifer with the river
- RBH207-210 show the highest upgradient heads
- Boreholes screened in the CHES (RBH203) and both CHES & MM (LKBH01 and LKBH03) show similar average heads, comparable to the ones in RBH201 and RBH202, suggesting a hydraulic connection of the CHES aquifer with the MM aquifer and the river.

5.3.31 The December 2022 –to February 2023 piezometry groundwater contour map is presented in Figure 5.2; the piezometry in the MM shows hydraulic heads between 28.88 mAOD at RBH210 to 26.61 mAOD in RBH202; the groundwater flow direction is E-W converging to the lowest head in RBH202 and likely further westward towards the river, but the lack of monitoring points does not allow to confirm this. The groundwater flow field shows that the River Irk is a gaining river, i.e., the MM aquifer is providing baseflow to the river.

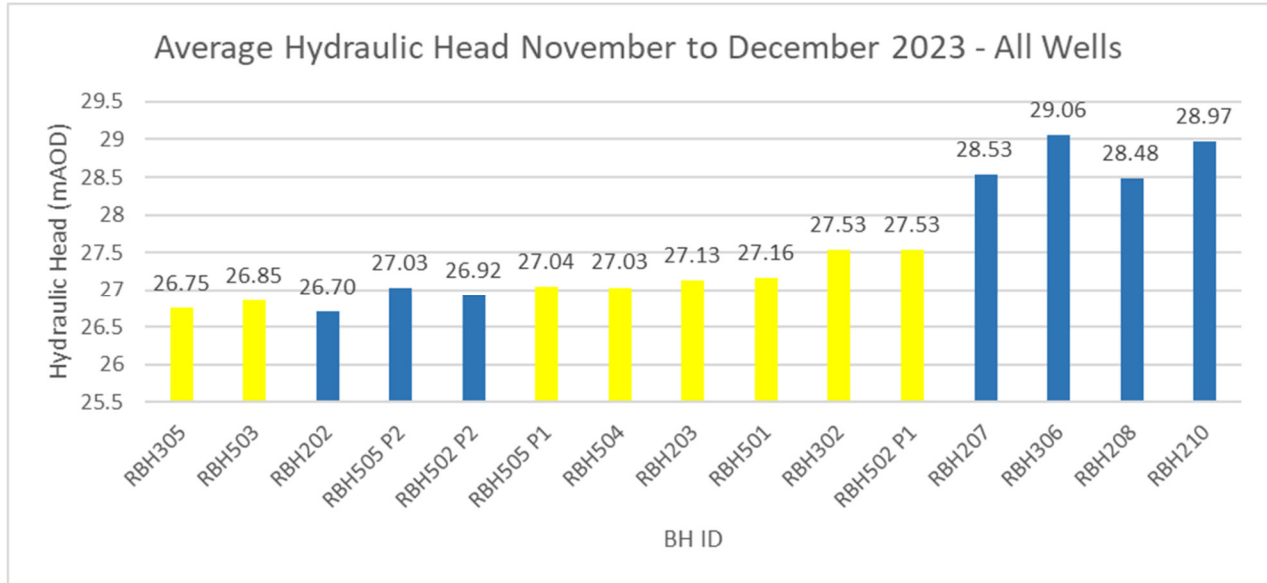
Figure 5.2 – Average Hydraulic Head December 2022 to February 2023 in the MM Aquifer



5.3.32 The November to December 2023 monitoring was completed on several separate monitoring visits from the 13th November until the 12th December and was carried out on a mixture of monitoring wells screened in the CHES & MM including the newly installed 50X series wells; as such, this monitoring round has been taken to be additional evidence of the CHES and MM average hydraulic head in winter. The chart below shows the following:

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Chart 5.3 – Average Hydraulic Head November to December 2023 (All Wells)



- RBH202 installed in the deeper MM at 21.00 to 25.00m bgl shows the lowest head, indicating a likely hydraulic contact of the MM aquifer with the river.
- Average hydraulic heads in wells installed in the CHES generally fall from south to north as shown on groundwater contours for the CHES presented in Figures 4328-ROC-ZZ-XX-DR-ES-ES205 E to H in Appendix A which show a general groundwater flow towards the north-northeast.
- As with the 2022 data RBH207, RBH208, RBH210 and RBH306 show the highest upgradient heads

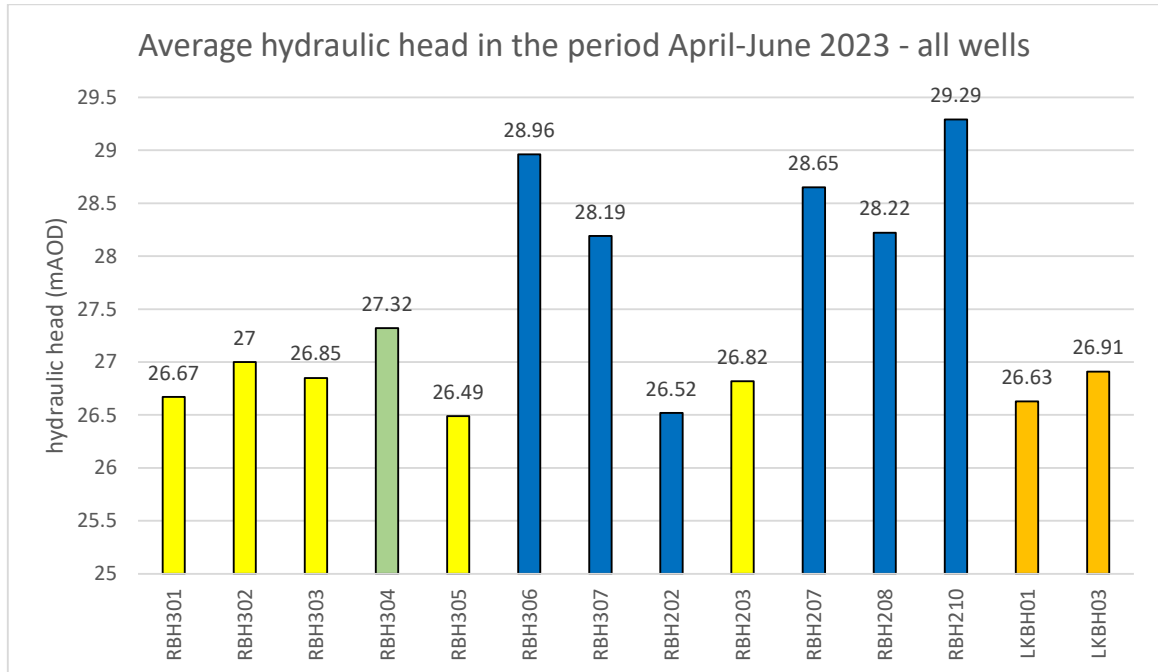
The November 2023 piezometry groundwater contour map for the MM presented in Figure 4328-ROC-ZZ-XX-DR-ES-ES205 K shows a general groundwater flow to the west, consistent with the slope of the MM surface presented in Figure 4328-ROC-ZZ-XX-DR-ES-ES204 B in Appendix A.

Spring

- 5.3.33 The hydraulic heads monitored in the period April-June 2023 can be assumed as representative of the spring season, where the monthly rainfall ranges from 55.81mm (April) to 64.61mm (June). In April 2023, the Phase 2e monitoring wells (RBH3XX series) were constructed and monitored monthly, together with the Phase 2a boreholes (RBH2XX series) and the historic LK boreholes. The Phase 2 GIs holes also included one monitoring well (RBH304) with response zone targeting the River Terrace Deposits. Overall, this monitoring period represents the most complete groundwater level dataset available.
- 5.3.34 The chart in Chart 5.3 below shows the hydraulic head in all the monitoring wells. The heads monitored in the RBH3XX series boreholes show a more pronounced difference in piezometry between the CHES (yellow in chart) and MM (blue in chart) aquifers, with the CHES heads ranging from 26.49 to 27.00 mAOD and the MM heads ranging from 28.19 to 29.29 mAOD, when not including the well RBH202 likely in hydraulic contact with the river. In this respect, the LK wells (orange in the chart) more closely represent the CHES piezometry, with LKBH01 possibly also in contact with the river. This piezometric distribution implies the existence of two laterally connected aquifers with different hydraulic conductivities and hydraulic heads, this fact is reflected by the ground profile beneath the site (Section 5.1).

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Chart 5.4 – Average Hydraulic Head April to June 2023 (All Wells)



Summer

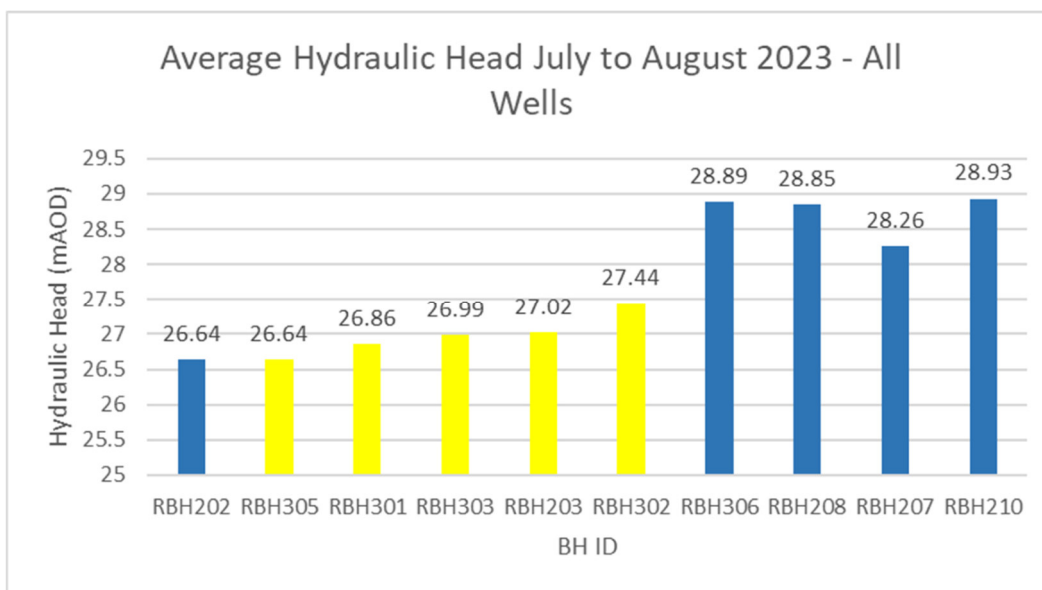
5.3.35 The July to August 2023 monitoring was completed on two separate visits and was carried out in a mixture of monitoring wells screened in the CHES & MM; as such, this monitoring round has been taken as representative of the CHES and MM average hydraulic head in Summer. Chart 5.4 below shows the following:

- Boreholes screened in the MM (blue in the chart) located on Plot NT03 (RBH202) has the lowest head. Boreholes screened in the MM located in the eastern area of site (RBH207, RBH208, RBH210 and RBH306) have the highest heads, likely due to the effect of the thickening of the Till towards the east and that, albeit hydraulically connected, the CHES and the MM aquifers have a different piezometry, due to the geological setting of the site and different hydraulic conductivities of the two formations. Drawing 4328-ROC-ZZ-XX-DR-ES-ES205J provided in Appendix A depicts the groundwater flow contours from the visit undertaken on the 31/08/2023. Generally, the hydraulic gradient appears to be towards the north / northwest in the area of Plot NT04, around the boundary of Plot NT04 and NT03 the predominant flow direction appears to change from north / northwest to west.
- Boreholes screened in the CHES (RBH203, 305, 301, 303 and 302 shown as yellow in the chart) have hydraulic heads within the range of those wells screened within the MM aquifer in the west and east of the site indicating that, albeit hydraulically connected, the CHES and the MM aquifers have a slightly different piezometry, due to the geological setting of the site and different hydraulic conductivities of the two formations.

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- The lowest hydraulic head in the CHES aquifer recorded at RBH305 (26.64mAOD) is located in the north of plot NT03 and the lowest hydraulic head in the MM Aquifer recorded at RBH202 is located in the central western portion of Plot NT03. This would suggest there are two separate presiding flow directions within the two aquifers. The MM aquifer displays a gradient sloping to the west in the area of Plots NT02 and NT03 and the CHES aquifer displaying a gradient sloping to the north / northeast.

Chart 5.5 – Average Hydraulic Head July to August 2023 (All Wells)



5.3.36 The groundwater flow field underneath the site displays the following characteristics:

- The groundwater flow within the MM Aquifer is generally directed from east to west in the direction of flow of the River Irk, in hydraulic contact with both aquifers.
- Contours for the CHES indicate a flow direction towards the north-northeast towards the River Irk located 21m to the north of the site at its closest point.
- The piezometric distribution shows monitoring anomalies at RBH306 (high point located in the centre of Plot NT03) and in the RBH202 / RBH305 area (low point located in northwest of Plot NT03).
- The area between the above piezometric anomalies shows an abrupt increase in the groundwater contour spacing, and associated increase in the hydraulic gradient, which is thought to be the effect of the contact between the two aquifers with different hydraulic conductivities.

5.3.37 Monitoring rounds imply that the groundwaters underneath Plot NT02, where the majority of the leachable and groundwater contamination exceedances have been detected, is fluxed by relatively uncontaminated groundwater from the east under a high hydraulic gradient, with a possible associated dilution of the concentrations.

Aquifer Recharge

- 5.3.38 Recharge can be broadly defined as water that reaches an aquifer from any direction (down, up, or laterally) whilst infiltration refers to water movement from the surface into the subsurface (Scanlon et al., 2002).
- 5.3.39 The groundwater contour maps presented above show that the aquifer/river relationships between the River Irk and the bedrock aquifer are such that the river is a gaining river; as such there is no aquifer recharge from the river into the aquifer. Therefore, we can assume that the aquifer recharge is solely due to the infiltration.
- 5.3.40 For the climate period 1991-2000, the annual rainfall at the Woodford station is estimated to be 864.40mm/year (Section 2.2.2).
- 5.3.41 The UK average evapo-transpiration losses are typically 40%. Approximately 95% of the site is anticipated to be hardstanding and / or covered by buildings in the final development, thus increasing runoff. Based on the site topography, it is feasible for there to be a small quantity of surface water runoff to the northwest in the direction of the River Irk. The remaining area (5%) will be soft cover facilitating widespread infiltration.
- 5.3.42 Based on the above assumptions, the infiltration (aquifer recharge) has been estimated to be approximately 20% of the total rainfall, and therefore ~173 mm/year.

6.0 Contamination Assessment

- 6.0.1 The results from all phases of ground investigations have been used to complete a refined assessment of risks posed by ground contamination and ground stability issues beneath the site, building on the preliminary conceptual site model (CSM) and environmental risk assessment outlined in the Phase 1 Desktop Study. The current assessment considers the above risks both in terms of the site's current arrangement and usage, as well as any potential future development (and associated construction process).
- 6.0.2 The assessment has been collated with reference to various statutory and non-statutory guidance documents relating to land contamination and ground stability. Specifically, the assessment has been conducted in accordance with the Environment Agency Land Contamination Risk Management (LCRM) guidance relating to the "Tier 2 Generic Quantitative Risk assessment" process (revised April 2021).
- 6.0.3 In accordance with this method, a refined Conceptual Site Model has been prepared based on the results of the ground investigations findings. This model is based around the Source / Pathway / Receptor methodology as outlined in Figure 6.0 and detailed in Appendix J.

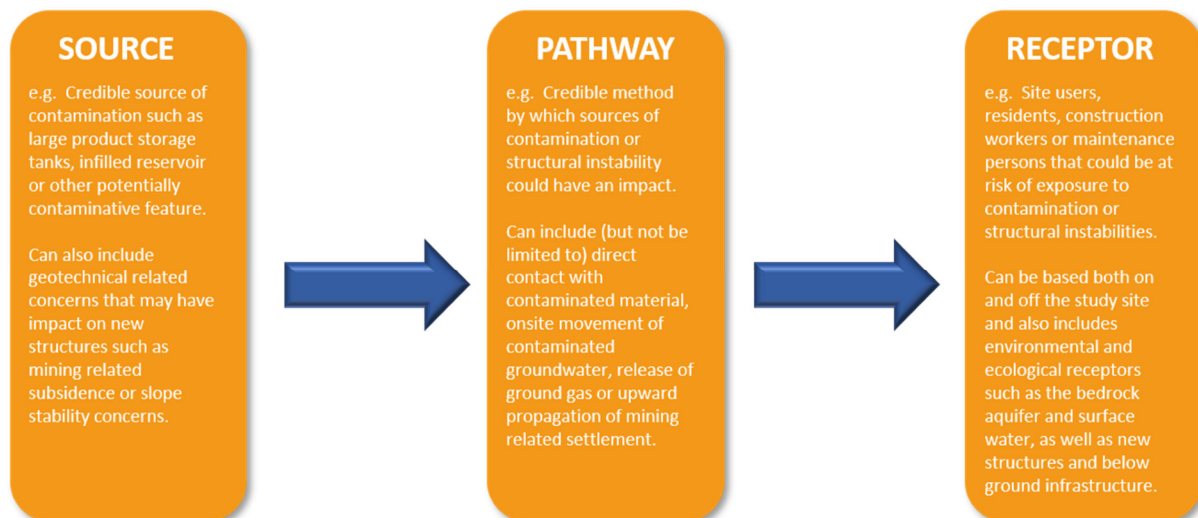


Figure 6.0 Source Pathway Receptor Diagram

6.1 Refinement of the conceptual site model

- 6.1.1 The ground conditions encountered during the investigation generally confirmed the geological succession anticipated in the preliminary conceptual site model (CSM). The majority of the site has a surface covering of concrete and tarmac within and outside of buildings which is typically underlain by Made Ground of granular demolition fill type material, becoming a gravelly clay with depth. Made ground thickness was variable across the site with maximum thicknesses of 3.0 m in Plot NT02, 10.5 m in Plot NT03 and 9.0m in Plot NT04.

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- 6.1.2 Superficial deposits of River Terrace Deposits described as sand or sandy gravel, were encountered in the south of Plot NT03, possibly extending on to the west of Plot NT04 with a thickness of at least 4.8 m and a maximum unproven thickness of 10.1 m in one location. Devensian Till described as a sandy and gravelly clay becoming stiffer with depth, was encountered in all three plots generally thickening west to east with maximum thicknesses of 2.6 m, 4.5 m and 8.2 m in Plots NT02, NT03 and NT04 respectively. The Till was noted to be absent in the west of Plot NT02 where the made ground was directly underlain by bedrock and the south of NT03 where River Terrace Deposits were encountered.
- 6.1.3 In Plot NT02, sandstone bedrock of the Chester Formation (CHES) was encountered beneath Made Ground in the west and Devensian Till deposits in all other locations with a proven thickness of 4.8 m to 13.8 m. In Plot NT03, the CHES was underlain by Till in all locations with the exception of RBH401 and RBH403 located in the southeast where mudstone was found to underly the River Terrace Deposits. The encountered thickness of the CHES in Plot NT03 was 1.0m to 9.3m. The upper horizons of the CHES were encountered to be significantly weathered and are effectively sand for up to the first 6.0 to 8.0 m. Bedrock of the CHES was encountered in only one location at the western edge of NT04 at RBH206 with a thickness of 6.32 m.
- 6.1.4 The Manchester Marls Formation (MM) was proven to underly the CHES to the maximum drilled depth of 25.00 m bgl. On Plot NT04 the MM was found to directly underly the superficial deposits. The MM was found to comprise a reddish brown mudstone with layers of sandstone and siltstone and is shown to dip towards the west of Plot NT02 with the lowest surface elevation recorded at RBH502.
- 6.1.5 The CHES is designated as a Principal aquifer. The nearest down gradient surface water receptor is the River Irk located 21 m to the north of the site and is reported to be of low water quality (Grade E). The Principal aquifer is considered to be the primary controlled waters receptor associated with the site. The primary human health receptors are considered to be current commercial site users and future residents. The Holt Brewery was 533m to the west of the site where water is abstracted from groundwater for use in breweries/wine process water, however the abstraction is not deemed to be at risk as the dominant groundwater flow within the CHES is to the north east away from this receptor.
- 6.1.6 Groundwater monitoring indicates two aquifers underlying the site in the CHES and underlying MM. Groundwater contours indicate that groundwater within the MM flows generally from east to west following the topography of the Manchester Marl and in the direction of flow of the River Irk. Contours for the CHES indicate a flow direction towards the north-northeast towards the River Irk located 21m to the north of the site at its closest point. Whilst there is likely some connectivity between the two aquifers, it is likely that mobile dissolved phase contaminants will migrate predominantly within the high conductivity weathered sandstone of the CHES, a Principal aquifer.
- 6.1.7 Soil and groundwater sampling across the site has identified the following sources:
- Made Ground found to contain elevated heavy metals, PAH and asbestos at locations across all three Plots.
 - Made Ground soils associated with the Network Rail Mound.
 - Diffuse soil contamination by trichloroethene (TCE) in the south of Plot NT02 in the location of the historic bolt works, possibly extending to the east onto Plot NT03.
 - Dissolved phase TCE and its daughter compounds dichloroethane (DCE) and vinyl chloride (VC) in groundwater within the CHES with highest TCE concentrations underlying the soil TCE source in the south of Plot NT02 and extending as a plume to the north across NT02 and the north east into the western area of Plot NT03.

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- Dissolved phase petroleum hydrocarbons and benzene in groundwater within the CHES and underlying shallow MM in the west and north of Plot NT02.

- 6.1.8 TCE is heavier than water and has a relatively low solubility limit and therefore can be present in groundwater as a dense non aqueous phase liquid (DNAPL), however numerous rounds of groundwater monitoring with an interface probe have not encountered any measurable DNAPL thickness. Due to the more cohesive nature of the MM mudstone underlying the CHES, it is likely that any DNAPL present would accumulate on the surface of the MM. Surface contours for the MM presented on figure 4328-ROC-ZZ-XX-DR-ES-ES204B show that the MM dips towards the west with the lowest point recorded at RBH502 located in the southwest of Plot NT02, approximately 20m to the west of RBH203 where the maximum dissolved phase TCE was detected. No evidence of DNAPL was encountered at RBH502 P2 installed within the top of the MM formation with dissolved phase TCE concentrations of 4 µg/l, significantly below the maximum concentration of 572 µg/l recorded at RBH203. The presence of dissolved phase TCE extending in the CHES to the north and east of RBH203 with the highest concentrations of the daughter compounds DCE and VC in the north of Plot NT02 supports the groundwater flow direction from contours based on the more recent and more comprehensive monitoring within the CHES towards the north-northeast.
- 6.1.9 Aliphatic and aromatic hydrocarbon bands C12-C16 and benzene were detected in groundwater samples from RBH502 P1 (CHES) and P2 (shallow MM) located along the southwest boundary of the site. TPH and benzene was also detected in the north of the Plot NT02 site at RBH505 P2 (shallow MM), RBH301 (CHES) and LKBH01 (across CHES and shallow MM), however the profile of the TPH fractions detected in the north of the site differ from those at RBH502 indicating that these contaminants are likely to be from a different source. Historically, the northwest area of Plot NT02 has been the location of industrial buildings and labelled as containing tanks on maps dated late 1940's to early 1950's, associated with either the Collyhurst Foundry or the Rubber Works located immediately west/gas works to the south. It is possible that the source of the benzene plume in this area is located on-site, however, there is negligible concentrations of benzene reported within the unsaturated soils. As such, it is more plausible that the source is located off-site perhaps relating to the historic rubber works to the west which would be consistent with the groundwater flow direction in the sandstone aquifer to the north-northeast.
- 6.1.10 With respect to the distribution of the lower permeability Till deposits noted to overly both the CHES and underlying MM formation, boreholes (namely BH207, BH209, BH208, BH306, BH303, BH203 & BH502 running northeast to southwest through the site) are stated to comprise a predominantly cohesive layer varying between 1.1 and 8.2m (average 4.07m). This Till layer appears to reduce in thickness from northeast to southwest, becoming more granular in nature towards the southwest corner in accordance with the appearance of the CHES, as is also noted in groundwater monitoring results and associated hydrogeological gradients. Corresponding groundwater chemical testing data from wells sealed into the MM across Plot NT04 (upgradient of plot NT02) do not indicate any levels of benzene and lighter TPH fractions (all of which were noted below limits of lab detection). Low levels (below GAC) of mid range TPH aromatic fractions were noted in RBH306 approximately 100m east of RBH502 on Plot NT03 within the MM but no benzene was detected. This lack of evidence of contamination in the upgradient plots and the presence of thicker low permeability Till in Plot NT03 and Plot NT04 upgradient of RBH502 limiting vertical migration into the underlying aquifer reduces the likelihood that the source of the benzene is located to the east of Plot NT02.
- 6.1.11 In addition to the above, the groundwater elevation within the MM suggests that in the west of the site the deeper MM groundwater table is recorded above the upper surface of the MM (resting within the CHES).

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There is the potential that fractured layers of mudstone permitting groundwater flow within the MM are being confined by less fractured/more competent shallower bands of mudstone in the upper reaches of this MM bedrock layer. As such, these more competent shallow mudstone layers are acting to confine the deeper groundwater within the MM, which in turn, would restrict the downward migration of any contamination from the sandstone above.

- 6.1.12 It is noted that it is unusual that the lighter TPH fractions/benzene appear to be primarily within the deeper marl rather than the overlying sandstone which may indicate it is more likely to be due to an off-site source such as the historic rubber works to the west and/or the gas works to the south. This is supported by the distribution of the TCE groundwater plume which is from a known on-site source and which has remained predominantly in the sandstone aquifer and has not significantly penetrated into the marl. Information from Manchester City Council (MCC) planning portal relating to the Gould Street gas works located beyond the railway line and Bromley Street to the south of Plot NT02 reports free phase tar was encountered at depth in the vicinity of the gas holders and tar tanks in the north of the site approximately 50 to 80 m from Plot NT02. Since benzene is likely to form a component of gas works tar, this is considered to be the likely source of the dissolved phase benzene and TPH detected at depth at BH502 P2 in the southwest of Plot NT02.
- 6.1.13 The following pollutant linkages are considered to remain potentially complete and require further assessment by GQRA:
- On site made ground soil contamination (Heavy metals, PAH, TPH and asbestos in made ground and from historic site usage - boltworks) – Current commercial site users and future residential site users - direct contact in areas of public open space – ingestion, dermal, dust/fibre inhalation and ingestion.
 - On-site contamination (VOC in unsaturated soils and from historic site usage - boltworks) – Current commercial site users and future residential site users – inhalation exposure with impacted soil and groundwater.
 - On-site contamination (VOC in unsaturated soils and from historic site usage - boltworks) – adjacent residential, industrial and commercial users – migration of potentially impacted groundwater – inhalation of vapours.
 - On-site contamination (made ground, and from historic site usage - boltworks) - current/future buildings and services - direct contact with contaminated soils or groundwater - chemical attack.
 - On-site contamination (Heavy metals, PAH, TPH, in made ground and VOC in unsaturated soils from historic site usage - boltworks) – Principal and Secondary B aquifers – leaching from soils/ percolation to aquifer/ lateral migration of dissolved phase etc.
 - On-site made ground - ground gas (methane and carbon dioxide) - current/ future site users – commercial / residential users - migration and ingress of ground gases into buildings, build-up in confined spaces and explosion/ asphyxiation
 - On-site made ground - ground gas (methane and carbon dioxide) - current/ future buildings and services - migration and ingress of ground gases into buildings, build-up in confined spaces and explosion
 - Off-site sources of ground gas (methane and carbon dioxide) - current/ future commercial / residential users - migration and ingress of ground gases into buildings, build-up in confined spaces and explosion/ asphyxiation

6.2 Soil Contamination

- 6.1.1 In order to consider the risks posed to human health from soil contamination, a quantitative risk assessment has been completed utilising the latest Environment Agency CLEA methodology. The assessment utilises the chemical testing results obtained during the site investigation fieldworks to characterise site conditions and facilitate the completion of the risk assessment process.
- 6.1.2 The assessment is based on the comparison of soil chemical testing results with published Environment Agency Category Four Screening Levels (C4SL's) under the proposed end use scenario to determine the sites suitability for use. C4SL values represent the highest acceptable values for contaminants within site soils under the proposed end use and are derived using the Environment Agency CLEA risk assessment methodology. A result in exceedance of a C4SL level may indicate the presence of contaminants within site soils and require further assessment.
- 6.1.3 It is noted only a limited number of C4SL values have been derived by the Environment Agency for use, and reference has been made to LQM/CIEH Suitable For Use Values (S4UL's) for a wider range of other contaminants (Heavy Metals, Poly Aromatic Hydrocarbons, TPH, SVOC and VOC's) to increase the depth and robustness of our assessment.
- 6.1.4 Chemical testing results are compared against C4SL and S4UL values for each determinant with any results reported in exceedance of screening criteria identified and their significance reviewed. When determining the significance of any exceedances within the dataset the magnitude and frequency of the exceedance needs to be taken into account, for example, a single exceedance of a screening value may be considered as localised hotspot whereas consistently elevated levels of a substance at multiple locations across the site may indicate a more prevalent contamination issue.
- 6.1.5 In addition to this assessment, an Asbestos Identification test (via the visual inspection method) has been completed on all samples of made ground obtained during the investigation to determine risks posed. Any positive occurrences of Asbestos have been subject to quantification analysis to further assess the extent and significance of risks posed.
- 6.1.6 As required, for each exceedance reference will be made to the Conceptual Site Model to establish the most likely source of contaminants and initial commentary given as to the likely scope of remedial measures. In addition, reference will also be made to the assumptions used to derive generic assessment criteria (C4SL and S4UL values) to determine their comparability with the proposed end use.

Summary and Assessment of Potential Risks Posed by Soil Contamination

- 6.1.7 It is understood that whilst the proposed development is to be surfaced predominantly with hardstanding/building footprint, there are some discrete areas of soft landscaping proposed across the site. While the proposed landscaped areas in Plot NT02 are to comprise small islands of green planting, relatively substantial swathes of communal greenspace are proposed across Plots NT03 and 04. In order to assess the soil contamination concentration results against the appropriate screening criteria, the results have been split into appropriate data sets according to the sample setting within the proposed development plan.

The datasets being considered in the assessment are:

- data set 1 areas beneath hardstanding/building footprint within the proposed development – commercial end use

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- data set 2 areas within soft standing within the proposed development – public open space end use

6.1.8 As an initial assessment, soil results for each data set have been compared against the relevant screening for the proposed end use of the areas of site from which they are derived. Data set 1 has been directly compared against screening criteria for commercial end use, considered most appropriate given the development layout, which is to comprise commercial units at ground level, with high rise residential above. Data set 2 has been directly compared against the screening criteria for public open space (public park), considered most appropriate given that soft landscaped areas are proposed in communal use. The use of both commercial and public open space GACs for the site have been agreed with Manchester City Council and the Environment Agency, correspondence is included in Appendix H.

Data set 1 – commercial end use

6.1.9 Exceedances of contaminants in soils from data set 1 are presented in the tables below, separated into the principal plot areas based on current land uses. Asbestos identifications and quantifications across all plots are summarised in a separate table later in this section.

Table 6.0: Summary of Commercial GAC Exceedances – Plot NT02

BH ID	Depth (m)	Determinants Exceeded and Determinants Reported with No GAC
Phase 2a Site Works		
TP202	0.50	Heavy Metals – Lead (7,660mg/kg), PAH –Benzo(b)fluoranthene (47.8mg/kg), Dibenzo(ah)anthracene (6.23mg/kg)
Phase 2e Site Works		
WS303	1.20	Heavy Metals – Lead (6640mg/kg)
WS308	1.00	VOC – Trichloroethene (1.13mg/kg)
Phase 2f Site Works		
RBH502	1.00	Heavy Metals – Lead (3610mg/kg)

6.1.10 When comparing data set 1 samples to relevant screening criteria, there is evidence of contamination in (unsaturated) soils beneath the southern warehouse within Plot NT02, primarily comprising lead, with PAH exceedances detected within a single position. Generally, there is no clear pattern to the distribution of these contaminants across the Plot, either laterally or with depth, indicating that the source of these contaminants may have arisen as a result of long-term industrial operations on site. There has been a high density of sampling and testing beneath the warehouse as part of a TCE contamination delineation exercise. Whilst soil TCE concentrations were only seen to exceed relevant screening criteria within one location (WS308 at 1.00mbgl) it should be noted that concentrations above the limit of detection were detected within unsaturated soils within almost all exploratory holes positioned beneath the warehouse. It is considered that the source of TCE contamination may be from historical use of lubrication or degreasing agents in bolt making operations and their leakage over time into soils through floor slabs or drainage networks.

- 6.1.11 The distribution of TCE concentrations across the site is indicated in the drawing 4328-ROC-ZZ-XX-DR-ES-ES208, presented in Appendix A, indicating the maximum concentration in each location and locations where it was tested but not detected.

Table 6.1: Summary of Commercial GAC Exceedances – Plot NT03

BH ID	Depth (m)	Determinant/s Exceeded
Phase 2f Site Works		
RBH504	1.50	Heavy Metals – Lead (44100mg/kg)
RBH504	1.90	Heavy Metals – Lead (3020mg/kg)

- 6.1.23 Concentrations of lead within the made ground soils of RBH504 have been determined to exceed relevant screening criteria, additional elevated concentrations of lead were recorded within several other locations across this Plot. The source of lead contamination is likely attributable to a combination of the makeup of the made ground (demolition fill material) and the historic site uses in this area which included a foundry and bolt works.
- 6.1.13 Though no exceedances were observed, elevated PAH concentrations above the limit of detection were recorded at several locations, thought to be associated with ash and clinker that was noted to be in made ground across the area. No contaminant concentration exceedances were observed within soil samples collected from the network rail mound and former Ryan Topsoil Mounds when compared to relevant screening criteria for a commercial end use.

Table 6.2: Summary of Commercial GAC Exceedances Plot NT04

BH ID	Depth (m)	Determinant/s Exceeded
Phase 2 Site Works		
TP216	1.20	Heavy Metals – Lead (12,000mg/kg),
TP218	0.50	Heavy Metals – Lead (1,560mg/kg)
WS209	0.40	Heavy Metals – Lead (18,100mg/kg)

- 6.1.14 Lead contamination again appears to be generally widespread across NT04 within made ground deposits. This is likely attributable to a combination of the makeup of the made ground (demolition fill material) and the historic site uses in this area which included a print works.

Data set 2 – public open space end use

- 6.1.15 Exceedances of contaminants in soils from data set 2 are presented in the tables below for Plots NT03 and NT04 which will contain areas of soft landscaping in the final development. Asbestos identifications and quantifications across all plots are summarised in a separate table later in this section.

Plot NT03

- 6.1.16 When comparing data set 2 samples to screening criteria for a public open space end use, none of the samples from Plot NT03 contained contaminant concentrations exceedances exceeding screening criteria.

Table 6.3: Summary of Public Open Space GAC Exceedances - Plot NT04

BH ID	Depth (m)	Determinant/s Exceeded and Determinants Reported with No GAC
Phase 2a Site Works		
TP214	0.80	Heavy Metals – Lead (3,920mg/kg)
	1.00	Heavy Metals – Lead (19,000mg/kg)
TP217	0.50	Heavy Metals – Lead (8,900mg/kg)
TP219	0.50	Heavy Metals – Lead (1,840mg/kg)

Asbestos

6.1.17 Positive identifications of asbestos have been made across all plots, and where this has occurred, results have been quantified as shown in the table below.

Table 6.4: Positive Identifications of Asbestos by Plot

Location	No. samples tested	No. samples with positive asbestos identification	Asbestos type/form	Asbestos quantification range (%)
Plot NT02	25	10	Chrysotile, amosite, anthophyllite and crocidolite loose fibres	<0.001 - 0.013
Plot NT03	14	5	Amosite and Chrysotile loose insulation/loose fibres Chrysotile cement (visible)	0.002 – 0.007 2.563
Earth stockpiles in former Ryan Topsoil yard	3	0	N/A	N/A
Soils in current Network Rail Mound	13	0	N/A	N/A
Plot NT04	27	3	Chrysotile and amosite loose fibres	<0.001 – 0.007

6.1.18 The majority of positive asbestos samples are located beneath areas of proposed hardstanding/building footprint. Out of 76 samples analysed, 16 returned positive results, equating to just over 20%. Of these 16 positive asbestos samples, all but 1 sample reported a mixture of chrysotile, amosite, anthophyllite and crocidolite loose fibres and loose insulation at quantification levels between <0.001% (below the laboratory limit of detection) and 0.013%. A single sample from TP203 at 1.20m bgl, located within Plot NT03, reported a visible piece of asbestos chrysotile cement with a quantification value of 2.563%.

6.1.19 A lesser number of samples located within areas of proposed soft landscaping were analysed for the presence of asbestos (7 samples) and of these samples, 2 samples returned positive asbestos results, equating to almost 30% of tested samples. Both positive samples reported the presence of chrysotile loose fibres at quantification levels of 0.007% for a sample from Plot NT04 and 0.002% for a sample from

Plot NT03

Soil Vapour

6.1.20 To further assess the risks posed by volatile organic compounds in the location of the southern warehouse, we have undertaken direct testing of soil vapour sampled from three locations. These have been tested by a UKAS accredited laboratory for a suite of Volatile Organic Compounds and results of the testing are presented in Appendix C. In the absence of more established assessment criteria, we have assessed the results to Generic Assessment Criteria (v-GAC) developed internally by RSK for the assessment of indoor human health exposure. A copy of these, explaining their derivation, are presented in Appendix I.

Table 6.5: Summary of Soil Vapour Concentrations

	Residential GAC	Commercial GAC	WS303	WS309	WS301
Benzene (C4SL)	3740	47000	363.2	109	-
Toluene	1580000	47007000	219	250	-
Ethylbenzene	83100	2488000	164.1	54.7	-
Xylenes	62300	1967000	255.8	114	-
Trimethylbenzenes	1900	64000	161	11.8	-
Naphthalene	820	28000	14.6	2.2	-
Vinyl chloride (C4SL)	6500	192000	6.4	-	-
Tetrachloroethene (PCE) (C4SL)	11000	274000	45.4	79.4	-
1,1,1-Trichloroethane	679000	86000	9.8	-	-
Trichloroethene (TCE) (C4SL)	1360	20165000	129726	100265	2393
1,1-dichloroethane	226000	163000	-	7.5	-
1,1-dichloroethene	65000	6720000	19.8	-	-
Chloroethane	3234000	1915000	-	4.7	-
Chloromethane	2900	96011000	-	8.9	-
cis-1,2-dichloroethene	6500	86000	531	250	-
trans-1,2-dichloroethene	19000	4346000	46	30.9	-
Trichloromethane (chloroform)	43000	568000	3722.7	2160	72.3
Highlights indicate exceedance of GACs, all units ug/m3					

6.2 Assessment of Soil Contamination

General

- 6.2.1 Exceedances of human health criteria have been observed in shallow Made Ground across all three plots, predominantly comprising lead, with PAH exceedances at a single location (TP202) at Plot NT02. In addition, a single exceedance of soil TCE concentration was observed in WS208 within the Made Ground beneath the warehouse at Plot NT02. Lead in particular is frequently identified at an elevated concentration at sites with a former industrial land use. The recorded concentrations are typical of Made Ground in previously developed brownfield sites and could be attributable to either the former site activities (including a foundry and bolt works in NT02, iron works in NT03 and print works in NT04), or of demolition fill material.
- 6.2.2 The scheduled laboratory screening for asbestos found detectable asbestos fibres within 18 samples of made ground across all three Plots. However, asbestos was not identified in samples obtained from the earth stockpiles in the former Ryan Topsoil yard or in the Network Rail Mound. Asbestos (at microscopic level) was present as chrysotile, amosite, anthophyllite and crocidolite loose fibres, and chrysotile loose insulation. Subsequent asbestos quantification detected a maximum value of 0.013 % (chrysotile and anthophyllite loose fibres) by weight present in the sample from WS308 at 1.00 m. Visible asbestos in the form of chrysotile cement was identified in TP203 at 1.20m bgl in Plot NT03. The majority of the site is proposed to be surfaced with hardstanding, and in these areas the risk to future site users from ACM within the made ground soils beneath the site is considered to be low due to the absence of a viable pathway. However, where areas of soft standing are proposed, there remains a risk of asbestos exposure to future site users. Where areas of soft standing are proposed, remediation measures will be required, most likely comprising a clean cover system, involving a placement of a minimum of 600 mm of either topsoil/subsoil or suitable compacted gravel is placed over a geotextile separation/marker layer. Appropriate health and safety precautions during the construction phase will need to be incorporated to protect construction workers.

Chlorinated Solvents

- 6.2.3 Following identification during the initial RoC Consulting site investigation of Trichloroethene exceedances in groundwater and limited observations in soils, the supplementary Phase 2e GI works incorporated extensive additional testing of soils beneath the southern warehouse, for the purpose of identifying the potential extents of any contamination plume in this area, or other source. While no specific point source has been observed, the testing has identified widespread Trichloroethene contamination of soils in the south of Plot NT02, extending east into the southwestern area of Plot NT03, including a majority of the Made Ground soils tested in this location.
- 6.2.4 The distribution of these and surrounding testing is such that we cannot yet conclusively delineate the extent of the area of contamination, although potential estimates of the extent, and the exceedances themselves, are shown on Drawing 4328-ROC-ZZ-XX-DR-ES-ES208 in Appendix A. Other Chlorinated Solvents, such as Dichloroethene, Vinyl Chloride and Carbon Tetrachloride have also been detected, albeit less often and at significantly lower concentrations. Generally, these are anticipated to be either related to or daughter products of Trichloroethene and assessment of risks relating to these is

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encompassed in the risk assessment and remedial recommendations below.

- 6.2.5 Chlorinated solvents, such as Trichloroethene (also called Trichloroethylene) and Vinyl Chloride are relatively commonly occurring and remediated contaminants in the UK, particularly in groundwater. They are a category of Volatile Organic Compound containing Chlorine. Typically, Trichloroethene degrades sequentially in the environment to Dichloroethene and Vinyl Chloride, themselves also harmful halocarbons. This is caused by a type of bacteria called Dehalococcoides in specific conditions: typically, anaerobic with low to medium pH.
- 6.2.6 Chlorinated solvents were first widely produced in the 1920s and were used intentionally rather than as by-products of other industrial processes due to their ability to dissolve a large variety of organic compounds in industrial processes.
- 6.2.7 Trichloroethene was extensively used as a dry-cleaning fluid as well as in the chemicals industry and was most widely used as a degreasing agent for metal components.
- 6.2.8 There have been onsite land uses which could potentially have used chlorinated solvents. In particular they might have been used as degreasing agents at **Victoria Screw & Bolt Works / Collyhurst Foundry**. The smithy in NT02 and Scrap Works at NT03 are also potential sources although those works were of a smaller scale. If these compounds were used in significant quantities, it is likely they would have been stored onsite, although below ground storage is considered to be unlikely.
- 6.2.9 While other uses of chlorinated solvents are highly specific, degreasers have a wider variety of applications across a number of industrial land uses, and the local area has an extensive history of industrial development, not all of which will be documented.
- 6.2.10 Drawing upon our assessment of the offsite history, as well as the nearby offsite site investigation reports we have assessed, the likelihood of these originating from offsite sources is assessed in the table below. The assessment has focused on the closest and most intensive recorded historical offsite industrial land uses.

Table 6.6: Assessment of Chlorinated Solvent Source

Land Use	Distance	Likelihood of chlorinated solvent use	Likelihood of affecting the site
Railway viaduct	Adjacent to south	Low – low intensity industrial land use	Very low, less feasible than onsite hypothesis
Rubber Works / Parker Street Mills	5 – 70m west	Moderate – chlorinated solvents were used to clean rubber works machinery and are listed as an associated contaminant by the relevant DOE profile. The previous site investigation did not test for relevant compounds (VOCs) and did not undertake testing of groundwater. Architectural plans of the rubber works do not indicate the presence of a tank, although this is not	Moderate – adjacent to site, spread through groundwater would be perpendicular to hydraulic gradient

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Land Use	Distance	Likelihood of chlorinated solvent use	Likelihood of affecting the site
		unusual. Site development underway and may have resulted in betterment. If further sources of contamination are identified during construction this should be highlighted through validation process.	
Gas Works	10m north	Low – chlorinated solvents are not a core part of gas works operation and would be limited to cleaning operations. Their presence is not indicated by the relevant DOE profile.	Low – limited evidence of presence and spread to site would be against hydraulic gradient
Gas Works	50m south	Low – chlorinated solvents are not a core part of gas works operation and would be limited to cleaning operations. Site has been subject to limited remediation. Their presence is not indicated or suggested by previous site investigations or the relevant DOE profile.	Low – feasible pathway but limited evidence of presence
Gas Works / Chemical Works / Print Works	65 -100m northwest	Moderate – chemical works is associated with a broad range of contaminants	Low – distance from site and spread to site would be against hydraulic gradient
Chemical Works / / Button Manufactory / Metal Foundry / Timber Yard / Engineering Works / Scrap Works	100 – 200m west	Moderate – chemical works is associated with a broad range of contaminants	Low – distance from site and spread to site would be against hydraulic gradient
Union Bridge Iron Works / Chemical Works / Oil Works	160 – 220m west	Moderate – chemical works is associated with a broad range of contaminants	Low – distance from site and spread to site would be against hydraulic gradient
Dye Works	180m northeast	Moderate – dye works is associated with a broad range of contaminants and chlorinated solvents are listed as an associated contaminant by the relevant DOE profile	Low – distance from site and spread to site would be against hydraulic gradient
Gas Works	200m northeast	Low – chlorinated solvents are not a core part of gas works operation and would	Very low – limited evidence of presence, distance from site and

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Land Use	Distance	Likelihood of chlorinated solvent use	Likelihood of affecting the site
		be limited to cleaning operations.	spread to site would be against hydraulic gradient
Potentially unrecorded land uses	N/A	Moderate – relatively widely used compound in mid to late 20 th Century	Difficult to attribute contamination to this source in the absence of positive evidence

- 6.2.11 Having considered potential sources of Trichloroethene arising on and across adjacent sites we are of the view the mostly likely source of any chlorinated solvent contamination will relate to historic Bolt Works located in Plot NT02 and the southwest of Plot NT03.
- 6.2.12 As previously noted, no specific storage tank feature or other potential point source of the Trichloroethene has been noted on site (via review of historical map, aerial imagery or contemporary site observations). As such it is likely the contamination noted beneath the existing warehouse structures on Plot NT02 relates to a diffuse source, arising as a result of the operation of the former Bolt Works and bulk storage of degreasing agents that had the potential to migrate into the underlying soils via cracks or damage to the floor slab or drainage networks (or its storage / use on bare ground).
- 6.2.13 However, the presence of relic below ground storage features cannot be fully precluded at this time owing to the fact the warehouse building is still present on site and partially in operation. As such the presence of relic storage tank features or other concentrated sources of Trichloroethene (such as drums, relic supply infrastructure or grossly TCE impacted waste material) may still be present beneath this portion of the site).
- 6.2.14 The findings of the above have been used to update the Refined Conceptual Site Model (provided within Section 7.0).

6.3 Ground Gas Risk Assessment

- 6.3.1 The Preliminary Conceptual Site model identified made ground as being a potential source of ground gas generation. The site is not said to be located within in an area at risk from Radon gas ingress (Section 2.2).
- 6.3.2 The Scope of Ground Gas monitoring was designed taking in to account the sites previous operations and the proposed site development and structure layout. The ground gas risk assessment has been undertaken in accordance with BS8576-2013 and CIRIA C665. The risk assessment has been founded on the following Conceptual Exposure Model reviewed below in Table 1.

Table 6.7: Ground Gas Conceptual Model

Source	Pathway	Receptor
Site-wide made ground deposits from historic development. Potentially containing ground gasses (CH ₄ , CO ₂ , H ₂ S, CO) and reduced levels of O ₂	Ground Gas migration and entry into buildings via structure defects or construction joints in floor slabs and/or service entry points, resulting in accumulation and explosion/ poisoning/ asphyxiation	Future site/construction workers; Future site employees/occupiers of future buildings

- 6.3.3 It is presumed there will be no considerable change to existing site Ground Gas levels because of the development, and that the proposed structures will undergo traditional construction including a ground bearing floor slab. In addition, it is understood a basement is proposed on Plot NT04 beneath one of the proposed towers. However no other deep below ground structures (outside drainage runs) are proposed beneath the site.
- 6.3.4 Risk Assessment methodology according to CIRIA 665 requires classification of developments as Situation A or Situation B, where Situation B comprises Low rise housing with a ventilated underfloor void and is subject to different assessment methodology. The development is classified as Situation A.

NT02 & NT04

- 6.3.5 A total of 6 visits of Ground Gas monitoring round have been completed the results (Appendix E). A summary of results is reported below:
- Maximum CH₄ Value = 0% volume
 - Maximum CO₂ Value = 13.4% volume (WS204) on 25th August 2022
 - Minimum O₂ Value = 0.6% volume (LK WS103) on 25th October 2022
 - Maximum flow rate = 3.3l/s (LK WS201) on 14th October 2022
 - H₂S and CO values 0ppm for all measurements
 - Variable atmospheric pressures between 992 and 1016Mb
- 6.3.6 Monitoring works were completed during the period between 25th August 2022 to 28th October 2022 under varying atmospheric pressure conditions including falling. The works were completed using a GFM 435 portable gas analyser which was suitably calibrated by the supplier throughout the duration of monitoring works (the calibration certification for which can be provided upon request).

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- 6.3.7 Calibration records for gas monitoring equipment are presented in Appendix F.
- 6.3.8 A standard Ground Gas risk assessment has been undertaken to consider the risks posed to future site users from CO₂ and CH₄. The assessment undertaken followed guidelines in accordance with the principles outlined in the CIRIA guidance document (Assessing risk posed by hazardous ground gases to buildings, CIRIA C665).
- 6.3.9 The method used to categorise the site ground gas regime is covered in the CIRIA C665 document and defines gas concentrations and borehole flow rates to calculate a gas volume flow (Gas Screening Value) and classify a characteristic situation.
- 6.3.10 Gas Screening Values (GSVs) have been calculated using the formula:

$$\text{GSV (l/hr)} = \text{borehole flow rate (l/hr)} \times \text{gas concentration (v / v \%)} / 100$$
- 6.3.11 This calculation has been applied to the maximum Carbon Dioxide and flow rates recorded of the course of monitoring to represent a reasonable worst-case scenario for the entire site. In most cases, ground gas measurements from the site found no change in flow rates which remained at 0.0% for each of the six measurement visits. Where this has occurred a nominal flow rate of 0.1l/hr has been adopted for calculation purposes.

Table 6.8: Summary of GSVs

Monitoring Visit	Highest Flow Rate (l/hr)	Highest CO ₂ (% v / v)	CO ₂ GSV (l/hr)	Characteristic Situation*
Visit 1	0.0	13.4	0.0134	1 (Very Low Risk)
Visit 2	0.0	11.5	0.0115	1 (Very Low Risk)
Visit 3	3.3	11.4	0.3762	2 (Low Risk)
Visit 4	0.0	9.8	0.0098	1 (Very Low Risk)
Visit 5	0.0	8.9	0.0089	1 (Very Low Risk)
Visit 6	0.0	8.5	0.0085	1 (Very Low Risk)

*Where Characteristic Situation 2 < 0.07l/hr

- 6.3.12 In addition to the above, CIRIA665 Table 8.5 also recommends that Characteristic Situation 2 (CS2) is adopted in instances where methane and carbon dioxide concentrations typically exceed the thresholds of 1% and 5% respectively. Given the levels of CO₂ recorded in several of the boreholes on NT02 being above 5% it is recommended that the Characteristic Situation of Plot NT02 alone is upgraded to CS2. On Plot NT04 no such CO₂ concentrations were encountered and therefore Plot NT04 should be classified as CS1.
- 6.3.13 The worst-case scenario for the site corresponds with Characteristic Situation 2 (low risk), with 'typical Made Ground' the likely source of any ground gas generation. The typical scope of ground gas protection measures recommended for Residential uses under this characteristic level, as detailed in CIRIA 665, should include:
- Characteristic situation 2 – Two levels of protection required, typically to include:

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- A reinforced concrete cast in situ floor slab with at least 1200g DPM and underfloor venting.
- Beam and block or pre-cast concrete and 2000g DPM / reinforced gas membrane and underfloor venting.
- All joints and penetrations sealed.

6.3.14 A risk from Volatile Organic Compounds has been identified on Plot NT02. Assessment of this is currently ongoing and it is recommended that the design of gas protection measures is postponed until the risk from vapours originating from VOC contamination has been fully assessed.

Plot NT03

6.3.15 A total of 6 visits of Ground Gas monitoring round have been completed the results (Appendix E). A summary of results is reported below:

- Maximum CH₄ Value = 0.2% volume
- Maximum CO₂ Value = 8.3% volume (WS310) on 31st August 2023
- Minimum O₂ Value = 0% volume (LK WS312) on 11th May 2023
- Maximum flow rate = 0.1l/s (no recorded flow rate during any of the visits).
- H₂S and CO values 1 and 2ppm respectively maximum recorded levels
- Variable atmospheric pressures between 997 and 1024Mb

6.3.16 Monitoring works were completed during the period between 28th April 2023 to 31st August 2023 under varying atmospheric pressure conditions including falling. The works were completed using a GFM 435 and GA5000 portable gas analyser which was suitably calibrated by the supplier throughout the duration of monitoring works.

6.3.17 Calibration records for gas monitoring equipment are presented in Appendix F.

6.3.18 A standard Ground Gas risk assessment has been undertaken to consider the risks posed to future site users from CO₂ and CH₄. The assessment undertaken followed guidelines in accordance with the principles outlined in the CIRIA guidance document (Assessing risk posed by hazardous ground gases to buildings, CIRIA C665).

6.3.19 The method used to categorise the site ground gas regime is covered in the CIRIA C665 document and defines gas concentrations and borehole flow rates to calculate a gas volume flow (Gas Screening Value) and classify a characteristic situation.

6.3.20 Gas Screening Values (GSVs) have been calculated using the formula:

$$\text{GSV (l/hr)} = \text{borehole flow rate (l/hr)} \times \text{gas concentration (v / v \%)} / 100$$

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6.3.21 This calculation has been applied to the maximum Carbon Dioxide and flow rates recorded of the course of monitoring to represent a reasonable worst-case scenario for the entire site. In most cases, ground gas measurements from the site found no change in flow rates which remained at 0.0% for each of the six measurement visits. Where this has occurred a nominal flow rate of 0.1l/hr has been adopted for calculation purposes.

Table 6.9: Summary of GSVs

Monitoring Visit	Highest Flow Rate (l/hr)	Highest CO ₂ (% v / v)	CO ₂ GSV (l/hr)	Characteristic Situation*
Visit 1	0.1	2.5	0.0025	1 (Very Low Risk)
Visit 2	0.1	2.8	0.0028	1 (Very Low Risk)
Visit 3	0.1	3.5	0.0035	1 (Very Low Risk)
Visit 4	0.1	6.7	0.0067	1 (Very Low Risk)
Visit 5	0.1	7.8	0.0078	1 (Very Low Risk)
Visit 6	0.1	8.3	0.0083	1 (Very Low Risk)
*Where Characteristic Situation 2 < 0.07l/hr				

6.3.22 In addition to the above, CIRIA665 Table 8.5 also recommends that Characteristic Situation 2 (CS2) is adopted in instances where methane and carbon dioxide concentrations typically exceed the thresholds of 1% and 5% respectively. Given the levels of CO₂ recorded in several of the boreholes on Plot NT03 being above 5% it is recommended that the Characteristic Situation of is upgraded to CS2.

6.3.23 The worst-case scenario for the site corresponds with Characteristic Situation 2 (low risk), with 'typical Made Ground' the likely source of any ground gas generation. The typical scope of ground gas protection measures recommended for Residential uses under this characteristic level, as detailed in CIRIA 665, should include:

- Characteristic situation 2 – Two levels of protection required, typically to include:
 - A reinforced concrete cast in situ floor slab with at least 1200g DPM and underfloor venting.
 - Beam and block or pre-cast concrete and 2000g DPM / reinforced gas membrane and underfloor venting.
 - All joints and penetrations sealed.

6.4 Controlled Waters

Soils

- 6.4.1 Elevated concentrations of heavy metals, TPH and PAH have been detected in soils across the site, due to the absence of limited thickness of Till, particularly in the west at Plot NT02 and Plot NT03 there is the potential for leaching of contamination from unsaturated soils into the underlying CHES principal aquifer and MM Secondary B aquifer, particularly in areas not covered with buildings or hard standing. i.e. proposed areas of public open space.
- 6.4.2 Additionally, a diffuse TCE source in unsaturated soils has been identified beneath the warehouse in the southern portion of Plot NT02, extending into the southwest of Plot NT03, in an area where historic industrial activities including the bolt works and foundry were located. The leaching potential of the soils was initially investigated in the July 2022 and April 2023 site investigations by the analysis of 12no. soil leachate samples This was later supplemented in subsequent phases of site investigation by groundwater sampling from locations across the site and an additional 3no. soil leachate samples from the Network Rail mound in November 2023.

Soil Leachate

- 6.4.3 A total of 6no. soil samples from the July 2022 investigation and 6no. soil samples from April 2023 from locations across the NT02 and NT04 sites have been submitted for leachate analysis for heavy metals, VOC, PAH, PCBs and hydrocarbons and the results screened against appropriate target concentrations (Drinking Water Standards). An additional 3no. samples were obtained from the Network Rail mound in November 2023 and submitted for leachate analysis as above.
- 6.4.4 The soil leachate results found to exceed the GAC are summarised below.

Table 6.10: Summary of Soil Leachate Testing in Exceedance of GACs

Determinands	DWS (µg/l)	No. of tests	No. of Exceedances	Locations of exceedances and Max. Concentration (µg/l)
Plot NT02				
Arsenic (Leachable)	10	9	4	TP202, WS301, WS307, WS309 (37)
Lead (Leachable)	10	9	2	TP202, WS309 (2970)
Nickel (Leachable)	20	9	1	WS309 (61)
Sulphate (Leachable)	250,000	9	4	TP202 (386,870) , TP203, WS301, WS307
Indeno(1,2,3)pyrene	0.1	9	2	WS202, WS309 (0.18)
Benzo(k)flouranthene	0.1	9	2	RBH203 (0.21) , WS309
Benzo(g,h,i)perylene	0.1	9	1	WS309 (0.18)
Benzo(a)pyrene (Leachable)	0.01	9	3	RBH203 (0.39) , WS202,

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Determinands	DWS (µg/l)	No. of tests	No. of Exceedances	Locations of exceedances and Max. Concentration (µg/l)
				WS309
Benzo(b)fluoranthene (Leachable)	0.1	9	3	RBH203 (0.54) , WS202, WS309
Carbon Tetrachloride	3	4	1	WS302 (4)
Hydrocarbons Aromatic >C10- C12 (Leachable)	90	9	1	RBH203 (9,761)
Hydrocarbons Aromatic >C12- C16 (Leachable)	90	9	3	RBH203 (10,700) , WS202, WS309
Hydrocarbons Aromatic >C16- C21 (Leachable)	90	9	3	RBH203 (3,148) , WS202, WS309
Hydrocarbons Aromatic >C21- C35 (Leachable)	90	9	3	RBH203 (346) , WS202, WS309
Trichloroethene (TCE)	10	4	2	WS302 (69) , WS304
Network Rail Mound				
Arsenic (Leachable)	10	3	2	RBH403 (16) , RBH402
Lead (Leachable)	10	3	2	RBH403 (62) , RBH402
Sulphate (Leachable)	250,000	3	2	RBH403 (480,010) , RBH402
Benzo(a)pyrene	0.01	3	3	RBH402 (0.05) , RBH403
Hydrocarbons Aromatic >C10- C12	90	3	1	RBH403 (108)
Hydrocarbons Aromatic >C12- C16	90	3	1	RBH403 (162)
Hydrocarbons Aromatic >C16- C31	90	3	1	RBH403 (92)
Plot NT04				
Lead (Leachable)	10	3	2	TP214, TP216 (141)
Nickel (Leachable)	20	3	1	TP307 (24)
Sulphate (Leachable)	250,000	3	1	TP307 (647,830)
Notes: Location of maximum concentration for each Plot is shown in bold with the maximum concentration reported in brackets				
For hexachlorobutadiene and vinyl chloride the laboratory detection limit for leachate testing <1µg/l exceeds the DWS, however all test results were reported below the limit of detection				

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- 6.4.5 Leachate testing of the Made Ground soil across the site has shown the potential for the Drinking Water Standards (DWS) to be exceeded in the underlying groundwater particularly at Plot NT02 and below the NR Mound where numerous exceedances were reported for metals/inorganics, PAH and TPH fractions, with TCE present on Plot NT02 but not beneath the NR Mound. The leachate exceedances detected at Plot NT02 are generally confined to the southern area of the site, underlying the warehouse, while all exceedances at plot NT03 have been detected within samples taken from the Network Nail Mound. At plot NT04 lead has exceeded screening criteria for leachate at two locations in the southwest.
- 6.4.6 The current earthworks model for the proposed development (RoC drawing ref RDB/ROC/ZZ/XX/DR/C/0612) predicts that a net cut of c. 37,500m³ will be required to achieve formation levels for the development, indicating that a significant proportion of cut material will be disposed of to landfill.
- 6.4.7 A cut of up to 2.00mbgl is proposed in the area beneath the existing warehouse at Plot NT02, and whilst leachate exceedances were observed at depth of up to 3.00mbgl the made ground in this area (RBH203), the cut would serve to remove a significant portion of the leachate source material. It should also be noted that this area is proposed to be surfaced entirely with hardstanding, which would limit surface water infiltration to the underlying soils, thus reducing the potential for soil leaching to groundwater.
- 6.4.8 A cut of up to 9.00mbgl is proposed within the Network Rail mound. Whilst this would serve to remove the source of leachate exceedances of metals (lead, nickel and arsenic) PAH and TPH at RBH402, which were detected in the made ground at a depth up to 1.50mbgl, exceedances at RBH403 have been detected up to a depth of up to 9.90mbgl. Based on the current earthworks model, a proportion of soils with the potential to exhibit leachate exceedances will remain in situ. Current development plans indicate that the area in the vicinity of BH403 will be surfaced with hardstanding, restricting infiltration and soil leachability.
- 6.4.9 Soils exhibiting leachate exceedances of lead were detected in two discrete areas at TP214 and TP216 at plot NT04, at depths up to 0.80mbgl. TP214 is within a proposed soft landscaping area, and additionally within a proposed fill area according to the earthworks model. With that being said, the concentration of lead leachate at this location reported a relatively marginal exceedance of 12µg/l when compared to the GAC of 10µg/l. Though the lead exceedance within TP216 recorded a more significant exceedance of 141µg/l. The area of TP216 location is proposed to be surfaced with hardstanding which would limit surface water infiltration to the underlying soils, thus reducing the potential for soil leaching to groundwater.
- 6.4.10 The risks to groundwater have been assessed further by direct sampling and testing of groundwater. The results are presented and discussed in the sections below.

Groundwater

- 6.4.11 Prior to sampling, all wells were subject to purging of at least three well volumes to ensure representative levels of contaminants.
- 6.4.12 As the primary controlled waters receptor is the Principal aquifer (Chester Formation), the analytical results for groundwater samples have been assessed against DWS protective of groundwater quality. 45no. groundwater samples (plus three duplicate samples) have been tested from across the site (17no. groundwater samples (plus three duplicate samples from September/October 2022, 3no. groundwater

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samples from January 2023, 13no. groundwater samples from May 2023 and 12no. groundwater samples from November 2023).

6.4.13 The groundwater results found to exceed the GAC are summarised below.

Table 6.11: Summary of Groundwater Testing in Exceedance of GACs

Determinands	DWS (µg/l)	No. of tests	No. of sample Exceedances	Locations of exceedances and Max. Concentration (µg/l)
Plot NT02				
Arsenic	10	24	7	LK BH01, RBH201, RBH301(28) , RBH502
Sulphate	250,000	25	6	RBH201, RBH301, RHB502 P2 (2,370,000) , RBH503
Carbon Tetrachloride	3	24	16	LK BH01, LK BH03, RBH 203 (265) , RBH302, RBH501 P1
Chloroform	100	24	3	RBH203 (195)
Cis 1,2-Dichloroethene	50	24	6	LK BH1 (398) , RBH301, RBH503
Trans 1,2-Dichloroethene	50	24	3	LKBH01 (234)
Vinyl Chloride	0.5	24	6	LKBH01, RBH301, RBH503 (44)
Trichloroethene	10	24	11	LK BH03, RBH203 (572) , RBH501
Benzene (Aromatic Hydrocarbons (C5-C7))	1	24	8	LKBH01, RBH301, RBH502 P2 (385) , RBH503, RBH505
Aliphatic Hydrocarbons (C12-C16)	300	24	2	RH502 P2 (1,080)
Aromatic Hydrocarbons (C12-C16)	90	24	2	RH502 P2 (340)
Plot NT03				
Arsenic	10	13	2	RBH505 P2 (120)
Sulphate	250,000	13	6	RBH306 (515,000) RBH202, RBH504
Nickel	20	13	1	RBH306 (24)
Carbon Tetrachloride	3	13	3	RBH303 (38) , RBH504
Cis 1,2-Dichloroethene	50	13	2	RBH303 (82) , RBH504

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Determinands	DWS (µg/l)	No. of tests	No. of sample Exceedances	Locations of exceedances and Max. Concentration (µg/l)
Trichloroethene	10	10	2	RBH303 (277) , RBH504
Network Rail Mound				
Arsenic	10	1	1	RBH403 (49)
Cadmium	5	1	1	RBH403 (7.1)
Lead	10	1	1	RBH403 (607)
Nickel	20	1	1	RBH403 (102)
Selenium	10	1	1	RBH403 (20)
Benzo(a)pyrene	0.01	1	1	RBH403 (0.23)
Benzo(b)fluoranthene	0.1	1	1	RBH403 (0.29)
Benzo(ghi)perylene	0.1	1	1	RBH403 (0.15)
Benzo(k)fluoranthene	0.1	1	1	RBH403 (0.13)
Indeno(123-cd)pyrene	0.1	1	1	RBH403 (0.15)
Plot NT04				
Sulphate	250,000	11	4	RBH208, RBH209 (414,000)
Arsenic	10	11	1	RBH208 (10)
Manganese	50	2	2	RBH205, RBH206 (58)
Notes: Location of maximum concentration for each Plot is shown in bold with the maximum concentration reported in brackets For hexachlorobutadiene the laboratory detection limit for testing <1µg/l exceeds the DWS, however all test results were reported below the limit of detection Duplicate samples are excluded from sample counts but the highest measured concentration reported between the two samples are reported.				

6.4.14 Recorded Trichloroethene exceedances in groundwater are recorded in the table below; LK BH03 and RBH203 are located in the south of Plot NT02 and RBH303 is located in Plot NT03 approximately 5m from the boundary with Plot NT02 and approximately 20m to the northeast of LK BH03 and RBH203.

Table 6.12: TCE Exceedances in Groundwater

Date	LKRBH03	RBH203	RBH303	GAC
27/09/2022	-	480	-	10
04/10/2022	250	572	-	
19/01/2023	80	418	-	
04/05/2023	43	214	277	
10/05/2023	39	200	221	

- 6.4.15 Recorded concentrations of TCE and other chlorinated VOC reported to exceed the DWS are shown on figure 4328-ROC-ZZ-XX-DR-ES-ES209A and TPH and benzene concentrations in groundwater are presented in figure 4328-ROC-ZZ-XX-DR-ES-ES209B.

Plot NT02

- 6.4.16 Screening of groundwater results from wells installed within the Chester Formation in Plot NT02 has consistently recorded elevated concentrations of Trichloroethene (TCE) significantly above the DWS. These have been limited to the southern area of Plot NT02 in the vicinity of the southern warehouse at LKRBH03, RBH203, RBH303 and RBH501, with the highest concentration at RBH203.
- 6.4.17 As well as spatially assessing the elevated concentrations of TCE in groundwater, temporal variations in TCE concentrations have also been assessed. The highest concentration of TCE (572 µg/l), reported in RBH203, was detected in a groundwater sample taken during the second sampling event in October 2022. It can be said that the concentration of TCE generally decreases during the subsequent four sampling events with a value of 215 µg/l reported in the most recent sampling event (November 2023). This is also the case with the other two boreholes where elevated concentrations of TCE have been detected; RBH303 and LKBH03, although there are less sampling events to consider. Concentrations in RBH303 reduce from 277 µg/l reported in sampling event dated 4th May 2023 to 221 µg/l in sampling event dated 10th May 2023 (two sampling events). Concentration in LKBH03 reduce from 250 µg/l reported in sampling event dated 4th October 2022 to 39 µg/l reported in sampling event dated 10th May 2023 (four sampling events).
- 6.4.18 The reason for the general decrease in TCE groundwater concentrations is considered inconclusive at this stage but a number of factors that could be causing the variations observed. There does not appear to be a correlation between variations in groundwater elevations and the concentration of TCE. Groundwater elevations do not appear to change significantly between sampling events; there are slight seasonal variations as would be expected, particularly in RBH203 where groundwater elevations increase marginally in the Autumn. However, there is no conclusive data that suggests this slight increase in groundwater elevation relates to the decrease in TCE concentration. Another consideration is the effect of variations in sampling depth within the water column. Samples obtained in September and October 2022, particularly from LKBH03 and RBH203, were sampled from deeper within the water column at depths of between 10.00 and 13.00m bgl. These sampling events recorded the highest concentrations of TCE.
- 6.4.19 During the following sampling events in January and May 2023, groundwater samples were obtained from shallower depths within the water column at 7.40m and 7.60m bgl, and concentrations of TCE had significantly decreased. Higher concentrations recorded when sampling from deeper in the water column could be observed since TCE may migrate towards the bottom of the water column due to its higher density than water when in free phase form (DNAPL), although it is noted that no DNAPL was detected during any of the monitoring rounds by the interface probe and the maximum measured TCE concentration recorded at the site of 0.572mg/l is two orders of magnitude less than 1% of the solubility limit for TCE (water solubility limit 1000mg/l, from Russell et al. 1992, 1% equals 10mg/l). Due to the uncertainty around the impact of varying sample depth, there is a possibility of higher dissolved phase concentrations being present beneath the site have not been taken into account.

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- 6.4.10 The implications of this are discussed further in the DQRA report and in Section 7.1 Uncertainties. Another possible factor in the trend observed could be related to the performance of well development prior to sampling and whether the wells had been sufficiently developed to clear any settled silt that may have built up over time. Inadequate well development may have allowed impacted silts within the water column to build up, resulting in an unrepresentative TCE concentration within the wider aquifer.
- 6.4.11 Groundwater testing has also identified several other contaminants of note exceeding the DWS in Plot NT02 namely Arsenic and sulphate in the shallow and deep sandstone in the north of the site (routinely encountered in groundwater at brownfield sites) and several other VOC, namely carbon tetrachloride and chloroform predominantly in the shallow sandstone in the south of the site, and benzene and TCE daughter compounds cis-1,2-dichloroethene, trans 1,2-dichloroethene, vinyl chloride were reported to exceed the DWS in the CHES in the north of the site.
- 6.4.12 The presence of TCE daughter compounds in the shallow sandstone at LK BH01 and RBH301 in the north of Plot NT02 and at RBH503 in NT03 supports the updated groundwater contours for the CHES which indicate a flow direction towards the north-northeast in this area of the site as shown on groundwater contours on Drawing 4328-ROC-ZZ-XX-DR-ES-ES205 E-J in Appendix A. Groundwater samples also report some migration of chlorinated VOC into the deeper sandstone and top of the MM at RBH502 P2, RBH505 P2, RBH201 and RBH305, however concentrations detected are significantly lower than those reported in the CHES indicating migration of chlorinated VOC is primarily occurring in the higher permeable CHES formation.
- 6.4.13 Benzene exceedances are reported in groundwater in the CHES and the MM in the north of Plot NT02 and TPH fractions aliphatic and aromatic C12-C16 and benzene are reported to exceed the DWS in the southwest of the site. As discussed in Section 6.1 based on the profile of the TPH fractions there appears to be two distinct sources of TPH and benzene at the site and both are considered most likely to have migrated onto site from off-site sources to the west and south. Since the majority of the benzene contamination is in the deeper marl (secondary B aquifer) and not in the overlying principal sandstone aquifer and since it is most likely due to an off-site source, benzene is not considered to be a primary risk driver for site remediation.
- 6.4.14 It is noted that the metals, PAH compounds and TPH fractions detected in leachate testing and the other SVOC detected in soils testing were not reported at concentrations exceeding the GAC in groundwater, likely due to degradation in the unsaturated zone given and/or more preferential sorption to soils.

Plot NT03

- 6.4.15 TCE, carbon tetrachloride and cis-1,2-dichloroethene were reported to exceed the DWS in shallow sandstone at RBH303 and RBH503 located close to the western site boundary with Plot NT02. TCE was also detected in unsaturated soils at RBH504 with a maximum concentration of 49 µg/kg at 1.5m bgl, confirming the soil TCE source extends into the southwest of Plot NT03 within the footprint of the historic boltworks. TCE daughter compounds DCE and VC were also detected exceeding the DWS further down hydraulic gradient to the north of Plot NT03 within the CHES at RBH503. Low concentrations of TCE were also detected in the deeper CHES at RBH305 and in the MM at RBH202 in the north of Plot NT03. The contaminant distribution confirms that the majority of the TCE groundwater plume is migrating within the weathered shallow CHES rather than migrating vertically into the deep sandstone and underlying MM.

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- 6.4.16 Due to their localised nature and concentrations reported at the same order of magnitude as the DWS the reported exceedances for sulphate, manganese and nickel are not considered to pose a significant risk to the wider groundwater quality.

Network Rail Mound

- 6.4.17 A number of metal and PAH compounds were reported to exceed DWS within the River Terrace Deposits beneath the Network Rail Mound at RBH403. The most significant exceedance was lead which is 60 times in exceedance of the DWS. However, due to the localised nature of these exceedances within the River Terrace deposits and concentrations generally being of the same order of magnitude as the DWS, these exceedances are not considered to pose a significant risk to the wider groundwater quality.

Plot NT04

- 6.4.18 Localised exceedances of the DWS for sulphate, manganese and nickel are reported at concentrations of the same order of magnitude as the DWS and are not considered to pose a significant risk to the wider groundwater quality within the underlying Manchester Marl. Thus, risks to controlled waters at Plot NT04 are considered to be low.

Surface Water

- 6.4.19 As a further line of evidence, due to the presence of River Irk in close proximity to the site, samples of the surface water have been collected to provide a direct assessment of the water quality.
- 6.4.20 Two surface water samples, namely SS301 and SS304, were collected downstream and upstream of the site respectively, in May and June 2023.
- 6.4.21 Some of the analytical results for surface water samples are above the relevant GAC protective of surface water receptors indicating possible impact to the surface water body. The exceedances are shown in the table below.

Table 6.13: Summary of Surface Water Testing in Exceedance of GACs

Determinands	EQS (µg/l)	No. of Exceedances	Upstream sample (SS304)	Downstream sample (SS301)
Copper	1	1	4	<4
Nickel	4	1	<2	4
Zinc	10.9	2	18	25

- 6.4.22 For certain analytical compounds, as listed in the table below, the laboratory limit of detection exceeds the relevant GAC. In these instances, measured concentrations may exceed the EQS GAC, but equally the concentrations may fall below the GAC.

Table 6.14: Summary of Groundwater Testing Where LOD is greater than the GAC

Determinands	Limits of Detection (µg/l)	EQS (µg/l)	Upstream Sample (SS304)	Downstream Sample (SS301)
Mercury	<0.1	0.07	<0.1	<0.1
1,2,3-Trichlorobenzene	<3	0.4	<3	<3
1,2,4-Trichlorobenzene	<1	0.4	<1	<1
Hexachlorobutadiene	<1	0.6	<1	<1
Benzo(a)pyrene	<0.01	0.00017	<0.01	<0.01
Fluoranthene	<0.01	0.0063	<0.01	<0.01
Bis(2-ethylhexyl) phthalate	<10	1.3	<10	<10
Pentachlorophenol	<1	0.4	<1	<1
Phenol	<10	7.7		<10

- 6.4.23 It is evident from the table above that concentrations of nickel and zinc increase as they move from upstream to downstream passed the site. With respect to nickel, the concentration doubles from <2 µg/l to 4 µg/l towards the downstream sampling location where it exceeds the GAC. Zinc already exceeds the GAC on the upstream side of the site but further increases as it flows passed the site. Copper is reported to be relatively consistent at both the upstream and downstream locations.
- 6.4.24 It should be noted that there is an industrial site (Preservation Paints Ltd) located immediately adjacent to the River Irk, approximately 400m upstream. Several land parcels that have been historically used for industrial purposes in the recent past and a site in between Plots NT02-NT04 and the River Irk that could have historically or are currently contributing to the contamination status of the River Irk.
- 6.4.25 The reported exceedances of the EQS found in surface water, particularly nickel, were reported as a compound exceeding the DWS in groundwater. Copper and Zinc were not reported as exceeding the DWS in groundwater. Trichloroethene was of particular concern within soil leachate and groundwater samples, however, detectable concentrations above the laboratory limit of detection have not been reported in either the upstream or downstream surface water samples.
- 6.4.26 As exceedances include copper, nickel and zinc, further assessment has been undertaken using the UKTAG Metal Bioavailability Tool (M-BAT) approach. The tool has been used to calculate the site-specific predicted no effect concentrations (PNEC) for these compounds.
- 6.4.27 Laboratory results have then been compared with the PNEC. The regional background concentration of zinc of 2.9 µg/l has been subtracted from the exceedances.

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- 6.4.28 The analytical results for surface waters are below the PNEC indicating that concentrations of copper, nickel and zinc recorded in groundwater have not currently resulted in the presence of unacceptable concentrations of determinants within the adjacent surface water.

Contaminants of Concern for Controlled Waters DQRA

- 6.4.29 The primary aim of the Generic Controlled Waters Risk Assessment (GQRA) is to provide an initial screen, through the comparison of soil leachate and groundwater laboratory results to generic assessment criteria (DWS and/or EQS), to identify the Contaminants of Concern (CoCs) that could potentially pose a risk to controlled waters.
- 6.4.30 Once this initial (Tier 1) screen has been completed, the assessment of risk posed by the CoC is further refined through a Detailed Quantitative Risk Assessment (DQRA). Prior to the DQRA, and in accordance with the Part 2A regime, CoC exceeding the generic screening criteria are subject to a further process of refinement to avoid unnecessary detailed assessment of CoCs; as such, CoCs meeting the following criteria, are not taken forward to modelling:
- Marginally exceeding their GACs
 - Reflective of natural background concentrations; and,
 - Isolated and infrequent.

- 6.4.31 In this instance, the primary receptors for on-site groundwater or leachate contamination are as follows:-

- 1) Chester Triassic Sandstone bedrock formation (classed as a Principal Aquifer)
- 2) Manchester Marls calcareous Mudstone & Siltstone formation (Secondary B aquifer)
- 3) Surface water course the River Irk (located 20m from site at its closest point)

- 6.4.32 Following the GQRA assessment of controlled waters as outlined in the current section, the priority contaminants of concern that are being considered to be taken forward to the DQRA are as follows:

Plot NT02

- TCE, carbon tetrachloride, cis and trans-1,2-dichloroethene and vinyl chloride.
- Due to the localised nature of the chloroform DWS exceedances at RBH203 in the south of the site and the absence of exceedances at the down gradient site boundary in the north of the site with concentrations two orders of magnitude below the DWS, chloroform was not taken forward to DQRA.
- Since no clear source has been identified for the benzene detected close to the northern site boundary at Plot NT02 and the TPH and benzene source in the MM detected at RBH502 P2 in the southwest of the site and the likelihood that these contaminants are due to an off-site sources, benzene has not be proposed to take forward for DQRA, Chlorinated solvents are considered the primary risk driver for the site.

Plot NT03

- The primary contaminants of concern for controlled waters at Plot NT03 are TCE, carbon tetrachloride and cis-1,2-dichloroethene detected in groundwater close to the western boundary with Plot NT02. These contaminants will be considered within the proposed DQRA for Plot NT02.

Plot NT04

- None required
- 6.4.33 The above Coc's are based on the results from our initial screening assessment. These results indicate that the groundwater table and leachate potential beneath Plot NT02 is the most significantly impacted as a result of former site operations. This is to be expected given the previously discussed soil sources of contamination noted in this area as a result of former industrial activity and we are minded to recommend these substances are taken forward to the DQRA modelling stage to further assess risks posed and inform likely scope of remedial measures to redress.
- 6.4.34 Across Plots NT03 and 04 evidence of groundwater impacts from the adjacent Plot NT02 are not as pronounced, with Coc's associated with sulphate, manganese and lead noted. With respect to lead, this is a very environmentally persistent substance, and it is unlikely DQRA assessment would show a significant variation in levels as it flows through the water table into the aquifers or nearby water course. As such we are minded to exclude these substances from modelling works and instead specify remedial clean up target concentrations based on established Human Health screening values for the intended end use scenario.

6.5 Below Ground Concrete Construction

Plot NT02

- 6.5.1 Peak potential sulphate concentrations range between 10 and 1470mg/l with soil pH values ranging between 7.16 and 10.56 providing a characteristic pH of 7.62 and a characteristic sulphate of 940mg/l. Based on these results, it is considered that well compacted buried concrete should be designed in accordance with Class DS-2 AC-1s requirements as specified in BRE Digest Special Digest 1:2005 *Concrete in aggressive ground: Version 3*.

Plot NT03

- 6.5.2 Peak potential sulphate concentrations range between 22 and 1740mg/l with soil pH values ranging between 7.64 and 9.4 providing a characteristic pH of 7.8 and a characteristic sulphate of 1490mg/l. Based on these results, it is considered that well compacted buried concrete should be designed in accordance with Class DS-2 AC-1s requirements as specified in BRE Digest Special Digest 1:2005 *Concrete in aggressive ground: Version 3*. It should be noted that in a groundwater sample obtained from WS311 within made ground deposits a water soluble sulphate concentration of 2,650mg/l was reported. This would equate to DS-3 and it is recommended any concrete in contact with the water body in this area of the site match this specification.

Network Rail Mound

- 6.5.3 Peak potential sulphate concentrations range between 28 and 1450mg/l with soil pH values ranging between 7.86 and 8.67 providing a characteristic pH of 7.875 and a characteristic sulphate of 1435mg/l. Based on these results, it is considered that well compacted buried concrete should be designed in accordance with Class DS-2 AC-1s requirements as specified in BRE Digest Special Digest 1:2005 *Concrete in aggressive ground: Version 3*.

Plot NT04

- 6.5.4 Peak potential sulphate concentrations range between 10 and 504mg/l with soil pH values ranging between 6.78 and 9.30 providing a characteristic pH of 7.38 and characteristic sulphate of 405mg/l. Based on these results, it is considered that well compacted buried concrete should be designed in accordance with Class DS-1 AC1s requirements as specified in BRE Digest Special Digest 1:2005 *Concrete in aggressive ground: Version 3*.

6.7 Detailed Quantitative Risk Assessment

- 6.7.1 Following completion of the Generic Risk Assessment, and as noted in Section 6.4, a number of contaminants of concern were identified to be taken forward to Detailed Quantitative Assessment stage to further assess risks to controlled waters. The purpose of this assessment will be to further consider the potential impacts that may arise from the TCE contamination plume noted to the southwest on the Principal Bedrock aquifer and off-site receptors.

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6.7.2 The modelling assessment has been provided as a stand-alone report (ref: 11847 R01 (01)) included within Appendix I and should be reviewed in tandem with current assessment. The DQRA modelling assessment has identified the following headline conclusions.

- 1) The results from the soil leaching and dissolved phase assessments indicate that predicted concentrations of TCE, DCE, VC and carbon tetrachloride at a theoretical compliance point 50 m down gradient of the site exceed the target concentrations.
- 2) Therefore, a pollutant linkage is considered to exist between the VOC soil source and dissolved phase plume extending beneath Plot NT02 and the west of Plot NT03 and controlled waters via vertical migration through the unsaturated zone and/or lateral migration through dissolved phase to the wider principal aquifer.
- 3) In accordance with this remediation shall be required at the site. Subject to agreement of the targets derived with the EA, the RTVs presented in this report should be used to inform remedial works at the site.
- 4) Uncertainty remains on the full extents of the TCE soil source area, which may extend further east into Plot NT03, however sensitivity analysis showed no measurable change in predicted concentrations at the 50m compliance point for a +/- 20% change in source width.
- 5) Although some uncertainty remains, given the inherent conservatism associated with the modelling and the results of the sensitivity analysis and model calibration, the conclusions drawn from this assessment are considered robust.

6.7.3 The output from the modelling assessment has allowed Remedial Target Values to be derived for the contaminants of concern. These values, as reproduced from Table 16 of the DQRA report, indicate the values to which site soils and groundwater will require treatment for the protection of controlled waters.

“Table 16”, Soil & Groundwater RTV's from DQRA modelling works

COPC	Soil RTV (mg/kg)	Locations of soil RTV exceedances and max concentration (mg/kg)	Groundwater RTV (mg/l)	Locations of groundwater RTV exceedances and max concentration (mg/l)
Trichloroethene (TCE)	0.224	WS302 1.5m bgl (0.602) WS304 0.5m bgl (0.23) WS305 1.0m bgl (0.427) WS308 0.6 & 1.0m bgl (max 1.13)	0.0271	LKBH03 (max 0.250), RBH203 (max 0.572), RBH303 (max 0.277)
Carbon tetrachloride	0.116	NR	0.149	RBH203 (max 0.265), RBH302 (max 0.207)

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COPC	Soil RTV (mg/kg)	Locations of soil RTV exceedances and max concentration (mg/kg)	Groundwater RTV (mg/l)	Locations of groundwater RTV exceedances and max concentration (mg/l)
Cis and trans-1,2-dichloroethene	NA	NA	0.0902	LKBH01 (max 0.602) RBH301 (0.102) RBH503 (0.100) RBH504 (0.151)
Vinyl chloride	NA	NA	0.00425	LKBH01 (max 0.016) RBH503 (0.044)
NR – no RTV exceedances recorded NA – DCE and VC not included in the leaching pathway model				



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7.0 Refined Conceptual Site Model

- 7.0.1 In this Section, the significant source-pathway-receptor contaminant linkages have been refined following the GQRA and DQRA in line with industry good practice, providing an updated CSM based on the findings of the ground investigation and analytical results, also drawing on the ground and groundwater conditions, and contamination assessment presented in the above Sections 4-6.
- 7.0.2 The Environmental Protection Act Part IIA: 1990, defines contamination as land containing levels of contamination which form a risk to human health, controlled waters, or other ecosystems. Therefore, contamination in exceedance of the relevant screening values is considered a source. Table 7.0 assesses and summarises the sources, pathways and receptors that may exist at the site, in the context of the proposed redevelopment as *mixed high and medium rise residential buildings with small areas of soft landscaping and new access roads* future land use scenario.



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Table 7.0: Refined Conceptual Site Model

Table 7.0		Refined Conceptual Site Model					
Source	Pathway	Receptor	Severity	Probability	Risk definition	Comments	
On Site Made Ground arising from previous site operations and subsequent redevelopment and clearance. (Metals, PAHs and Asbestos)	Oral, dermal and inhalation exposure with impacted soil, soil vapour and dust and asbestos fibres	Current Site Users: temporary event space	Medium	Unlikely	Low	Exceedances of human health criteria have been observed in shallow Made Ground across all three plots, predominantly comprising lead, with PAH exceedances at a single location (TP202) at Plot NT02. In addition, a single exceedance of soil TCE concentration was observed in WS208 within the Made Ground beneath the warehouse at Plot NT02. Asbestos has been identified in made ground soils in all plots across the site at quantification levels between <0.001% and 0.013%, with a single occurrence of visible chrysotile cement reported in Plot NT03. The majority of NT02 is covered with buildings and hard standing and is anticipated to remain as such, which will significantly inhibit the potential pathway to human health risk.	
		Construction workers	Medium	Likely	Moderate	Elevated concentrations of heavy metals and PAH have been detected within the Made Ground across the site. Asbestos was also identified in made ground soils in all plots across the site at quantification levels between <0.001% and 0.013%, with a single occurrence of visible chrysotile cement reported in Plot NT03. Therefore a potential risks to construction workers from direct contact with contaminated made ground exists. Construction workers will likely be the most exposed to the identified contaminants on site when breaking ground. Risks to construction workers will require careful control measures through the construction phase, through the use of full PPE and the adoption of good hygiene and site practices.	



**COMPLEX CHALLENGES ...
MADE SIMPLE**

Table 7.0		Refined Conceptual Site Model					
Source	Pathway	Receptor	Severity	Probability	Risk definition	Comments	
On site Made Ground arising from previous site operations and subsequent redevelopment and clearance. (Metals, PAHs and Asbestos)	Oral, dermal and inhalation exposure with impacted soil, soil vapour and dust and asbestos fibres	Future Site Users: Residents, commercial site users and users of areas of public open space	Medium	Likely	Moderate	Exceedances of human health criteria have been observed in shallow Made Ground across all three plots, predominantly comprising lead, with PAH exceedances at a single location (TP202) at Plot NT02. In addition, a single exceedance of soil TCE concentration was observed in WS208 within the Made Ground beneath the warehouse at Plot NT02. Asbestos has been identified in made ground soils in all plots across the site at quantification levels between <0.001% and 0.013%, with a single occurrence of visible chrysotile cement reported in Plot NT03. The majority of the site is proposed to be covered in buildings and hard standing, which will significantly inhibit the potential pathway to future end-users. Areas of public open space are proposed and there is a potential risk of site users coming into contact with contaminated soils. Remedial measures in the form of contaminated soil removal and installation of cover systems is to be carried out and is documented within the site's Remediation Strategy.	
		Adjacent site users: Residents and commercial site users to the south and west.	Medium	Low likelihood	Moderate/low	Elevated levels of heavy metals, PAH, chlorinated solvents and asbestos have been identified within soil samples across the site which present a risk to adjacent site users.. The majority of the site will be covered in hardstanding and buildings which will restrict the migration of dust and fibres to adjacent sites. A combination of contaminated soil removal and use of cover systems in areas of public open space will inhibit the pathway further. During the construction phase, measures will be required to restrict the migration of dust and fibres so	





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Table 7.0		Refined Conceptual Site Model					
Source		Pathway	Receptor	Severity	Probability	Risk definition	Comments
	On Site Made Ground arising from previous site operations and subsequent redevelopment and clearance.						that adequate protection is offered to adjacent site users. These measures will be outlined in the site's Remediation Strategy.
	(Metals, PAHs and Asbestos)	Chemical attack and permeation	Below ground infrastructure & construction	Medium	Likely	Moderate	Elevated levels of heavy metals, PAH and TPH have been identified within soil samples across the site which present a risk to water supply pipes on site. A UU pipe risk assessment should be undertaken in light of the final drainage and earthworks layout. This could feasibly be undertaken after completion of the site earthworks at such a time when proposed depth and pipe run alignments are confirmed. On Plot NT02 below ground concrete structures are to be designed in accordance with a Class DS-2 AC-1s requirements. On Plot NT03 below ground concrete structures are to be designed in accordance with a Class DS-2 AC-1s requirements. A single reported value of sulphate at WS311 of 2,650mg/l has been reported which increased the DS classification to DS-3. It is recommended that any concrete in this area of the site takes this reported concentration into account in the design. In the Network Rail mound below ground concrete structures are to be designed in accordance with a Class DS-2 AC-1s requirements. On plot NT04 below ground concrete structures are to be designed in accordance with a class DS-1 AC-1s as specified in BRE Digest Special Digest 1:2005 Concrete.



COMPLEX CHALLENGES ... MADE SIMPLE

Table 7.0		Refined Conceptual Site Model					
Source		Pathway	Receptor	Severity	Probability	Risk definition	Comments
	On Site Made Ground arising from previous site operations and subsequent redevelopment and clearance. (Metals, PAHs and Asbestos)	Plant uptake	Ecological	Mild	Low likelihood	Low	Phytotoxic contaminants have been identified on site including lead. Via a combination of soil removal and installation of clean cover systems in areas of soft landscaping, future ecological receptors are considered to be suitably protected.
	Leaching from soils to dissolved phase and percolation to aquifer	Groundwater within Principal Aquifer (CHES) and Secondary B aquifer (MM)	Medium	Low Likelihood	Moderate to Low	Localised exceedances reported in groundwater, particularly lead, indicate some degree of leaching has occurred, however the majority of site is proposed to be covered in hard standing/buildings post development which will reduce the rate of infiltration considerably. Furthermore, large volumes of made ground in the areas where leachate exceedances have been reported are proposed to be cut, thus removing the source of contamination;	
	Lateral migration to wider aquifer	Groundwater in wider Principal and Secondary B aquifers	Medium	Unlikely	Low	Localised exceedances are unlikely to be migrating off site. Most of the site is proposed to be covered in buildings / hard standing post development reducing the rate of infiltration that can occur, and locations where exceedances in leachate have been reported are in areas of made ground proposed to be cut.	
	Lateral migration to surface water	River Irk located 21m north	Mild	Low Likelihood	Low	Surface water impact severity is low due to the existing quality in the River Irk being classified as poor given it has already been impacted by the wider industrial area that included historic gas works etc. It is unlikely that the made ground on site would significantly further impact surface water quality in the Irk	
	On Site Diffuse TCE source in unsaturated soils in south of Plot NT02	Direct contact - dermal contact, ingestion and Inhalation of vapours	Current Site Users: Temporary event space	Medium	Low Likelihood	Moderate to Low	A body of evidence, including visual and olfactory evidence, soils testing, water sampling in this investigation, and water sampling supports the presence of chlorinated solvent contamination beneath the southern warehouse and surrounding areas.



**COMPLEX CHALLENGES ...
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Table 7.0		Refined Conceptual Site Model					
Source	Pathway	Receptor	Severity	Probability	Risk definition	Comments	
and southwest of Plot NT03 likely associated with historic bolt works. Plus underlying dissolved phase chlorinated VOC plume (incl TCE and daughter products DCE and VC)	Direct contact - dermal contact, ingestion					Direct testing of soil vapour has been undertaken to assess the likely risks posed to human health from soil vapour. Concentrations measured are below commercial GACs. In addition to depth, the presence of buildings and hardstanding across the affected area significantly inhibits the potential pathways to human health risk receptors. Consequently, we do not consider this risk to require remedial action for this temporary end use scenario.	
		Construction workers	Medium	High Likelihood	High	It is likely construction works will come into contact with TCE contaminated soils, particularly within the southern portion of the existing warehouse on Plot NT02. Remediation of these soils will be required for the protection of controlled waters receptors which will go some way to mitigating these risks, however as with other more conventional sources of contaminated noted on site (Heavy Metals, PAH, Asbestos etc) a residual risk will remain and appropriate PPE, control measures and welfare facilities will be required during the development process to mitigate risks.	



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Table 7.0		Refined Conceptual Site Model					
Source	Pathway	Receptor	Severity	Probability	Risk definition	Comments	
On Site Diffuse TCE source in unsaturated soils in south of Plot NT02 and southwest of Plot NT03 likely associated with historic bolt works. Plus underlying dissolved phase chlorinated VOC plume (incl TCE and daughter products DCE and VC)	and Inhalation of vapours	Future Site Users: Residents, commercial site users and users of areas of public open space	Medium	Likely	Moderate	The chlorinated solvents present in unsaturated soils have the potential to pose a risk to future residents across the Plot NT02 and the southwest of Plot NT03, via direct contact with site soils or via vapour generation and ingress into buildings or enclosed spaces. It is noted some form of primary source remediation and treatment of this soil contamination will be required to reduce the risks posed to controlled waters which will reduce the severity of risks posed. The use of clean soil capping systems within all soft landscaping plots and the proposed presence of widespread building / hard standing cover across the NT02 and NT03 site will also impede direct contact (dermal and ingestion) exposure pathways (and reduce risks posed) Direct testing of soil vapour has been undertaken to assess the likely risks posed to human health from soil vapour. Concentrations measured are in excess of residential GAC, although these have not been developed for a high-rise style residential land use. Further consideration of VOC vapour risks will need to be considered in the post remediation phase as a result.	
	Leaching to underlying groundwater and lateral migration of dissolved phase contaminants off-site followed by migration of	Adjacent site users: Residents and commercial site users to the south and west.	Medium	Unlikely	Low	There is evidence of leaching of chlorinated VOC to groundwater beneath Plot NT02 and the west of Plot NT03, with contamination primarily present in the CHES. Groundwater in the CHES has been shown to be flowing in a north-northeasterly direction, therefore it is unlikely that VOC will be migrating off-site to the west and south.	





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Table 7.0		Refined Conceptual Site Model					
Source	Pathway	Receptor	Severity	Probability	Risk definition	Comments	
On Site Diffuse TCE source in unsaturated soils in south of Plot NT02 and southwest of Plot NT03 likely associated with historic bolt works. Plus underlying dissolved phase chlorinated VOC plume (incl TCE and daughter products DCE and VC)	vapours into off-site buildings and inhalation by adjacent site users						
	Chemical attack and permeation	Below ground infrastructure & construction	Medium	Likely	Moderate	It is possible that drinking water supply pipes will be routed through areas where chlorinated VOC contamination has been detected in soils. It is noted some form of primary source remediation and treatment of this plume soil contamination will be required to reduce the risks posed to controlled waters which will reduce contaminant concentrations. A UU pipe risk assessment should be undertaken in light of the final drainage and earthworks layout. This could feasibly be undertaken after completion of the site earthworks at such a time when proposed depth and pipe run alignments are confirmed. On Plot NT02 below ground concrete structures are to be designed in accordance with a Class DS-2 AC-1s requirements. On Plot NT03 below ground concrete structures are to be designed in accordance with a Class DS-2 AC-1s requirements. A single reported value of sulphate at WS311 of 2,650mg/l has been reported which increased the DS classification to DS-3. It is recommended that any concrete in this area of the site takes this reported concentration into account in the design. In the Network Rail mound below ground concrete structures are to be designed in accordance with a Class DS-2 AC-1s requirements.	





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Table 7.0		Refined Conceptual Site Model					
Source		Pathway	Receptor	Severity	Probability	Risk definition	Comments
	On Site Diffuse TCE source in unsaturated soils in south of Plot NT02 and southwest of Plot NT03 likely associated with historic bolt works.						On plot NT04 below ground concrete structures are to be designed in accordance with a class DS-1 AC-1s as specified in BRE Digest Special Digest 1:2005 Concrete.
	soils in south of Plot NT02 and southwest of Plot NT03 likely associated with historic bolt works.	Leaching from soils to dissolved phase and percolation to aquifer	Groundwater underlying the site within Principal Aquifer (CHES) and Secondary B aquifer (MM)	Medium	High Likelihood	High	There is evidence of leaching of chlorinated VOC to groundwater beneath Plot NT02 and the west of Plot NT03, with reported concentrations exceeding the controlled waters GAC in the CHES.
	Plus underlying dissolved phase chlorinated VOC plume (incl TCE and daughter products DCE and VC)	Lateral migration of dissolved phase VOC to wider aquifer	Groundwater in wider Principal aquifer	Medium	Likely	Moderate	Whilst TCE concentrations at monitoring wells close to the down gradient northern site boundary are greatly reduced compared to concentrations in the plume core, TCE daughter products DCE and VC are present at concentrations exceeding the DWS in the north of the site. DQRA modelling identified potential exceedances of the DWS at the 50 m compliance point indicating potential impact to the wider principal aquifer and therefore remediation of both the soil source and groundwater plume is proposed to meet the remedial target values identified in the DQRA. It is considered the likely remediation works necessary to address ground contamination issues identified within site soils and groundwater will achieve betterment in terms of water quality or potential off-site impacts that may be occurring.
		Lateral migration to surface water	River Irk located 21m north	Mild	Likely	Moderate to low	DQRA modelling indicates that chlorinated VOC could potentially be migrating >50m from the site to the north-northeast however the River Irk in the vicinity of the site is reported to be of low water quality (Grade E).





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Table 7.0		Refined Conceptual Site Model					
Source		Pathway	Receptor	Severity	Probability	Risk definition	Comments
							Previously a gas works was located adjacent to the northern site boundary between the site and the River Irk. There are also numerous other potentially polluting current and historic industrial sites within the vicinity of this stretch of the River Irk including a dye works and additional gas works. Due to the already poor surface water quality reported in the River Irk due to the long industrial past of the wider surrounding area, the river is considered to be of low sensitivity from the site. It is also of noted that the River Irk is located approximately 100m from the TCE impacts identified in unsaturated soils in the south of Plot NT02 extending into the southwest of Plot NT03. Proposed remediation of chlorinated VOC in soils and groundwater in the CHES for the protection of the wider principal aquifer will also act to lower the risks to surface water.
	On-site Dissolved phase Benzene/TPH predominantly in shallow MM in southwest of Plot NT02 (RBH502 P2)	Direct contact – inhalation of vapours	Current Site Users: Temporary event space	Medium	Unlikely	Low	Benzene has been detected at depth in groundwater in the MM at approx. 15 to 20m bgl possibly emanating from an off site source. it is unlikely that vapours would migrate vertically over this distance into buildings on site. Furthermore no significant concentrations of benzene were detected in unsaturated soils and soil vapour testing did not identify any exceedances in residential vGAC
			Future Site Users: Residents, commercial site users and users of areas of public open space	Medium	Unlikely	Low	
			Construction workers	Medium	Unlikely	Low	Due to the depth of the contaminated groundwater it is considered unlikely that this will pose a risk to construction workers. If proposed construction works are likely to come into contact with groundwater in these areas of the site, suitable mitigation measures





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Source	Pathway	Receptor	Severity	Probability	Risk definition	Comments	
						(appropriate PPE, control measures and welfare facilities) will be required.	
		Adjacent site users: Residents and commercial site users to the south and west.	Medium	Unlikely	Low	Whilst groundwater in the MM is indicated to flow in a westerly direction towards the adjacent residential site, given the depth of the contaminated groundwater it is considered unlikely to pose a risk to adjacent site users.	
		Lateral migration to wider aquifer	Groundwater in wider Principal and Secondary B aquifers	Mild	Likely	Moderate to low	The benzene detected in the MM at RBH502 P2 is located close to the down gradient site boundary (west) and could potentially be migrating off-site, however the MM is classed as a Secondary B aquifer and is therefore of lower sensitivity than the overlying CHES (principal aquifer). As discussed in Section 6.1 it is possible that the benzene in the MM originates from an off-site source (most likely the historic gas works to the south of the site), considering this combined with the lower sensitivity of the MM, this benzene source was not considered a primary risk driver for the site and was not taken forward to DQRA.
	Lateral migration to surface water	River Irk located 21m north and ~100m west	Mild	Low likelihood	Low	Groundwater in the MM is indicated to flow in a westerly direction, given the distance to the river Irk in this direction of at least 100m there is a low likelihood that the benzene detected in the MM will be impacting surface water quality.	
	Onsite: Made Ground soils associated with the Network Rail Mound	Direct contact - dermal contact, ingestion and Inhalation of vapours	Current Site Users: Temporary event space	Medium	Unlikely	Low	Soil testing of the Network Rail Mound has indicated exceedances of metals, particularly lead, PAH and TPH. In addition, a total of 13no. soil samples were analysed for the presence of asbestos and no asbestos was detected in any of the samples. It is understood that there are no current site users in this area of the site as Ryan Topsoil operations have ceased. There is also not expected to be any site uses





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Source	Pathway	Receptor	Severity	Probability	Risk definition	Comments	
(Metals, TPH and PAHs)						in the interim period between the present and the beginning of construction / enabling works.	
		Construction Workers	Medium	Likely	Moderate	Soil testing of the Network Rail Mound has indicated elevated metals, particularly lead, PAH and TPH concentrations. Construction workers will likely be the most exposed to the identified contaminants on site when breaking ground. Risks to construction workers will require careful control measures through the construction phase, through the use of full PPE and the adoption of good hygiene and site practices.	
		Future Site User: Residents, commercial site users and users of areas of public open space	Medium	Unlikely	Low	The Network Rail mound is to be reprofiled to increase developable area for the development and a retaining wall constructed to support soils adjacent to the viaduct adjoining the sites southern boundary. New high-rise buildings are proposed in close proximity to the retaining wall but it is envisioned that the retaining wall itself, and a soil capping layer atop, will serve to eliminate any pathways from contaminants that remain present within the mound and future site users. Access to the top of the mound and retaining wall will also be limited and not open to the public / future residents, further limiting exposure potential.	
		Adjacent site users: Residents and commercial site users to the south and west.	Medium	Unlikely	Low	The Network Rail mound is to be reprofiled to increase developable area for the development and a retaining wall constructed to support soils adjacent to the viaduct adjoining the sites southern boundary. Soil contamination in the form of lead, PAH and TPH, has been identified within mound soils and although asbestos was not detected in the investigation, it's presence should not be completely ruled out. As such, during the construction phase, measures will be required to restrict the migration of dust and fibres so	





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Source	Pathway	Receptor	Severity	Probability	Risk definition	Comments	
						that adequate protection is offered to adjacent site users. These measures will be outlined in the site's Remediation Strategy.	
	Plant uptake	Ecological	Mild	Low likelihood	Low	Phytotoxic contaminants have been identified on site including lead. Via a combination of soil removal and installation of clean cover systems in areas of soft landscaping, future ecological receptors are considered to be suitably protected.	
	Chemical attack and permeation	Below ground infrastructure & construction	Medium	Likely	Moderate	The Network Rail mound is to be reprofiled to increase developable area for the development and a retaining wall constructed to support soils adjacent to the viaduct adjoining the sites southern boundary. However, elevated levels of heavy metals, PAH and TPH have been identified within soil samples which may present a risk to water supply pipes located in this area. A UU pipe risk assessment should be undertaken in light of the final drainage and earthworks layout. This could feasibly be undertaken after completion of the site earthworks at such a time when proposed depth and pipe run alignments are confirmed. Using current data, the Network Rail mound below ground concrete structures are to be designed in accordance with a Class DS-2 AC-1s requirements.	
	Leaching from soils to dissolved phase and percolation to aquifer	Groundwater within Principal Aquifer (CHES) and Secondary B aquifer (MM)	Medium	Low Likelihood	Moderate to Low	Elevated leachate concentrations were reported in RBH402 at 1.50m bgl and RBH403, albeit much deeper at 9.90m bgl. Additionally, elevated levels of contaminants were reported in groundwater testing from RBH403 which is sealed into the River Terrace Deposits beneath the made ground soils of the Network Rail mound. A well was also installed in the neighbouring RBH401 with the same response zone, however RBH401 contained no groundwater. Due to this it is believed that the groundwater encountered in RBH403	





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Source	Pathway	Receptor	Severity	Probability	Risk definition	Comments
						is sitting above a layer of clay and is a limited pocket of perched groundwater localised to the area of this borehole and extending no further westwards than RBH401. A cut of up to 9.00mbgl is proposed within the Network Rail mound. This would serve to remove the source of leachate exceedances reported at RBH402 but a proportion of soils with the potential to exhibit leachate exceedances will remain in-situ. However, current development proposals indicate that the area in the vicinity of RBH403 will be surfaced in hardstanding, restricting infiltration and soil leachability. In addition to the above, current proposals are for the retaining wall to be piled and given the above, a piling risk assessment will be required in advance of construction of the Network Rail retaining wall to assess the risk of any potential pathways that may be created by piling works.
	Lateral migration to wider aquifer	Groundwater in wider Principal and Secondary B aquifers	Medium	Unlikely	Low	Localised exceedances are unlikely to be migrating off site. Most of the site is proposed to be covered in buildings / hard standing post development reducing the rate of infiltration that can occur, and locations where exceedances in leachate have been reported are in areas of made ground proposed to be cut.
	Lateral migration to surface water	River Irk located 21m north	Mild	Low Likelihood	Low	Surface water impact severity is low due to the existing quality in the River Irk being classified as poor given it has already been impacted by the wider industrial area that included historic gas works etc. It is unlikely that the made ground on site would significantly further impact surface water quality in the Irk





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Table 7.0		Refined Conceptual Site Model					
Source	Pathway	Receptor	Severity	Probability	Risk definition	Comments	
Ground Gas Generation from on-site made ground	Migration / Accumulation	Current Site Users	Severe	Low likelihood	–Moderate	Site wide Made Ground deposits are considered to be a viable source of on-site ground gas generation. A total of 6 ground gas monitoring visits have been carried out at the site. The plots NT02 and NT03 have been designated CS2 with a corresponding requirement for gas protection measures. On Plot NT04 no such CO2 concentrations were encountered and therefore Plot NT04 should be classified as CS1. If for any reasons risks relating to chlorinated solvents are not sufficiently remediated, vapour protection measures may be required in the affected area.	
		Construction workers	Severe	Low likelihood	–Moderate		
		Adjacent site users: Residents and commercial site users to the south and west.	Severe	Low likelihood	–Moderate		
		Future Site Users	Severe	Low likelihood	–Moderate		
Off site	Off-site: Potentially Contaminative Sources; Historic industrial site uses to the immediate west (Rubber Works) and south (Gas Works)	Direct contact - dermal contact, ingestion and Inhalation of vapours	Current Site Users: Temporary event space	Medium	Unlikely	Low	Given that a source of benzene has not been detected in the unsaturated zone on site It is considered that the benzene detected in the north of the Plot NT02 site at LKBH01 is due to migration of contamination in the CHES from the former rubber works adjacent to the west. Similarly, the benzene detected in the deeper groundwater in the MM at RBH502 P2 is possibly due to migration of impacted water in the MM from the historic gas works locate to the south of the site. However, given the depth of this contamination it is considered unlikely that it would migrate at significant concentrations into buildings on site. Direct testing of