BROWNFIELD SOLUTIONS LTD

GEO-ENVIRONMENTAL ENGINEERING EXCELLENCE

INTRO DEVELOPMENTS / MCR PROPERTY GROUP

Gould Street, Manchester

Phase I & II Geo-Environmental Assessment Report

MB/C5692/13303 Rev A

October 2024

EXECUTIVE SUMMARY	
Location and Brief Site Description	The site is located off Gould Street, Manchester, M4 4HY and currently comprises an active hardstanding car park split over two levels separated by a circa 3m retaining wall running broadly east-west through the site. A Cadent Pressure Reduction Station (PRS) gas valve/pipe compound is located in the centre of the site on the lower level, a telecommunications mast is present on the upper level towards the east of the site. Various above ground gas pipelines and underground services are located across the site.
Site History	Evidence from historical mapping indicates that the site has included industrial use as gas works from prior to 1848 up until the 1980s, thereafter parts of the site were in use as a depot/call centre, a maintenance garage, Gas Pressure Reduction System (PRS) and most recently for car parking.
Published Geology	• Made ground; over • Superficial deposits – glacial Till; over • Solid geology/bedrock – Chester Formation.
Mining and Mineral Extraction	The site is located in a Coal Mining Reporting Area but lies outside of a Development High Risk Area. The risk from mining has been assessed and no further consideration is required.
Hydrogeology and Hydrology	• Superficial Deposits – Secondary Aquifer (Undifferentiated). • Solid Geology – Principal Aquifer. • Nearest Watercourse – River Irk (117m NW).
Environmental	There are two historic landfill sites within 500m, the closest located 361m north. There are historical licenced pollutant releases Part A(2)/B) located on site for vegetable drying processes, likely related to the historic tobacco works abutting the site. The site is located in an area where no radon protection measures are required.
Ground Conditions	Generalised ground conditions from the ground investigation comprise (top down): • Made ground generally comprising gravelly sand, sandy gravel and gravelly clay. • Depth to made ground varied considerably on the lower deck (northern portion) – related to the historical below ground gas holders and tar tanks within which made ground was typically between 8-10m deep. Outside of the former gasholders, made ground was typically between 3-4m deep. • Natural superficial deposits comprising gravelly clay proven to depths between 3.50m and 12.00m bgl. • Solid geology comprising sandstone and mudstone proven to depths ranging between 13.00m and 50.00m bgl. • Groundwater levels (made ground) ranging between 1.20m and 8.20m bgl during site works. • Groundwater levels (superficial/bedrock) ranging between 7.20m and 16.50m bgl during site works. • Post site works monitoring levels ranging between 0.37m and 19.20m bgl
Human Health - Soils Contamination	• Made ground pervasively impacted by metals and PAHs across the site. • Localised and sometimes gross contamination of the made ground in the form of petroleum hydrocarbons, benzene, SVOCs, cyanide and phenols, associated with the former gasworks structures. • Localised areas of asbestos contamination; trace asbestos should be assumed across Phases 1 to 3, and concentrations of asbestos exceed trace concentrations in three locations within Development Phases 1 and 3. Suspected visible ACMs have been encountered during the previous investigations at two locations to date.
Controlled Waters – Surface and Groundwater Contamination	• Groundwater testing results indicate the principal Aquifer underlying the site is impacted by various contaminants including metals, cyanide and other inorganic compounds, PAHs, phenols, petroleum hydrocarbons, benzene and xylene. • The concentrations of contaminants in the Principal Aquifer also appear to be greater in general within installations located in the western part of the site, at this stage suggesting that groundwater quality is of lower quality down-gradient of the site compared to up-gradient. • The results indicate groundwater quality is worse within the shallow perched groundwater in the made ground, suggesting current ground conditions comprising hard standing at surface,

EXECUTIVE SUMMARY	
	brick/concrete bases to the gasholders and underlying superficial clay deposits are likely to be restricting contaminant migration to a degree across the site as a whole. • However, based on the initial assessments completed, there is considered to be a viable source-pathway-receptor linkage between the deep made ground and the Principal Aquifer, and the overall risk to controlled waters is considered to be moderate to high at this stage. • Further detailed assessment will be required in the form of a detailed quantitative risk assessment (DQRA)
Ground Gas	Based on the monitoring, the site is classified as CS2 and ground gas protection measures will be likely to be required. However, given the extensive earthworks programme and remediation which will take place during enabling works, this is likely to result in significant betterment of the ground gas regime, therefore it is recommended that further ground gas and vapour monitoring and assessment takes place following enabling works, which may result in a reclassification of the site.
Waste	Made ground within gas holders / tar tanks / former ammonia plant areas and areas of gross contamination – classified as hazardous. General made ground soils outside of the gas holders - non-hazardous. General made ground from Phases 1 and 2 were classified as non-hazardous during the previous reporting undertaken by Hydrock. Natural – classified as non-hazardous.
Foundations and Floor Slabs	Based on the proposed development and encountered ground conditions, piled foundations are considered the most suitable foundation option socketed into the competent sandstone bedrock. As a preliminary guide, allowable axial loads for a circular pile range between 1.3MN for a 600mm diameter pile with 1.0m embedment up to 8.8MN for a 900mm diameter pile with 9.0m embedment. Detailed foundation design will need to be completed by a suitably qualified specialist. Basement floor slabs and suspended floor slabs should be supported by piles.
Concrete Classification	Made ground: DS4 AC-4 conditions prevail. Natural soils: DS1 AC-1 conditions prevail. Bedrock: DS1 AC-1 conditions prevail.
Highways Design	A site wide programme of earthworks will alter the properties of the existing made ground and providing these soils are placed to a suitable specification, CBR values in the range of 3- 5% would likely be achieved in granular fill and 2% for cohesive fill. To aid design proposals during construction of haul roads etc, based on Table 5.1 from DMRB IAN 73/06 Rev 1 equilibrium CBR values of 5% are likely to be achieved in undisturbed natural granular soils where they are encountered and 2% for made ground and natural clays soils for pavement design purposes, unless proven otherwise by in-situ testing at formation level by a specialist geotechnical engineer. The above should be confirmed by in-situ testing at formation level by a specialist geotechnical engineer during construction.
Site Drainage	Falling head tests were carried out in five locations with the made ground, superficial cohesive strata and sandstone bedrock, with Hydraulic Conductivity results in the range of 10^{-3} m/s to 10^{-6} m/s being calculated. However, the use of sustainable drainage systems, such as traditional soakaways within the natural ground, is not likely to be feasible over large areas of the site due to the presence of low permeability cohesive strata underlying the site, alongside the presence of variable and potentially contaminated made ground near the surface and extending to depths in excess of 10.00m bgl.
Slope Stability & Retaining Walls	A large retaining wall approximately 6m high of concrete and brick construction is present onsite bisecting approximately the centre, running west to east across the entire width of the site, with two ramp features to provide access between the upper and lower levels. It was outside the scope of this investigation to undertake a detailed inspection of the construction or a structural inspection of the walls. BSL recommends inspection of the walls by a structural engineer to assess their condition and determine what, if any, specialist requirements there are in respect to

EXECUTIVE SUMMARY	
	demolition and removal. Inadequate demolition may result in the instability of soils behind the wall, potentially resulting in dangerous collapse.
Further Work	The following further works will be required to progress to the construction phase: • Undertake Detailed Quantitative Risk Assessment for controlled waters. • Undertake remediation options appraisal with design of Remedial Strategy and confirmation with the Local Authority /EA / warranty provider. • Production of Earthworks Specification. • Production of Materials Management Plan (MMP) under the CL:AIRE DoWCoP, if required. • Confirmatory testing and supervision of excavations in Tar Tank No. 1 on commencement of enabling works. • Undertake confirmatory ground gas / vapour monitoring post-earthworks, if required. • Production of Ground Gas Protection Measures Verification Plan, if required. • Implementation of the Remedial Strategy and verification of the remedial works.

This executive summary should be read in conjunction with the full report, reference MB/C5692/13303 Rev A and not as a standalone document. Report template version 4.5.

PROJECT QUALITY CONTROL DATA SHEET

Site Name:	Gould Street, Manchester		
Document Name:	Phase I & Phase II Geo-Environmental Assessment Report		
Reference:	MB/C5692/13303 Rev A		
Status:	-	30/09/2024	Interim – awaiting final ground gas monitoring results.
	A	30/10/2024	Final – following completion of ground gas monitoring and comments from remediation contractor (Jackson Remediation).

Issued By:	**Client:**	**Civil/Structural Engineer**
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CONTENTS

1.0 INTRODUCTION 1

1.1 Context 1
1.2 Proposed Development 1
1.3 Previous Reports 2
1.4 Objectives and Scope 2
1.5 Limitations 3

2.0 THE SITE 6

2.1 Location 6
2.2 Site Description 6

3.0 GEO-ENVIRONMENTAL SETTING 8

3.1 Historical Setting 8
3.2 Published Geology 10
3.3 BGS Exploratory Hole Records 11
3.4 Mining and Mineral Extraction 11
3.5 Hydrogeology 11
3.6 Hydrology 12
3.7 Landfill and Waste Management Sites 12
3.8 Environmental Regulatory Data 13
3.9 Radon 13
3.10 UXO Risk 13
3.11 Other Potential Development Constraints 14

4.0 SUMMARY OF PREVIOUS REPORTS 15

4.1 Parkman - Site Investigation Report (1992/1993) 15
4.2 Entec UK Limited - Site Investigation Report Factual (February 2003) 15
4.3 Entec UK Limited - Factual Supplementary Site Investigation Report (October 2009) 17
4.4 Entec UK Limited - Hydrogeological Risk Assessment (March 2010) 19
4.5 Entec UK Limited - Stage 5 Remediation Strategy Report (September 2010) 23
4.6 AMEC Environment & Infrastructure UK - Human Health Risk Assessment (October 2011)24
4.7 Amec Environment and Infrastructure UK Ltd - Final Verification Report (October 2011) 25
4.8 WYG - Area A Supplementary Ground Investigation Factual Report (June 2015) 27
4.9 ECUS Environmental Consultants - Summary of Remediation Works (November 2015)..... 28
4.10 WSP - The Gasworks, New Town, Environmental Statement (November 2020)..... 29
4.11 WSP - Asset Survey and Proposed Groundwater Monitoring Technical Note (March 2021)29
4.12 Hydrock - Report Review and Gap Analysis (November 2021) 29
4.13 Hydrock - Ground Investigation Report (February 2022)..... 30
4.14 Hydrock - Preliminary Risk Assessment and Outline Remediation Strategy (January 2022) . 32
4.15 Environment Agency Comments on Proposals to Date..... 34

5.0 PHASE 1 PRA SUMMARY AND RISK ASSESSMENT..... 35

5.1 Introduction 35
5.2 Potential Contaminative Sources 35
5.3 Pathways 38
5.4 Receptors 38
5.5 Preliminary Conceptual Site Model (CSM) 40

6.0 PRELIMINARY GEOTECHNICAL ASSESSMENT 48

6.1 Hazard Identification 48
6.2 Foundation and Geotechnical Design 48

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CONTENTS

6.3 DRAINAGE 48
6.4 RECOMMENDATIONS 49

7.0 METHOD OF INVESTIGATION 50

7.1 CONTEXT AND OBJECTIVES 50
7.2 COVERAGE AND METHOD OF SITE INVESTIGATION 51
7.3 SITE WORKS 53
7.4 SAMPLING STRATEGY 56
7.5 MONITORING 56
7.6 LABORATORY TESTING 58

8.0 GROUND CONDITIONS 60

8.1 SUMMARY 60
8.2 MADE GROUND 60
8.3 NATURAL SUPERFICIAL STRATA 62
8.4 SOLID GEOLOGY 63
8.5 GROUNDWATER 64
8.6 OBSERVATIONS 66

9.0 TEST RESULTS 69

9.1 GEOTECHNICAL LABORATORY TESTING 69
9.2 AGGRESSIVE GROUND CONDITIONS – GEOTECHNICAL CHEMICAL TESTING 71
9.3 IN SITU GEOTECHNICAL TESTING 72
9.4 GEO-ENVIRONMENTAL TESTING 72

10.0 GEOTECHNICAL ASSESSMENT 74

10.1 GROUND MODEL 74
10.2 DESIGN SOIL PARAMETERS 75
10.3 FOUNDATIONS 82
10.4 BUILDING NEAR TREES 85
10.5 FLOOR SLABS 86
10.6 SITE PREPARATION AND CONSTRUCTION 86
10.7 BASEMENT CONSTRUCTION 87
10.8 CONCRETE CLASSIFICATION 88
10.9 HIGHWAYS 88
10.10 SITE DRAINAGE 89
10.11 RETAINING WALLS 89
10.12 EARTHWORKS 90

11.0 GEO-ENVIRONMENTAL RISK ASSESSMENT 93

11.1 INTRODUCTION 93
11.2 SOILS TEST RESULTS AND RISK ASSESSMENT – HUMAN HEALTH 93
11.3 SUMMARY – HUMAN HEALTH RISK ASSESSMENT 97
11.4 FORMER GAS HOLDERS – SOILS TESTING ASSESSMENT 98
11.5 WATER TEST RESULTS – CONTROLLED WATERS 101
11.6 CONTROLLED WATERS RISK ASSESSMENT 106
11.7 PERMANENT GROUND GAS AND VAPOURS RESULTS 110
11.8 GROUND GAS RISK ASSESSMENT 111
11.9 QUALITATIVE RISK ASSESSMENT 112
11.10 OUTLINE REMEDIAL MEASURES 119
11.11 HEALTH AND SAFETY ISSUES 119
11.12 ASBESTOS 120

12.0 WASTE SOIL CLASSIFICATION & ASSESSMENT 122

12.1 SUMMARY 122

CONTENTS

12.2 SOILS WASTE CLASSIFICATION PROCEDURE 122
12.3 WASTE CLASSIFICATION AND WASTE ACCEPTANCE CRITERIA (WAC) 123
12.4 RE-USE OF SOILS 126

13.0 CONCLUSIONS 128

13.1 GEO-ENVIRONMENTAL 128
13.2 GEOTECHNICAL 129
13.3 FURTHER WORK 130

14.0 ABBREVIATIONS AND DEFINITIONS 131

15.0 REFERENCES 134

DRAWINGS		
Drawing Number	**Rev**	**Title**
GDS-AHR-SO-00-DR-A-PL-003	2	Level 0 – Site Plan
GDS-AHR-SO-XX-DR-A-PL-101	-	Phasing Plan – Phase 1
GDS-AHR-SO-XX-DR-A-PL-102	-	Phasing Plan – Phase 2
GDS-AHR-SO-XX-DR-A-PL-103	-	Phasing Plan – Phase 3
GDS-AHR-SO-XX-DR-A-PL-104	-	Phasing Plan – Phase 4
2277-PLA-XX-XX-DR-L-1000	P09	Hardworks
2277-PLA-XX-XX-DR-L-0001	P10	Landscape General Arrangement
2277-PLA-XX-XX-DR-L-3000	P08	Proposed Levels (Strategic)
C5692/01	-	Site Location Plan
C5692/02	-	Post-Remediation Exploratory Hole Plan
C5692/03	D	Combined Exploratory Hole Location Plan
C5692/05	-	Summary of Completed Remediation to Date
C5692/06	A	Pre-Development CSM
C5692/07	-	Current Site Features Plan
C5692/08	-	Historical Site Features Plan
C5692/09	-	Depth To Made Ground Base, mBGL (Phases 3 And 4)
C5692/10	-	Depth To Made Ground Base, mAOD (Phases 3 And 4)
C5692/11	-	Ammonia Location Plan
C5692/12	-	Benzene Location Plan
C5692/13	-	Cyanide Location Plan
C5692/14	-	Naphthalene Location Plan
C5692/15	-	Phenols Location Plan
C5692/16	-	Bedrock Groundwater Level Contour Plan, mAOD
C5692/17	-	Monitoring Well Location Plan
C5692/18	-	Deep Drainage Survey Extract

APPENDICIES	
Appendix	**Title**
Photographs	Site Walkover and Site Works Photographs
Appendix A	BSL Methodology and Guidance
Appendix B	Historical Maps
Appendix C	Geo-Environmental Data Report
Appendix D	Mining Search Report
Appendix E	UXO Screening Map & UXO Desk Study
Appendix F	Exploratory Hole Logs
Appendix G	Chemical Testing Results
Appendix H	Geotechnical Testing Results
Appendix I	Monitoring Results
Appendix J	Waste Assessment Report
Appendix K	Amec Exploratory Hole Records – PRS compound

1.0 INTRODUCTION

1.1 Context

This report describes a Phase I and II Geo-Environmental Assessment carried out by Brownfield Solutions Limited (BSL) for Intro Developments / MCR Property Group on a site off Gould Street, Manchester and has been completed in general accordance with the following guidance:

- Environment Agency guidance - Land Contamination: Risk Management (LCRM).
- BS 10175:2011+A2:2017 Investigation of Potentially Contaminated Sites.
- BS5930: 2015+A1:2020 Code of Practice for Ground Investigations.
- BS EN 1997-1:2004+A1:2013 Eurocode 7. Geotechnical design. General rules plus UK National Annex.
- BS EN 1997-2:2007 Eurocode 7 Geotechnical design. Ground investigation and testing plus UK National Annex.

Definitions of terms and acronyms used within this report is presented in Section 14.0.

1.2 Proposed Development

The proposed development is to comprise fifteen 3 to 34 storey residential blocks with commercial units and town houses on the ground floor and associated car parking and soft landscaping areas, as shown on Level 0 – Site Plan, drawing No. GDS-AHR-SO-00-DR-A-PL-003 provided to BSL by the client.

The development will be completed over four phases, initially comprising phases 1 and 2 which cover the southern half of the site, followed by phases 3 and 4 which cover the northern half of the site, as detailed on the Phasing Plans (Phase 1-4), drawing Nos. GDS-AHR-SO-XX-DR-A-PL-101 to GDS-AHR-SO-XX-DR-A-PL-104.

The below table compiles information available within the Design & Access Statement produced by AHR Architects Ltd in September 2020, as well as other drawings available on the Manchester City Council Planning Portal:

Phase	Building Ref.	Building Height	Lowest Level
1	A	6-7 (+ Ground Floor)	Level 0 (45.60m AOD)
	B	6-7 (+ Ground Floor)	
2	C	6-7 (+ Ground Floor)	Level 0 (45.60m AOD)
	D	6-7 (+ Ground Floor)	
3	E	9 (+ Ground Floor)	Level -2 (39.60m AOD)
	F	16 (+ Ground Floor)	
4	G	10 (+ Ground Floor)	Level -2 (39.60m AOD)
	H	13 (+ Ground Floor)	
	I	31 (+ Ground Floor)	

Level 0 refers to the proposed site levels within the central spine access through the site referred to as "The Lanes and Square". Relatively Level 0 for Phase 1 and Phase 2, is below the surrounding ground level to the south of the site, such that Level 0 can be considered to be below ground level. Level 0 at this central area of the site is proposed to be 45.60m AOD, with Phases 3 & 4 with sub-ground floor levels G-1 at 42.60m AOD and G-2 at 39.60m AOD.

The development falls under Manchester City Council (MCC) Planning Application Number 128248/FO/2020.

1.3 Previous Reports

The following reports have been produced for the site and should be read in conjunction with this assessment (in date order):

- Parkman - Site Investigation Report, dated 1993.
- Entec UK Limited - Site Investigation Report Factual, reference 05760RR183i1, dated February 2003.
- Entec UK Limited - Hydrogeological Risk Assessment, reference 05760RR231i1, dated April 2009
- Entec UK Limited - Factual Supplementary Site Investigation Report, reference 05760RR283i2, dated October 2009
- Entec UK Limited - Stage 5 Remediation Strategy Report, reference 05760RR285i3, dated September 2010
- AMEC Environment & Infrastructure UK - Human Health Risk Assessment, reference 05760RR283i1, dated October 2011
- AMEC Environment and Infrastructure UK Ltd - Final Verification Report, reference 05760RR577i3, dated October 2011
- WYG - Area A Supplementary Ground Investigation Factual Report, reference A074754-55-1, dated June 2015
- ECUS Environmental Consultants - Summary of Remediation Works, reference AG-6656-151125-ID-E, dated November 2015.
- WSP - Asset Survey and Proposed Groundwater Monitoring Technical Note, reference 128248/FO/2020, dated March 2021.
- Hydrock - Report Review and Gap Analysis, reference 21353-HYD-XX-XX-RP-GE-0001, dated November 2021.
- Hydrock - Preliminary Risk Assessment and Outline Remediation Strategy, reference 21353-HYD-XX-XX-RP-GE-0002, dated January 2022.
- Hydrock - Ground Investigation Report, reference 21353-H21353-HYD-XX-XX-RP-GE-0003, dated February 2022.
- UXO Risk – EOD Detailed Explosive Ordnance Desktop Study, reference EOD/24/24210/DTS/REV1/Gould Street, Manchester, M4 4BH, dated June 2024.
- BSL, Ground Investigation Scoping Report, reference AJS/C5692/13232, dated June 2024.

1.4 Objectives and Scope

This report has been prepared pursuant to Condition 4 of MCC Planning Application 128248/FO/2020. For ease, this condition is presented below:

"*All stamped as received by the City Council* [in regard to previously submitted information], *as Local Planning Authority, on the 16 November 2020, no development shall commence until the following information has been submitted for approval in writing by the City Council, as Local Planning Authority, to identify and evaluate all potential sources and impacts of any ground contamination, groundwater contamination and/or ground gas relevant to the entire site:*

- Preliminary risk assessment which has identified (a)

o All previous uses.
o Potential contaminants associated with those uses.
o A conceptual model of the site indicating risks arising from contamination at the site.

- Review of the previous remediation strategy undertaken at the site (b).

- Submission of Site Investigation Proposals and Risk Assessment Report (c)- to provide information for a detailed assessment of the risk to all receptors that may be affected, including those off-site.

- Submission of a Remediation Strategy (d) including full details of the remediation measures required and how they are to be undertaken The remediation of the entire site shall be carried out in accordance with the approved strategy and shall not be phased.

Reason - To ensure that the presence of or the potential for any contaminated land and/or groundwater is detected and appropriate remedial action is taken in the interests of public safety, pursuant to policies EN17, EN18 and DM1 of the Manchester Core Strategy (2012).

For ease of reference, BSL have added the l to the individual condition elements.

The objectives of this report are to address elements a to c referenced in the condition above, and to determine the geo-environmental setting and ground conditions of the site, highlighting potential risks and areas of concern that may govern the development under the current planning regime.

A Ground Investigation Scoping Report (reference AJS/C5692/13232 dated June 2024) was produced in order to ascertain the requirements for further ground investigation and address the first half of the condition 4(c) i.e. the requirement for a Site Investigation Proposal. From correspondence with the Local Authority received via email from MCC dated 12th September 2024 it was stated " *We have looked at the outline Site Investigation proposals for the site (Brownfield Solutions) and this is acceptable for Phase 3 and 4 of the site".* Further to this, the Environment Agency (EA) in their response reference SO/2024/124359/01-L01 stated *"the investigation work proposed within the scoping report (sec. 3.0) appear suitable",* but BSL acknowledge this comment should also be viewed in the context of the wider EA response with comments regarding condition wording.

The Phase I section of this report is intended to meet the requirements of a Preliminary Investigation as defined in BS10175:2011+A2:2017, whilst the factual and interpretive Phase II sections are produced in general accordance with the recommendations for a Tier 2 Generic Quantitative Risk Assessment as described in LCRM guidance. This assessment is also intended to fulfil the requirements of a Ground Investigation Report (GIR) as detailed in BS EN 1997-2:2007.

The scope of works comprises a Desk Study and site walk-over, with a review of the site, surroundings, historical uses and environmental setting in order to develop a preliminary Conceptual Site Model (CSM).

A summary of previous investigations and remediation carried out at the site has also been undertaken.

Following the Desk Study, an intrusive investigation was undertaken to confirm the findings of the preliminary CSM and risk assessment and meet any objectives that had not been satisfied. The intrusive investigation was undertaken using trial pitting, window sampling, cable percussive drilling, rotary drilling, ground gas and groundwater monitoring, laboratory chemical and geotechnical testing, with reporting on the findings.

1.5 Limitations

This assessment has been prepared in accordance with the relevant current legislative framework, guidance and risk assessment methodology as outlined in Appendix A. BSL is not liable for any subsequent changes in the guidance and legislation.

The findings and opinions conveyed via this report are based on information obtained from a number of sources as detailed within this report, BSL have assumed this information is correct and reliable. Nevertheless, BSL cannot and does not guarantee the authenticity or reliability of the information it has relied upon.

BSL have used reasonable skill, care and diligence for the investigation of the site and the production of this report. There may be other conditions prevailing on the site which are outside the scope of work

and have not been highlighted by this assessment and therefore have not been considered by this report. Responsibility cannot be accepted for such site conditions not revealed by the assessment.

This report has been prepared for the sole use and reliance of the Client, Intro Developments / MCR Property Group. No other third parties may rely upon or reproduce the contents of this report without the written permission of Brownfield Solutions Ltd (BSL). If any unauthorised third party comes into possession of this report, they rely on it at their own risk and BSL do not owe them any Duty of Care. This report may not be relied upon by the client or submitted to a third party for their reliance for the purposes of valuation, mortgage, insurance and regulatory approval, until all invoices have been settled in full.

The investigation carried out on the site has been conducted to provide the best information on the ground conditions within site access and budgetary constraints. The inherent variation of ground conditions allows only for definition of the actual conditions at the locations and depths of exploratory locations at the time of the investigation. Different ground conditions may exist that have not been identified within this investigation.

The recommendations in this report assume that ground levels will remain as existing, unless stated otherwise within the report. If there is to be any re-profiling (e.g. to create development platforms or flood defences) then the recommendations may not apply.

The groundwater results described are only representative of the dates on which they were recorded, and levels may vary seasonally (e.g. due to changes in weather).

This assessment has been based on the proposed planning layouts provided. Any subsequent change to the planning layout may have an impact on the validity of recommendations made within this report. Furthermore, new information, changed practices or new legislation may necessitate revised interpretation of the report after the date of its submission.

Although every effort has been made to position exploratory holes in the least sensitive areas of the site, exploratory hole positions were located approximately as part of this investigation and no guarantee can be given as to their accuracy. Consideration should be given to the possibility that exploratory holes excavated as part of this investigation and indeed any previous ground investigation work by others may be encountered beneath or within the influence of individual foundations. BSL cannot be held responsible for structural failures caused by the location of foundations of any form of structure within the influence of exploratory holes.

Where it has not been possible to reasonably use an EC7 compliant investigation technique, a practical alternative has been adopted to obtain indicative soil parameters and any interpretation is based upon engineering experience, local precedent where applicable and relevant published information.

The chemical testing carried out for this report was not scoped to comply with the requirements of the water supply company and further work may be required, unless otherwise stated.

Notwithstanding site observations concerning the presence or otherwise of archaeological issues, asbestos-containing materials (ACM) or invasive weeds (e.g. Japanese knotweed), this report does not constitute a formal survey of these potential issues.

Asbestos in structures was not covered in this report. It should be noted that an asbestos demolition survey will be required prior to any demolition of structures. If asbestos is present in soils, these will need to be dealt with in accordance with the Control of Asbestos Regulations (CAR) 2012.

The site plans enclosed in this report should not be scaled off. Any site boundary line depicted on plans does not imply legal ownership of land.

Any recommendations made in this report should be confirmed with the Regulatory Authorities prior to implementation to ensure compliance.

2.0 THE SITE

2.1 Location

The site is located off Gould Street, Manchester, M4 4HY, centred on National Grid Reference 384666, 399247 as shown on the Site Location Plan, Drawing No. C5692/01.

2.2 Site Description

A site reconnaissance survey was carried out at the site on 24th June 2024. The main site features and potential issues identified are detailed below and are shown on the Current Site Features Plan, Drawing No. C5692/07. A selection of photographs from the site walkover are presented to the rear of this report.

Feature	Description
Site Area	Approximately 2.8 hectares.
Site Access	Access to the site is gained off Gould Street to the southwest.
Site Overview Imagery	 Orientated North. Update from Google: All images: Imagery Google©2024, Imagery ©2024 Airbus, CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies, The Geoinformation Group, Map data ©2024.
Current Land Use and Site Features	The site currently comprises an active hardstanding car park split over two levels and is broadly split into two areas accordingly as detailed on the client development phasing plans and the BSL Current Site Features Plan; the southern half of the site (upper level) comprises phase 1 and 2, whereas the northern half of the site (lower level) comprises phases 3 and 4. A retaining wall runs broadly east to west across the centre of the site and divides the upper and lower levels of the car park. A Pressure Reduction Station (PRS) gas valve/pipe compound in the centre of the site on the lower level, and a telecommunication mast is present on the upper level towards the east of the site. A gas pipeline spans across the centre of the site along the base of the retaining wall and also runs within the central PRS compound. A medium pressure gas pipeline is also known to be present, running from the PRS compound to the north-east, towards the boundary of the site. Numerous manhole covers were noted across the site, denoting possible drainage/sewers. Historical mapping also indicates the presence of a deep sewer running across the lower car park area, within close proximity to the PRS compound.
Potential Sources of Gross Contamination	There is an electrical sub-station along the southwest boundary of the site on the upper level. Several areas of fly tipped materials were noted along the south-eastern boundary of the upper level.
Vegetation / Ecology	There are sporadic mature/semi-mature trees around the peripheries of the site and along the retaining wall between both levels of the site.

Feature	Description
Topography	The site is generally flat across each plateau, but is split over two levels with a circa 3m retaining wall creating the split levels. Ramps are located at the eastern and western ends of the site which allows access to the two levels of the car parks. The top car park resides at circa 45m above OD retaining wall which provides vehicular access to the lower level of the car park in the north of the site at circa 42m AOD. The north, northwest and west boundaries of the site also comprise retaining walls of up to circa 5m height.
Site Boundaries	Brick walls enclose the site to the north, east and west. The south of the site is bound by an active construction site separated by wooden hoarding.
Surrounding Area	The site is set within a mixed commercial and residential area, bordered by a railway line to the north, brownfield land to the east, an active construction site to the south and residential apartments to the west. Immediately northwest of the site is an electricity substation.

3.0 GEO-ENVIRONMENTAL SETTING

3.1 Historical Setting

To form the basis of a comprehensive overview of all available information, a review of the available historical Ordnance Survey Maps and satellite imagery has been conducted for the entire Phase 1-4 area, with the pertinent issues that may have affected the site, or its environs, summarised below. The Historical Maps are presented in Appendix B. A review of the historical industrial data within the geo-environmental data report has also been undertaken below, the report is presented in Appendix C. A summary of the pertinent historical features identified is presented in the Historical Site Features Plan, drawing ref. C5692/08.

Notable features on site, and potentially contaminative or geotechnically relevant features within 100m of the site boundary have been presented. Any features that have potentially been infilled will be considered up to 250m from the site boundary.

Feature	Distance (m) & Direction	Years Present	Description
Gas Works and Gas Holders	Onsite - N	Pre-1848 to 1980	A gas works has been present on site from the earliest mapping dated 1848 up until the 1980 mapping. The distribution of buildings, gasholder tanks and other features has changed over the years, with the works originally comprising 3 gasometers and associated distillery and cisterns within the north-west of the site, with various buildings located in the west, and stables in the south-east, whereas no development was noted in the north-east and centre of the site. By 1891, the gasworks (entitled Rochdale Road Gas Works) had expanded across the rest of the site, with 4 new, larger gasometers constructed across the northern half of the site, replacing the original 3 No. gasometers formerly in the north-west. Multiple tanks are also evident across the centre and east of the site. The remainder comprises unnamed buildings, assumed to be offices and processing buildings. The eastern most gasometer was removed prior to the 1908 mapping and replaced by a building and a building to the west of the site is also listed as ruins on the 1948-1953 mapping. Structures on site were connected via rail to Oldham Road goods depot towards the south via a series of railway sidings. The remaining 3 gasometers and majority of structures were removed prior to 1978, with the gas works replaced with a depot by 1984.
Tanks	Onsite	1891 - 1965	Various tanks are present on site as part of the associated gas works from 1908 to the 1965 mapping, most abundantly within the central and eastern parts of the site.
Railway Sidings	Onsite - S	1891 - 1964	Numerous railway sidings are present across the southern portion of the site between 1891 and 1964; the number of sidings being progressively reduced until none are shown on mapping dated 1970.
Depot, then Call centre	Onsite - S	1984 - 2010	A depot is present on the south of the site from 1984 mapping to mapping dated 2003. Previous reporting suggests that the building was used as a call centre at this time and the building remained until at least the 2010 mapping. Aerial photography confirms its demolition by 2015 with the subsequent use of the site as carparking.
Telecoms Mast	Onsite - S	1984 - present	A telecommunication mast is present on site from the 1984 mapping until the present.
Cadent PRS compound	Onsite – Centre	1984 – Present	Whilst not labelled, the gas Pressure Reduction System compound is first indicated to be present on site from 1984 and is still operational.
Garage	Onsite - NE	1984 – 2003	A large unnamed building is first shown on mapping dated 1984 and remains on mapping until 2003, but is no longer present on subsequent mapping. Anecdotal information from previous reporting for the site indicates this was a maintenance garage.

Feature	Distance (m) & Direction	Years Present	Description
Electrical Substations	Onsite - W	1970 - 1978	An electrical substation is indicated to be present in the west of the site on the 1970 mapping and has been removed between 1978 and 1984.
	Onsite -SW	1984 - present	An electrical substation is present on-site towards the southwest boundary of the site from 1984 and was still present at the time of the walkover.
	Abutting W corner	1970 - present	A large electrical substation is indicated to be abutting the western corner of the site on the 1970 mapping and is still present.
	80m east	1952-Present	An electrical substation is indicated to be approximately 80m east of the site and is present on mapping from 1952 to the present.
Depots/ Garages	From adjacent to SE/E	1953-Present	Various garages / depots located predominantly to the south-east of the site, the earliest located approximately 50m east from 1953 mapping until the present, with the remainder appearing to the southeast of the site from 1970 mapping onwards. The closest is a depot abutting the south-eastern boundary
Railway line and goods depot	Adjacent to NW	Prior to 1848-Present	A railway line running northeast from the nearby Victoria Station is present on all historical mapping.
	Adjacent to SE	1891-1965	Railway lines connected the gas works on site to Oldham Road goods station towards the southeast of the site, these are largely removed prior to the 1970 mapping.
Unspecified works	From 10m northeast	1970-Present	Unspecified works are present on historical mapping from the 1970 to the present, whilst the works are still present it is unclear whether they are still in use. Further works are adjacent from the 1978 mapping approximately 40m northeast of the site, this is removed prior to the 2009 aerial photography of the area.
Tobacco works/ factory	10m west	1908-Present	Tobacco works are present from 1908 mapping approximately 10m west of the site to the present, noted to expand prior the 1949 mapping. Present day use of these structures appears to be residential apartments, it is unclear when this change of use took place.
Rubber works	50m NW	1892-2003	Rubber works are present to the northwest of the site from 1892 mapping to the 2003 mapping and are largely removed in the subsequent aerial photography.
Asphalt works	50m N	1953-1980	Asphalt works are present approximately 50m north of the site in place of the previous foundry/bolt and nut works from 1953 mapping till the 1980 mapping where it is replaced by a depot.
Foundry/ Bolt and Nut works	50m NW	1891-1953	Whilst not described as such until 1908 mapping, the bolt works first appears on mapping from 1891 approximately 50m north of the site to the 1953 mapping, with the addition of a chimney in 1908 and being renamed to Collyhurst Foundry in 1949. It was replaced by the asphalt works and the adjacent rubber works.
Bus Depot	80m E	1949-1993	A trolley bus depot is present approximately 80m east of the site from the 1949 mapping till the 1993 mapping, the location Is now used as parking.
Police Station	80m E	1978-2010	A police station is present approximately 80m east of the site from 1978 mapping to the 2010 mapping, the location Is now used as parking.
Tanks	95m N	1949-1965	2 tanks of unknown use are present approximately 95m north of the site from 1949 mapping to the 1965 mapping.
Paper works/ Warehouse	95m SW	1893-2000	A paper works is present approximately 95m southwest of the site from 1893 mapping to the 2000 aerial photography, being replaced by residential apartments prior to the 2009 aerial photography. It is listed as ruins in the 1953-1958 mapping (possible WWII bomb damage) and as a warehouse from the 1970 to 1988 mapping wherein it was described as works.

In summary, the map evidence indicates that the site has included industrial use as gas works from prior to the earliest mapping up until the 1980s, thereafter parts of the site were in use as a depot/call centre, a maintenance garage, Gas Pressure Reduction System (PRS) and most recently for car parking.

Historical land use in the surrounding area has been predominantly industrial with various works, depots, garages, railways in the surrounding area. Further to the Gas Works on site, an additional Gas Works (Rochdale Road) was also located circa 125-150m north between 1892 and 1970., which lies between the subject site and the River Irk further to the north for reference.

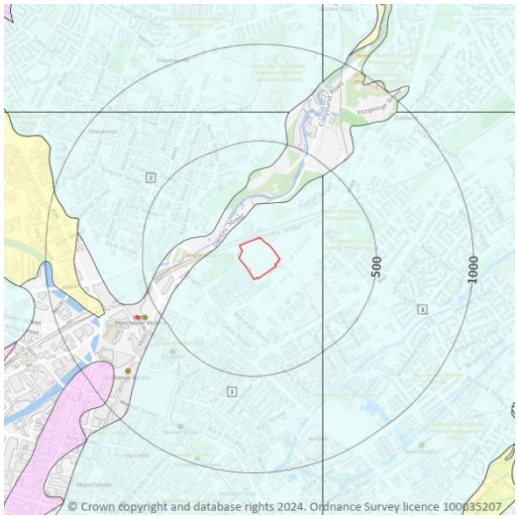
3.2 Published Geology

The following publications of the British Geological Survey (BGS) were examined in respect of the geology underlying the site:

- British Geological Survey (BGS) 1:50,000 Scale Geological Map Sheet 85 Manchester. Solid and Drift Edition.
- BGS Geology of Britain Map Viewer.
- BGS GeoIndex Onshore.
- Coal Authority Interactive Map.
- Geo-Environmental Data Report.

Extracts of the 1:10,000 geological mapping from the Geo-Environmental Data Report are presented below for reference:

BGS 1:10 000 Superficial Geology



BGS 1:10 000 Solid Geology



Made Ground
BGS mapping indicates the presence of made ground deposits (undivided) across the entire site. Based on the historical mapping and the development that has taken place, significant made ground deposits are highly likely to be present.

Superficial Deposits
The site is indicated to be underlain by glacial Till. This stratum typically comprises clays, sands and gravels.

Solid Geology
The deeper solid geology is indicated to be part of the Chester Formation which typically comprises Sandstone.

No faults are shown on or within an influencing distance of the site

3.3 BGS Exploratory Hole Records

There are no BGS exploratory hole records within a relevant distance of the site (assumed as an approximate 50m radius).

3.4 Mining and Mineral Extraction

Coal Mining
The online Coal Authority Interactive Map layers have been reviewed and the details are summarised in the table below:

Relevant Interactive Map Data	Issue at Subject Site?
Coal Authority Reporting Area	Yes
Development High Risk Area	No

As the site lies within the Coal Authority Reporting Area, a mining search has been undertaken as the site could be affected by past or current coal mining. The mining searches are presented in Appendix D, the main findings of which are presented below.

Highlighted Evidence	Issue	Details
Past Underground Mining	Yes	The property is in a surface area that could be affected by underground mining in 2 seams of coal at 395m and 760m depth, last worked in 1965. Any movement in the ground due to coal mining activity should have stopped.
Present Underground Mining	No	
Future Underground Mining	No	
Mine Entries	No	
Past, present and future opencast coal mining	No	
Coal mining subsidence	No	
Mine gas	No	
Withdrawal of support	Yes	The property lies within an area where a notice of entitlement to withdraw support has been published. Notices were issued in 1955 and 1963. The property does not lie within a geographical area in which a revocation notice has been given under section 41 of the Coal Industry Act 1994

3.5 Hydrogeology

Based on the inferred geology, a summary of the Environment Agency aquifer designations is presented in the table below:

Stratum	Coverage	Aquifer Designation
Glacial Till	Full Site	Secondary Aquifer (Undifferentiated). The classification is assigned where it is not possible to attribute either category A or B to the aquifer.
Chester Formation	Full Site	Principal Aquifer. This is Geology of high intergranular and/or fracture permeability, usually providing a high level of water storage and may support water supply/river base flow on a strategic scale.

A summary of the pertinent hydrogeological features within the Geo-Environmental Data Report are provided below:

Feature	Distance (m) & Direction	Details
Nearest Active Groundwater Abstraction	612m NW	Licence No: 2569004011 Details: Process Water for Brewery Direct Source: Ground Water – North West Region Point: BOREHOLE AT DERBY BREWERY, CHEETHAM, MANCHESTER 3 Annual Volume (m3): 75,000 Original Start Date: 17/02/1966
Nearest Active Potable Groundwater Abstraction	612m NW	Whilst the record above is not officially recorded as potable, given the activity and location it is considered possible that this may ultimately be used as drinking water once treated (i.e. as alcoholic beveridges). The nearest active potable groundwater abstraction is over 2000m away.
Source Protection Zones	-	None within 500m.

3.6 Hydrology

A summary of the pertinent hydrological aspects within the Geo-Environmental Data Report are provided below:

Feature	Distance (m) & Direction	Details
Nearest Watercourse	117m NW	River Irk. N to S flow.
Nearest Surface Water Abstraction	-	None within 2000m
Closest Active Licenced Discharge Consent	118m NW	Permit Number: 01MAN0310 Effluent Type: SEWAGE DISCHARGES – SEWER STORM OVERFLOW Receiving Water: RIVER IRK Issue Date: 21/03/2018 Effective Date: 01/04/2018

Information obtained from the Environment Agency (EA) Risk of Flooding from Rivers and the Sea (RoFRaS) database indicates that the risk of flooding across the site is negligible.

The British Geological Survey indicate there is a potential for groundwater flooding at the subject site, with a low to moderate risk rating.

No further consideration of flood risk is undertaken in this report. Specialist flood risk advice should be sought with regards to drainage and flooding.

3.7 Landfill and Waste Management Sites

There are two recorded historic landfills within 500m, the nearest is recorded 361m north at Queens Road Tip, registered to Manchester City Council, stated to accept Inert, industrial, household, commercial, special, liquid sludge wastes between 1955 and 1970.

There are four current waste management sites recorded within 250m of the site, the nearest is recorded 54m north at Warford Street off Dantzic Street, registered to Farlam Waste Management, a waste transfer station which is licenced to accept household, commercial and industrial waste from 2007, no end date is supplied.

There is one historical waste management site recorded as a scrap metal yard, located 34m to the northwest of the site. There is limited information provided on the waste site, except that it appears to have ceased operations in the 1980s.

3.8 Environmental Regulatory Data

A summary of the relevant environmental aspects, both on site and within 250m of the site contained in the Geo-Environmental Data Report, are presented in the table below:

Entry	On-site	0 – 50m	50 – 250m	Details
Recent Industrial Land Uses	2	8	18	The two on-site entries are listed as an electrical substation towards the west of the site, and a telecoms mast towards the east of the site. Other notable entries include various garages and vehicle body shops located within 50m of the site, the closest located 9m NW.
Current or Recent Fuel Stations	-	-	1	The nearest current or recent fuel station is listed as 130m southeast and is listed as obsolete.
Licensed Industrial Activities (Part A(1))	-	-	-	None within 250m.
Licensed Pollutant Release (Part A(2)/B)	1	-	5	The entry on-site is listed as a historical permit and the process as Vegetable Matter Drying Processes at Manchester Tobacco Ltd, Ludgate, Manchester. This is likely related to the tobacco works historically near the site. The other entries listed in close proximity to the site are historical.
Radioactive Substances	-	-	1	The entry is listed as 226m southwest of the site at Brooke Edgley Specialist Technical Services Ltd related to the disposal of radioactive waste, effect from 07/08/2000 and was revoked/cancelled as of 01/01/2015.
Pollution Incidents (EA/NRW)	-	-	2	The closest record was in 2001 and was 171m to the north, it is recorded as construction and demolition materials and wastes and a Category 3 (minor) impact to land. The other incident was 216m to the northwest and is recorded as waste materials including household and commercial waste, tyres and asbestos which had a Category 2 (significant) impact to land and a Category 3 (minor) impact to air.

In regard to the entries identified above, only the on-site electrical substation and various nearby garages are considered to be of significant relevance to be carried forward to the preliminary CSM. No other entries require further consideration based on these being either historical or sufficient distance from the site to present no significant concerns.

3.9 Radon

Information from the environmental database report indicates the property is in an area where <1% of properties are above the Action Level for radon, and therefore basic radon protective measures are not required in accordance with BRE Report 211 'Radon – Guidance on protective measures for new dwellings'.

3.10 UXO Risk

In accordance with CIRIA Report C681, BSL have reviewed non-specialist UXO data for the site using the online Zetica Bomb Risk Mapping data.

There is no indication of former military use from the Phase I Assessment. The map indicates the site to be in an area where the bomb risk is moderate. A copy of the map is presented in Appendix E.

The 1949 National Grid mapping shows a "ruin" in the western area of the site and areas of missing housing, suggesting bomb damage. This is most likely as a result of WWII bombing given the mapping date.

Since the site is considered to be at moderate bomb risk, in order to determine if and what further action may be required to mitigate the risk, a UXO detailed desk study was produced on the site by EOD Contracts Ltd at BSLs request, (report reference EOD/24/24210/DTS/REV1/Gould Street, Manchester, M4 4BH, dated 12 June 2024). Its findings are as follows:

The report was able to demine moderate risk areas of the site where supervision by a UXO engineer and scanning of intrusive position with a magnetometer would be required as highlighted within the yellow hatched areas below:



In addition, UXO awareness safety briefings should be provided to all site personnel. These areas would also present a risk during any below ground future excavation works or piling; this should be considered during the construction phase under CDM requirements.

3.11 Other Potential Development Constraints

A formal survey of asbestos within structures is not covered in this report. It should be noted that an asbestos demolition / refurbishment survey will be required prior to any work on structures. If asbestos is present in soils, these will need to be dealt with in accordance with the Control of Asbestos Regulations (CAR) 2012 and CARSOILS™.

There are known services on site, these may need to be disconnected prior to any construction activities. A telecoms mast is present in the eastern part of the site and a gas line is present across the site in an east to west direction

4.0 SUMMARY OF PREVIOUS REPORTS

A review of the previous ground investigation, consultancy and remedial works carried out on the former gas works site is presented in the section below in order to address element (b) of Condition 4 under MCC planning application 128248/FO/2020. This review focuses mainly on the environmental elements of the previous reports and does not include any elements of geotechnical assessment.

For ease of summation, areas where information has been repeated in subsequent reports, such as the site history and ground conditions, have been excluded in the review of the reports below.

4.1 Parkman - Site Investigation Report (1992/1993)

This investigation comprised sixteen shallow trial pits to a typical maximum depth of 3.5m bgl, they were all terminated within made ground or on obstructions. Twenty-seven soil samples were tested for a range of PAHs, metals, sulphates, chlorides, cyanides, phenols, cresols and loss on ignition.

The report available appears incomplete with no text available for review. An inspection of the laboratory test results reveals a range of elevated determinands present, although several samples did not reveal any concentrations above the limits of detection achievable at the time.

4.2 Entec UK Limited - Site Investigation Report Factual (February 2003)

The site is located at Gould Street, Central Manchester at National Grid Reference 384672 399254 (SJ 84672 99254) and covers an area of 2.67 hectares and is currently used as a call centre with associated parking. A Pressure Reduction System (PRS) is present in the centre of the site.

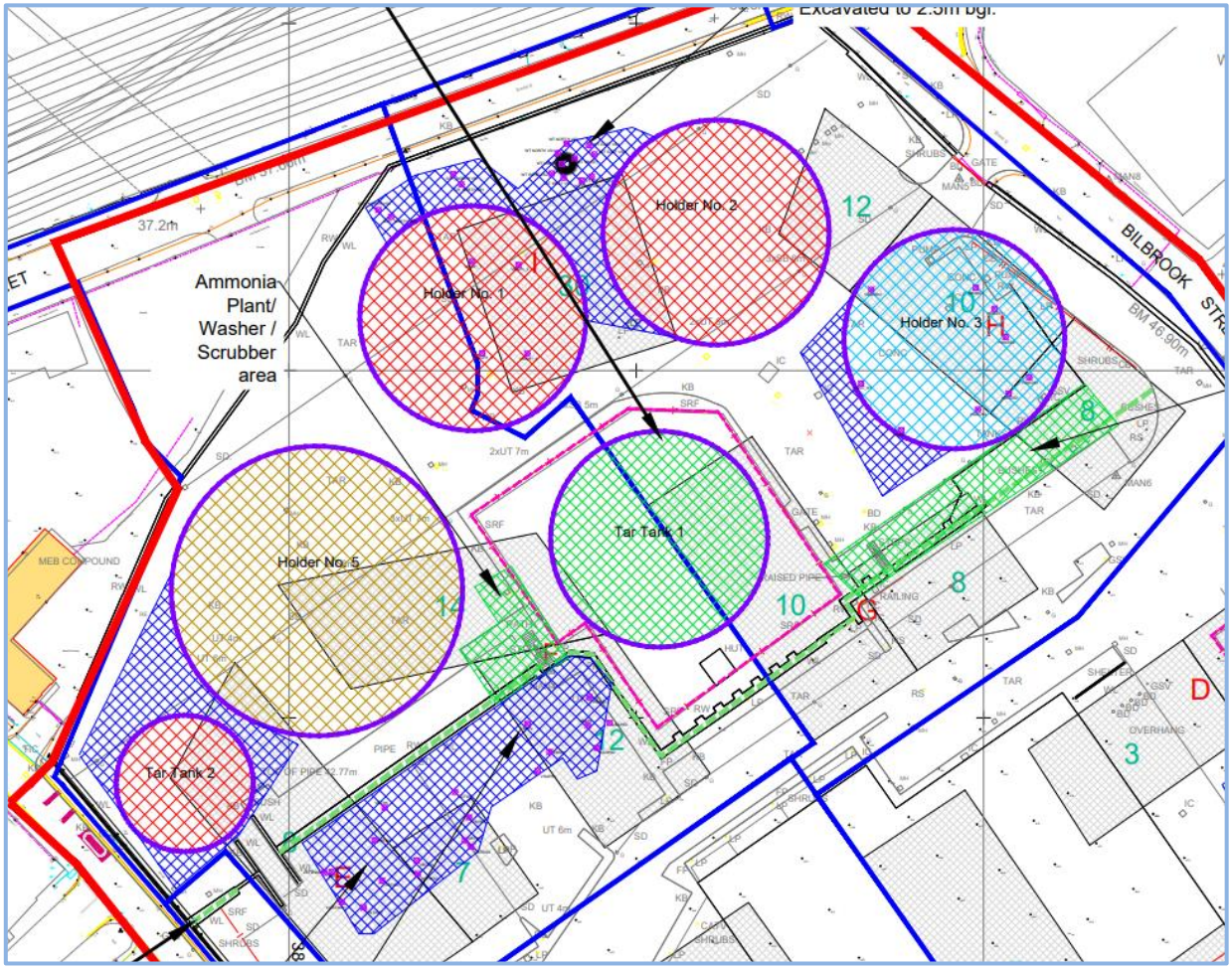
The site was previously used for the production and storage of gas, with an operational gas works present on site since 1824. The works started in the northwestern area of the site and then expanded south and east to cover the full site area. At its full extent, the retorts were present in the south of the site, with the holders and tar wells in the north. The purifiers, washers and condensers were present in the central area.

Published geological data indicates the site is located on glacial Till overlying sandstone bedrock. Fluvio-glacial deposits within the glacial Till were classified as a Minor Aquifer (classification now superseded), whilst bedrock was classed as Major Aquifer (also superseded). A total of fourteen groundwater abstractions were identified all of which are located between 800m and 1km from the site to the northwest.

The River Irk is located approximately 250m to the northwest of the site, at an elevation which is approximately 15m below the ground level of the site. The river is classified as Quality E - Poor.

Historic drawings of the former gas works show a sewer identified as 2ft wide by 2ft 6inches thick in size, but present at 37ft deep (11.30m bgl), shown running from Charlotte Street in the north between Gas Holders 5 and no 1 and south to the east of Tar Tank 1 where its course is not identified. It would have appeared to have picked up drainage from the valves at the base of some of the holders.

An inspection of historical maps by Entec has revealed three early small gas holders to be present in the northwest of the site. These were subsequently demolished and replaced by Tar Tank 1 and Holder 5. Holders 1, 2 and 3 were also constructed at a later date across the north of the site with Tar Tank 1 constructed just to their south. The base of the gas holders and tanks is typically reported as being between 8.00m and 9.00m bgl. Tank and holder names are displayed on the below:



The southern area of the site was historically occupied by the gas works process buildings, including purifiers, scrubbers, a retort house and a liquid purification plant.

The site Investigation comprised the following:

- 28 No. boreholes, 26 No. window samples, 29 No. trial pits and 13 No. hand dug pits excavated across the site. The exploratory holes were positioned around the structures on site present at the time which included:
  - A small security office at the entrance to the site, on the western boundary.
  - A large three storey office block used as a call centre in the south of the site.
  - Maintenance building/garage in the northeast of the site.
  - Telecommunications mast and small compound.
  - Substation on the western boundary close to site entrance gate.
  - Existing underground Transco pipework and infrastructure.
- A geophysical survey of the north of the site was carried out to profile major structures underground including the gas holders and tar wells and process buildings, all of which had been demolished prior to the investigation.
- The exploratory wells were drilled both inside and outside the former gas works structures including the tar wells and gas holders.
- 176 No. soil samples were tested for the following basic suite of determinands:
  - pH, loss on ignition, moisture content, stone content, exchangeable ammonium, water soluble sulphate, water soluble chloride, elemental sulphur, phenol (total and speciated), PAHs (total and 16 USEPA Priority), total metals (As, B, Cd, Cr, Cu, Pb, Hg, Ni, Se, Zn), easily liberated cyanide, total cyanide.

  - Selected samples were also tested for BTEX compounds, thiocyanate, asbestos and total petroleum.
- 26 No. groundwater samples were tested for the following suite of determinands:
  - pH, conductivity, suspended solids, total organic carbon, ammoniacal nitrogen, thiocyanate, sulphate, sulphide, total and free cyanide, phenols (total and speciated), PAHs, metals (As, Cd, Cr, Cu, Pb, Hg, Ni, Se, Zn, Fe), BTEX, TPH (expressed as diesel range organics).
- 24 No. soil samples were selected for leaching tests to allow an assessment of the potential for absorbed phase contaminants to partition as dissolved phase contaminants in groundwater.

The ground conditions encountered during the investigation are summarised below.

Made ground comprised of variable brick rubble and clayey sand and gravel, with the maximum depth of made ground encountered inside former Gasholder 1 where it extended to 9.3m bgl. The thickness of made ground generally increased northwards across the site, although was significantly influenced by the presence of infilled former structures. A large number of obstructions associated with the former gas works infrastructure were encountered.

Glacial Till was found to underlie the made ground in all exploratory holes which fully penetrated the latter. The top of the Glacial Till was encountered between 44.65m and 36.58m AOD, with the interface sloping down towards the northwest, which is consistent with the overall site topography. The Glacial Till was generally composed of firm to stiff, reddish brown, clay with varying amounts of sand and gravel. Fluvioglacial deposits were found within the Till primarily towards the base.

Sandstone bedrock was encountered below the Glacial Till deposits in the deeper boreholes in the north and southwest of the site. The weathered top of the bedrock was interpreted to be present between 28.48m and 31.35m AOD, again sloping down towards the north west.

Varying amounts of visual and olfactory gas works waste were encountered in numerous exploratory holes down to depths of 17m bgl during the investigation.

Groundwater was found to be perched within the made ground associated with structures and also present at depth within the Glacial Till at levels between 37.6m and 34.7m AOD. Groundwater within the sandstone was monitored at levels between 26.8m and 25.7m AOD.

4.3 Entec UK Limited - Factual Supplementary Site Investigation Report (October 2009)

Entec UK Ltd was commissioned by National Grid Property Holdings Ltd (NGPH) to undertake a supplementary site investigation to provide additional information to inform a detailed remediation design for the former gas works. The previous environmental assessment indicated a number of pollutant linkages requiring either further assessment or remedial action.

Note this environmental assessment has not been made available for inspection by BSL. However, the following Hydrogeological Risk Assessment report produced in March 2010 by Entec UK Limited summarised the findings which have been included below.

The objectives of the supplementary site investigation were as follows:

- Provide information to inform a Human Health Quantitative Risk Assessment (HHQRA) for the existing office to be re-occupied. Determine the presence or absence of contamination relating to former benzol plant and retort footings below the footprint of the building.
- To determination the costs for disposal of tar within Tar Tank 2.
- Provide further information (including WAC data) on backfill to in-ground structures, particularly the former holder bases containing spent oxide and residual tar.

- Complete wells within the underlying sandstone (then classed as a Major Aquifer) to update the conceptual site model for the Controlled Waters Quantitative Risk Assessment (CW QRA).
- Trial pits targeting previously unidentified structures and obtaining further information where previous data was limited.

The investigation comprised the following:

- 7 No. boreholes (BH301, 302, 302A, 303, 303A, 304 and 305) drilled by cable percussive methods to depths of between 0.5m bgl to 18.5m bgl. Two of the borehole locations (BH302 and BH303) were abandoned due to obstructions (concrete and a possible basement). These locations were replaced by BH302A and BH303A, respectively.
- 2 No. boreholes advanced with rotary drilling (boreholes BH301, 302A and 303A) to depths of 24.0 m and 26.5m bgl into the competent Sandstone.
- 10 No. window sample holes (WS301 to WS310) were drilled to depths ranging between 1.25m and 3.0m bgl through the ground floor slab of the large building in the south of the site.
- 13 No. trial pits (TP301 to TP313) were excavated to depths ranging between 1.6m to 6.0m bgl.
- 67 No. soil samples were tested for the following basic suite of determinands:
  - pH, loss on ignition, moisture content, stone content, exchangeable ammonium, water soluble sulphate, water soluble chloride, elemental sulphur, phenol (total and speciated), PAHs (total and 16 USEPA Priority), total metals (As, B, Cd, Cr, Cu, Pb, Hg, Ni, Se, Zn), free cyanide, complex cyanide, total cyanide, thiocyanate BTEX and total petroleum hydrocarbons (EC10 to EC40) (formerly known as DRO).
  - Selected samples were also tested for TPH-CWG, fraction of organic carbon (FOC), SVOC, VOC and Waste Acceptance Criteria (WAC).
- 13 No. groundwater samples were tested for the following suite of determinands:
  - pH, conductivity, suspended solids, total organic carbon, total ammonium, thiocyanate, elemental sulphur, sulphate, sulphide, chloride, total, free and complex cyanide, phenols (total and speciated), PAHs, metals (As, Cd, Cr, Cu, Pb, Hg, Ni, Se, Zn, Fe), BTEX including MTBE and TPH (EC10 to EC40).
  - Selected samples were also tested for TPH-CWG, whole oil and age profiling of oils.
- 3 No. soil samples were selected for leaching tests to allow an assessment of the potential for absorbed phase contaminants to partition as dissolved phase contaminants in groundwater.

The ground conditions encountered were similar to those anticipated from the previous investigation. The ground conditions generally consisted of a layer of made ground identified to a maximum depth of 9.3m bgl in Gas Holder 1. Obstructions were also identified in numerous exploratory holes.

The made ground was again found to overlie glacial deposits with sandstone at depth. The glacial deposits comprised glacial Till with layers of fluvio-glacial sand and gravel.

Groundwater was found to be present within man made structures in the made ground and within the sandstone. During this investigation, groundwater was not encountered within the fluvio-glacial deposits.

Visual and olfactory evidence of contamination was encountered in several areas of the site and the location and form of a number of underground structures was confirmed.

Monitoring of VOCs was undertaken with a PID during both Entec site investigations (2002 and 2009) as part of the gas monitoring visits. Readings of up to 3,031 ppm were recorded using the PID in 2002, with the highest readings recorded from BH3B (adjacent to Holder No.1) and BHC3 (within Holder No.1).

Monitored levels recorded during 2009 were significantly lower at these locations. The highest recorded levels during the 2009 monitoring visit were in BH02 where 32 ppm was noted and BH02A located adjacent to Tar Tank 2 where 39 ppm was recorded.

4.4 Entec UK Limited - Hydrogeological Risk Assessment (March 2010)

The objective of the report was to assess the risks to surface water and groundwater from contamination at the Gould Street Site, using the Environment Agency's Remediation Target Methodology to determine remedial targets for soil and groundwater remediation.

The Site Conceptual Model produced at the start of this report is outlined below and was formed based on the investigation data from the initial 2003 and 2009 supplementary investigations.

The site is underlain by made ground over glacial deposits. The glacial deposits comprise a sequence of glacial Till (clay) and fluvio-glacial sands. These deposits cover most of the site and overly the Wilmslow Sandstone Formation, which is part of the Sherwood Sandstone Group.

The glacial deposits include two fluvioglacial sand layers separated in the west of the site by glacial Till. In the east of the site, the Glacial Till is absent, and the upper and lower fluvioglacial layers are in hydraulic continuity with the underlying Wilmslow Sandstone Formation (a Principal Aquifer).

Shallow groundwater in the glacial deposits flows to the east and northeast of the site, where it is suspected to then drain vertically into the underlying sandstone aquifer at a location where the Glacial Till is absent. It is likely most groundwater within the glacial deposits at the site enters the sandstone aquifer in the eastern part of the site, and to the east of the site boundary.

Groundwater in the shallow aquifer is unlikely to provide base-flow to the River Irk as groundwater flow within this layer is not towards the river. The regional groundwater flow direction in the sandstone is towards the southwest. Locally, and beneath the site, groundwater flow is to the north towards the River Irk, in the same direction as the topographic gradient.

Soils Contamination
The assessment identified elevated concentrations of inorganic and organic contamination were associated with the contents of former gasworks structures, notably the gasholder bases and tar tanks. This was present in the form of tars and spent oxide, with elevated concentrations of Polycyclic Aromatic Hydrocarbons (PAHs), BTEX compounds (benzene, toluene, ethyl benzene and xylenes), phenols, complex cyanide, elemental sulphur and exchangeable ammonium.

Phenols were detected in the made ground both within structures at between 3.0 to 8.0m bgl (supply well, Gas Holder 2, Tar Well 1, historical tar pits (above the pits), and in soils adjacent to these structures. Phenols were also detected in soil at the southern part of the site boundary (WS01, WS02 and WS04) and associated with soils in the vicinity of the Condenser Plant, and adjacent to Gas Holder 3 at between 1-3m bgl. The maximum concentration measured in soil was 610 mg/kg of total phenols at the location of the historic Tar Well (BH11). Concentrations of total phenol greater than 100 mg/kg were found in soils from the Transco PRS compound (associated with Tar Well 1) and in shallow soils along the southern boundary of the site.

PAHs were detected over most of the site. Concentrations of total PAHs above 1,000 mg/kg were found in shallow (0.2 to 1.7m bgl) made ground to the north-west of Tar Well 2 and Gas Holder 5 and at the supply well, along the southern boundary of the site, around the condenser plant and above the historic Tar Well roof (at 4m bgl). The highest total PAH concentration of 8,100 mg/kg was in soils at BHC2, within Gas Holder 5.

BTEX compounds were identified in soil samples from the western corner of the site adjacent to the ammonia plant/PRS compound and Gas Holder 3; and in soils adjacent to Gas Holders 5 and 1, Tar Well 2. The maximum concentration of 22 mg/kg of toluene was identified at BH11 above the historic tar pits. A maximum benzene concentration of 9.7 mg/kg was identified in soil located adjacent to the ammonia plant/PRS compound and Gas Holder 3. Maximum concentrations of ethyl benzene (2 mg/kg) and xylenes (7 mg/kg) were found in a soil sample from WS01 on the southern boundary of the site.

Elevated concentrations of hydrocarbons (identified by TPHCWG analysis) were identified in made ground in the vicinity of Gas Holder 5 and Tar Tank 2, and adjacent to the disused site water supply well, the southern boundary of the site, and next to Gas Holder 3. The more elevated concentrations were between 10,000 and 52,000 mg/kg were identified in soils sampled from above the historic tar pits and in soils at the southern boundary of the site at WS01.

Several toxic and phytotoxic metals were detected on site including arsenic, chromium, lead, copper, zinc, boron and nickel. These species were detected throughout the made ground at depths of up to 1-5m bgl and up to 8m bgl in BHC2, at concentrations up to 100 mg/kg. Only copper, lead, nickel, chromium and zinc were present at concentrations greater than 100 mg/kg up to levels above 1,000mg/kg for lead (soil from the supply well, adjacent to Tar Well 1 and the condenser plant), chromium (Gas Holder 1) and zinc (Gas Holder 5).

Both free and complex species of cyanide were detected in the made ground next to all the gas holder structures on site, and also in the vicinity of the condenser plant. Total cyanide concentrations were measured at a maximum of 3,700 mg/kg in soils adjacent to the former condenser plant area and Tar Well 1. Elemental sulphur was identified to the north of Gas Holders 1 and 5, and also in the location of the ammonia plant. Concentrations of water-soluble sulphate greater than 1,000 mg/kg were identified across the site, with maximum concentrations identified in BHC2 of 6,200 mg/kg.

Ammonium was identified across the site at concentrations of between 10 and 200 mg/kg. Areas with elevated concentrations (greater than 200 mg/kg) in made ground included the soil above the historic tar pits, and north-west of Gas Holder 5 (BHC2 at 8.0m bgl). Low levels of ammonium (> 10 mg/kg) were also identified at 3.0m bgl in BHC2 suggesting localised contamination, and in TP08 and TP12 near to the condenser plant location.

Within the glacial deposits and the sandstone, phenols at concentrations greater than 9 mg/kg (Total Phenols) were found in natural ground in BH2 (at 8.5m bgl) and BH2A (at 8.3-10.7m bgl) at the western corner of the site, and at WS16 at the condenser site at 2m bgl. The maximum concentration of 780 mg/kg Total phenols was identified in soil at 8.5m bgl in BH2 located adjacent to Gas Holder 5 and Tar Well 2.

BTEX compounds were detected in natural ground in BH6 at 9.9m bgl and BH7 at 9.7m bgl. Concentrations of benzene greater than 200 mg/kg were identified in soil at 8.3m bgl from BH2A, adjacent to Gas Holder 5 and Tar Well 2. Soil samples at increasing depth from BH2A show decreasing concentrations of benzene, i.e. 6 mg/kg at 9.8m, 0.068 mg/kg at 10.7m and less than detection limits at 14 and 16m bgl. This suggests that downward migration of BTEX has occurred but also provides evidence of attenuation with depth.

Hydrocarbons (determined by TPHCWG analysis) at a concentration of 19,000 mg/kg were identified in natural ground in BH2 at 8.5m bgl and 630 mg/kg at BH2A (at 8.3m bgl). Elsewhere concentrations were typically less than 200 mg/kg.

Exchangeable ammonium was present in all samples of natural ground and generally showed higher concentrations at depths between 4.0m to 10m bgl. The maximum concentration was 350 mg/kg at BH6 (between Tar Well 1 and Gas Holder 1).

Samples of soil from depths below 15.0m bgl at BH1, BH3A and BH5A, i.e. within the underlying sandstone aquifer show no detectable contaminant concentrations.

Groundwater Contamination
Groundwater sampling and analysis has demonstrated that both the shallow glacial deposits aquifer and the deeper sandstone aquifers have been impacted by contamination.

The main contaminants of concern are PAHs, phenols, benzene, toluene, ethyl benzene and xylenes (the BTEX compounds), ammonium, cyanide, zinc, lead, nickel, mercury, cadmium and sulphate. The contaminant source for the shallow glacial deposits' aquifer is likely to be contaminated soils within and adjacent to historical structures.

Leakage of water and tar in historical structures (e.g. Gas Holder 5) is likely to be the principal source of deeper contamination within the sandstone. This is because the bases of historical structures partially penetrate the glacial deposits.

Made ground groundwater samples contained arsenic, nickel, cadmium (once at BHC2A) and lead at concentrations above Drinking Water Standards (DWS). Soil leachate samples contained concentrations of arsenic and nickel above DWS, whilst nickel, cadmium and lead were not detected.

Samples of groundwater from the sandstone aquifer contained nickel (at BH2A, BH3A and BH5A) and lead (at BH2A and BH4) above DWS. For arsenic, cadmium and lead the DWS is lower than the maximum reported background concentration for the Manchester and East Cheshire area.

Cadmium, lead, mercury, cadmium, nickel and arsenic were considered to not pose an unacceptable risk to identified receptors either because the levels detected are below DWS or they are at or below background concentrations.

Ammonium is present at elevated concentrations (above DWS) throughout all sampled media on the site and therefore poses a risk to downgradient receptors.

Sulphate concentrations in made ground groundwater were up to 4,000 mg/l or up to 16 times the DWS. Background concentrations of sulphate can be up to 666 mg/l (about 2.5 times the DWS). It is considered that the majority of sulphate concentrations identified in groundwater reflect variations in background concentrations in the glacial deposits. Consequently, sulphate was not considered within the quantitative risk assessment.

Cyanide was also present across the site at concentrations above DWS, in shallow and deep groundwater and in made ground perched groundwater. Cyanide will biodegrade to ammonium plus either bicarbonate or formate, depending on redox conditions (Meehan, 2000). The redox conditions beneath the site were not known, however it was assumed that available dissolved oxygen would be limited (as previously described) and therefore cyanide was modelled as part of a quantitative risk assessment.

Benzene has been identified at concentrations of 7.6 mg/l in groundwater, mainly associated with perched groundwater. It was not detected in groundwater from the sandstone aquifer. Benzo(a)pyrene was present above DWS in groundwater in the shallow and deep aquifers, and in three soil leachate samples from made ground. In some groundwater samples from made and natural ground the dissolved concentrations of heavier PAHs were reported as greater than that of lighter species. However, the aqueous solubility of lighter PAHs is much greater than that of heavier species. It appears likely that the more elevated dissolved concentrations, which are above literature solubility Values, are not representative of the dissolved phase and instead are due to the presence of suspended solids.

The reported groundwater concentrations of benzo(a)pyrene in samples with lower suspended solids content (less than 5,000 mg/l) ranges between 31×10^{-6} and 1600×10^{-6} mg/l. As the water quality target for benzo(a)pyrene is 1×10^{-5} mg/l it was considered likely that these representative concentrations of benzo(a)pyrene identified in groundwater samples will not pose a risk to receptors. As a result, benzo(a)pyrene was not considered further.

Hydrocarbons (TPH) in the carbon ranges C10 to C20 and C20 to C39 have also been detected in groundwater. The same groundwater samples have shown elevated naphthalene and benzene, both of which occur within these carbon bands. Therefore, it was assumed that the use of remedial targets for naphthalene and benzene in soil clean-up will also remove the risk posed by the TPH identified in soils on site. TPH bands were not therefore modelled as part of the risk assessment.

Elevated concentrations of total phenols were identified in leachate from leaching tests of soil samples from the made ground and the upper fluvio-glacial layer. The highest concentrations were noted in shallow soils sampled from above the historic tar wells and at the southern boundary of the site. Total phenols were mainly detected in, and, only exceeded the EQS in shallow groundwater in made ground. This suggested that phenols are not likely to pose a risk for the deep groundwater receptor.

Risk Assessment Remedial Targets
A groundwater risk assessment was undertaken by Entec to derive remedial target concentrations (RTCs).

Based on the above qualitative assessment, the quantitative risk assessment considered ammonium, total cyanide, naphthalene (representing PAHs) and benzene (representing BTEX compounds). The risk assessment was conducted using conservative assumptions about hydrogeological and geochemical parameters. RTCS were calculated for compliance points at 50m and 100m downgradient of the source.

Comparison of the RTCs for soils against observed soil concentrations indicates that for compliance points of 50m and 100m for the sandstone aquifer the following applies:

- Naphthalene, benzene and ammonium presents a risk of exceeding the Water Quality Threshold (WQT) at the compliance points.
- Phenol and total cyanide do not appear to present a risk of exceeding the WQT at the compliance points.

The results for Level 3 of the groundwater risk assessment indicate that for the compliance points of 50m for the sandstone aquifer the following applies:

- Ammonium presents a risk of exceeding the WQT at the compliance points.
- Naphthalene, benzene total cyanide and phenol do not appear to pose a risk of exceeding the WQT at the compliance points.

Entec concluded that the general absence of phenol and the low concentrations of total cyanide (and the absence of easy to liberate cyanide, free cyanide) in sandstone groundwater (at BH2A and BH3A) downgradient of sources support the results of this assessment, that suggests that these substances pose a low risk to downgradient groundwater.

The results for Level 3 of the groundwater risk assessment indicate that for the compliance points of 100m for the Sandstone aquifer the following applies:

- Ammonium presents a risk of exceeding the WQT at the compliance points.

- Naphthalene, benzene, total cyanide and phenol do not appear to pose a risk of exceeding the WQT at the compliance points.

Ammonium concentrations in groundwater exceed the calculated RTCs at most locations. However, it is unlikely that remediation of the site to the RTCs for ammonium is practical or technically feasible. The glacial deposits will likely sorb a significant proportion of ammonium ions through the process of cation exchange and Entec proposed RTCs for ammonium of 200mg/kg for made ground and 400mg/kg for glacial deposits.

The risk assessment has shown that the observed concentrations of ammonium in the sandstone aquifer represent a risk to down-gradient receptors. A remedial targets concentration for ammonium in groundwater has been proposed.

The maximum concentrations of ammonium in shallow and deep groundwater were measured in boreholes down hydraulic gradient of underground structures. It was recommended that the following measures be implemented to ensure that the impact on the sandstone aquifer from ammonium is mitigated and reduced in the long term:

- Contaminated materials (particularly tars) within underground structures should be removed, as far as is reasonably practicable.
- The deeper underground structures are either partially backfilled with low permeability material or a low permeability seal is constructed to prevent the downward migration of contaminants (from the shallow aquifer) to the sandstone aquifer in the future.

For benzene and naphthalene, the 50m remedial target suggests that remediation is required at the following locations:

- Historic tar tanks (BH11, TP309).
- Tar Well 2 (TP25A, TP24, BH2, TP308, TP311).
- Ammonia plant (TP307).
- Condensers/ purifiers (TP304, WS19).
- Gas Holders (BHC2, BH7, TP312).
- Southwest corner (TP1).
- Southeast corner (WS13).
- Beneath the call centre (WS301).

However, for a compliance point of 100m, the remediation of soils would not be required.

Remedial target concentrations for these determinands are proposed as follows:

- Benzene 5 mg/kg.
- Naphthalene 250 mg/kg.

Entec concluded that the above remedial targets are suggested as being reasonably protective of downgradient groundwater, whilst likely to be technically feasible.

4.5 Entec UK Limited - Stage 5 Remediation Strategy Report (September 2010)

The above Remedial Strategy was supplemented by a Phase 1 and 2 Supplementary Specification which precisely detailed the Performance Specification for Stabilisation of Holder Tanks No.1 and No.5 and the remedial requirements for Tar Tank 2.

Entec stated that key sources have been identified as made ground, most notably backfilled materials to:

- Tar Tank No.1.
- Tar Tank No.2.
- Two tar wells.
- Gas Holders No.1 and No.5.
- Water supply well.
- Gas Holder No.3.
- Made ground in the area of the former condensers/purifiers, ammonia plant, retorts and in discreet areas along the southern boundary.

Secondary sources have also been identified in the north-west of the site within the lower fluvio-glacial deposits associated with leakage of tar from Tar Tank No.2 and an isolated occurrence of emulsified oils within fluvioglacial deposits in the north-east of the site.

Both soil and shallow groundwater impact have been identified together with the presence of soil gas and organic vapours.

Impact within the deeper groundwater within the sandstone bedrock has also been identified.

Assessments undertaken assumed a continued commercial/industrial use. Other possible end-uses were not assessed.

4.6 AMEC Environment & Infrastructure UK - Human Health Risk Assessment (October 2011)

A DQRA for human health was undertaken for onsite workers within the offices via volatile release from contamination beneath the office building. This exposure scenario was based on an assessment for re-use of the current commercial property on site as office space, and commercial GAC values were used as screening targets.

Rather than derive site specific assessment criteria (SSAC) the ratio of Average Daily Exposure (ADE) to toxicological health criteria values (HCV) were assessed. The ADE/HCV ratio is an estimate of the intake of contaminant divided by the health criteria value for each contaminant. Where the ADE/HCV ratio is less than one, the exposure does not indicate an exceedance of the relevant health criteria value.

Risks from soil, void and ambient vapours to receptors identified beneath and within the building were assessed by the maximum measured concentrations of naphthalene, benzene, TPH aliphatic >EC5->EC10 and aromatic >EC5->EC10, from the vapour monitoring locations being directly assessed using the CLEA model to calculate the ADE/HCV ratio.

Additional comparison was made between the measured vapours within the building, void space and the modelled indoor vapour concentrations, given in the CLEA Software results for assessment of the measured soil vapour concentrations.

The DQRA identified that for soil vapours none of the calculated ADE/HCV ratios exceeded one, therefore no risk to office users within the building present on site at the time was identified.

Controlled Water Risk Assessment Summary
Generic Quantitative Risk Assessment was carried out for groundwater and exceeding contaminants were taken forward to Detailed Quantitative Risk Assessment (DQRA).

As part of the DQRA, Remediation Target Criteria were derived, and areas requiring remediation defined. The contaminants requiring remediation with respect to risk to groundwater are benzene, naphthalene and ammonium.

A remedial options appraisal was carried out, the outcome of which identified a combination of excavation/off-site disposal, ex-situ bioremediation and capping as the most appropriate remedial technique.

The remediation strategy included:

- The removal of tar from Tar Tank No.2 together with the smaller tar wells as a first phase of work.
- This will be followed by stabilisation of former Holders No.1 and No.5. as part of the Phase 2 works.
- Included within this second phase are the remaining areas for remediation which includes the ammonia plant, condensers, Holders No.2 and No.3 and the water well.

It was stated that at some point in the future a third phase of work may be required to address Tar Tank No.1. This is not addressed within the scheme above as it relies on the relocation of high pressure gas plant in the PRS compound.

It was anticipated that the remediation works will take approximately 33 weeks. Following soil remediation and source removal, additional groundwater monitoring or remediation may be required.

The above work was verified by Amec (formerly Entec) and detailed in the following report below.

4.7 Amec Environment and Infrastructure UK Ltd - Final Verification Report (October 2011)

The remedial works were carried out between October 2010 and July 2011.

The remedial works were undertaken in the northern part of the site and comprised the deep excavation and treatment of Gasholders No. 1, No. 2, No. 3, No. 5 and Tar Tank No. 2. Shallow excavations and treatment also occurred in the vicinity of and between Holders 1 and 2 and 3. Plus around Holder 5 and Tar tank 2. The Tar wells areas and Ammonia Plant Area just to the south of Holder No. 5 was also excavated and treated to depth. Together with a smaller area in the east of the site near the radio mast.

The tar impacted sediments and tank/wells backfill were removed off site for soil washing treatment and aggregate recovery after water separation. Residual contamination adjacent to the structures was removed where practicable and safe to do so. The structures were backfilled with low permeability clay, site won materials and finished with imported 6F5 and Type 1A.

The gas holders which were historically backfilled with waste comprising benzene, ammonia and naphthalene associated with spent oxide, were stabilised to immobilise contaminants and prevent leaching. Holder No. 5 has undergone in-situ stabilisation resulting in an increased impermeability and substantial reduction in contaminant leachability. This was demonstrated through verification leachate testing and permeability testing. The ex-situ stabilisation was equally successful.

Validation sampling and analysis was undertaken throughout the works to ensure removal of and treatment of contaminant areas.

Approximate quantities of material addressed at the site were 19,041m^3, of which a total of 15,518m^3 was recovered for either on-site or off-site reuse. This comprised 3,600m^3 of material which was stabilised ex-situ, 5,488m^3 disposed as either non-hazardous, hazardous or WAC failing and a further 1,669m^3 was recovered off-site by soil washing.

Additionally, 5,700m^3 of material was treated by in-situ stabilisation. Clean import material amounted to 5,170m^3. Approximately 78% of all materials were recovered either on or off-site.

After remediation of the areas above some minor localised RTC exceedances remained, notably naphthalene in one location, BH505, to the north of Tar Tank No. 2. The concentration of naphthalene reduced with depth and is compliant with the RTC at depth and a band of stiff clay was found to be providing protection to the underlying aquifer.

Amec concluded that the residual risk to groundwater had been significantly reduced as far as reasonably practicable, as the main source areas have been addressed and the residual exceedances of the remedial target concentrations are localised and are either isolated by structures or do not represent a significant volume of material.

Following discussions with the Environment Agency it was recognised and agreed that remediation works were not practical or of significant benefit in this area to warrant continuation.

After remediation and backfill, plate bearing testing was undertaken to ensure geotechnical compliance in remedial areas. In addition, as part of the remedial works a new surface water drainage system was installed in the north of the site.

Notably Tar Tank No1 in the Transco PRS compound was not remediated during this work and neither were areas under wayleaves or easements of existing Transco pipework present over the former Ammonia Plant and the area around the former Condenser/ Purifiers. However, AMEC carried out additional site investigation within Tar Tank No. 1 during their remediation works; BH601, BH601A, BH602, BH603 and TP601 were completed during July 2011. The exploratory hole logs and full chemical testing data were not included within the original version of Amec's Verification Report, but have since been made available to BSL by Jackson Remediation, and are enclosed within Appendix K.

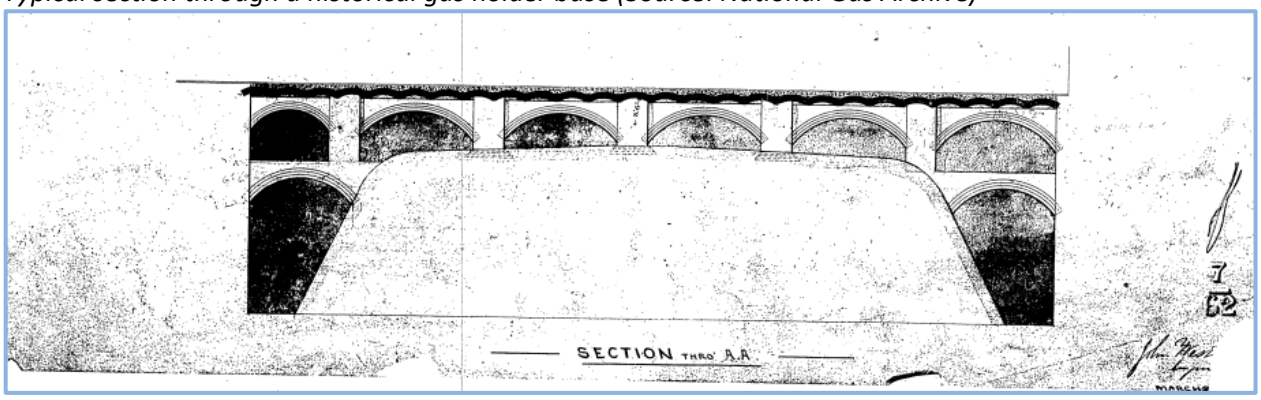
The ground conditions are summarised as follows:

Exploratory Hole	Made Ground	Natural Strata	Observations, comments
TP601	Made ground to 1.30m bgl, comprising dark brown / black gravelly sand. Naphthalene odour, odour becoming more sulphurous with depth.	None encountered.	Trial pit positioned to locate wall of former tar tank; wall encountered in face of pit at 0.20m bgl and pitting continued within tank. Trial pit terminated within made ground at 1.30m bgl due to water ingress.
BH601	Surface gravel over made ground. From 0.40-0.70m bgl this comprised black brown sand and gravel with mild tarry odour.	None encountered.	Targeting centre of tank. Terminated at 0.70m bgl due to obstruction. See BH601A.
BH601A	Surface gravel over made ground. From 0.40-2.80m bgl this comprised black sand and gravel. From 2.80-3.10m bgl this comprised firm brown clay with free phase tar in laminations within clay.	3.10-6.00m; predominantly firm to stiff clay.	Targeting centre of tank. Groundwater noted to have a **silvery sheen** from 1.50m bgl. **Free phase tar** encountered in made ground from 2.80-3.10m bgl. Natural clay has strong **ammonia odour** in upper horizons, decreasing with depth.
BH602	Made ground to 3.50m bgl, predominantly granular, ashy. Made ground changes to cohesive below obstruction at 2.80m bgl, and from 2.8m to 3.5m bgl comprises soft laminated brown clay with free phase tar in laminations.	3.50-5.30m; firm to stiff clay. No tar.	Targeting midpoint between centre and edge of tank, circa 7.00m from centre. Obstruction at 2.80m bgl, penetrated quickly. **Free phase tar** encountered in made ground from 2.80-3.05m bgl. Natural clay has **ammonia odour**.
BH603	Ground level to 3.80m bgl; granular but with limited recover. Tar odour.	None encountered.	Targeting edge of tar tank, 0.50m inside wall as identified in TP601. Evidence of **free phase tar from 3.80m to 8.00m bgl**. Borehole

Exploratory Hole	Made Ground	Natural Strata	Observations, comments
	throughout, reported as strong between 3.20m and 3.80m. 3.80m-5.00m bgl; granular but very to extremely tarry also with ammonia odour. 5.00-8.00m; almost exclusively liquid tar, becoming increasingly viscous with depth.		terminated at 8.00m bgl, unable to drill due to viscosity of tar.

In summary, the available records within Tar Tank 1 demonstrate a 'dumpling' basal profile, as typical profile of which is indicated from an historical section presented below. Within the central areas of the tank, the depth of made ground is only 3.10-3.50m in thickness (BH601A and BH602) whereas the depth of the tank towards the edges is at least 8m. BH603 confirms there is at least a circa 4m thickness of free phase tar located at the base of the tank, which is assumed to extend around the perimeter of the dumpling.

Typical section through a historical gas holder base (Source: National Gas Archive)



Amec obtained samples during the drilling works and the results of chemical testing are also presented within Appendix K. The results indicate significantly elevated concentrations of benzene, PAHs (naphthalene, benzo(a) pyrene and others), ammonium and lead. Contaminant concentrations generally increase towards the base of the made ground in each location, but in general concentrations of contaminants reduce significantly in the underlying natural soils (where encountered in the central areas) compared to the overlying made ground.

4.8 WYG - Area A Supplementary Ground Investigation Factual Report (June 2015)

The intrusive ground investigation works were undertaken by WYG in November 2014 and December 2014 was carried out in the southern part of the site only, within the existing office building and the surrounding area and comprised:

- 6 No. hand pits excavated to a maximum depth of 0.6m bgl.
- Collection of soil and soil-leachate samples.
- Gas and vapour monitoring from existing window sample well installations under the call centre building and internally within the building on 3 No. occasions.
- Collection of gas / vapour samples on 3 No. occasions.

In summary the following ground and contaminant conditions were identified.

- Made ground was encountered in all exploratory holes completed across the site to the maximum depth obtained in the hand excavated trial pits of 0.6m bgl comprising gravelly clayey sand and gravelly sandy clay. Obstructions / slabs were encountered between 0.4m and 0.6m bgl in all holes.
- No evidence of gross contamination or free product was identified during the ground investigation or subsequent monitoring works and no organic vapours (VOCs) measured above the limit of detection by hand held photo-ionisation detector (PID) during excavation.
- Groundwater was not identified during the ground investigation or monitoring works.
- Methane was not detected above the limit of detection in any of the borehole monitoring wells.
- Carbon dioxide was detected at concentrations between 0.4%v/v and 4.8%v/v in monitoring wells and up to 0.2%v/v in internal ground floor areas of the building.
- Oxygen was measured at its lowest concentration (9.8%v/v) in the monitoring well at WS306 and at its highest in WS108 (21.3%v/v).
- Gas flows varied between -0.1L/hr and <0.1L/hr.
- Volatile organic compound measurements varied between <0.1 and 1.7ppm in borehole well installations and <0.1 to 0.1ppm in internal ground floor areas of the building.

4.9 ECUS Environmental Consultants - Summary of Remediation Works (November 2015)

This review summarised the remedial works undertaken and verified by Amec.

The review also summarised the areas where remediation was not undertaken due to proximity to existing National Grid gas distribution plant or below the call centre building, which included:

- Tar Tank No. 1, below the Pressure Reduction Station (PRS).
- Immediately west of PRS on lower level (ammonia plant / washers / scrubbers)
- To east of PRS on lower level, near to gas pipeline (condensors / purifiers).
- Below the call centre building (borehole WS01).
- 2 x Isolated hotspots to the rear of call centre building.
- Areas where further investigation may identify additional areas where remediation required.
- Below call centre building (previous site investigation boreholes all met hard obstructions at shallow depths and hence the area was not fully investigated).

Ecus concluded that future remediation should mirror the strategy adopted by Amec in 2010-11, i.e. removal of gross contamination associated with historical gasworks features in order to reduce the risk of contamination of groundwater within the Principal Aquifer below the site.

- Tar Tank No. 1: Pump out any liquid tar and contaminated water present and dig out tar contaminated debris with long-reach excavator. Based on previous remediation, a temporary 'tent' structure is likely to be required to contain tar odour / vapours during remediation works. The below-ground structure could then be broken out if preferred, to aid the pile installation.
- Ecus also identified that the logs to the boreholes (BH601A, BH602 and BH603) drilled in tar Tank 1 were not included within Amec report and recommended that these be inspected before remediation.
- Other historical gasworks features: Dig out contaminated materials and remove off-site for treatment / disposal (the Client has indicated a preference against on-site bioremediation, due to the required timescales).
- Ecus flagged potential issues with driven piles and obstructions and recommended that bored piles may be more suitable as these would bring to the surface contaminated soils to the surface and not drive them to depth, although with an added cost increase for disposal.

4.10 WSP - The Gasworks, New Town, Environmental Statement (November 2020)

The above report did not include any further detailed assessment of contaminant ground conditions and has not been considered further.

4.11 WSP - Asset Survey and Proposed Groundwater Monitoring Technical Note (March 2021)

WSP were commissioned to undertake a site visit including a round of groundwater monitoring and an assessment with proposed further environmental works, for the Gould Street Site.

The site is intended for re-development into multi-storey residential buildings with ground floor commercial use and associated car parking (planning application reference 128248/FO/2020), which is to be delivered over four phases of development.

The Environment Agency (EA) recommended planning conditions with respect to the assessment, and if required, remediation of potential groundwater contamination. The EA recommend that these works are to be undertaken as a single package of works, rather than a phased approach. This is because any potential requirement for remedial work would likely extend across several phases of the site.

It was recommended by WSP that the current status of groundwater quality was established as the starting point for any response to the EA, using the pre-existing monitoring well infrastructure. In order to make this assessment, it would be necessary to locate, open and assess the wells (asset survey) to determine their viability for sampling.

EA Planning Consultation Responses
The site is in a high sensitivity location with respect to controlled waters, overlying the Wilmslow Sandstone Formation.

- The EA considers the bedrock Wilmslow Sandstone Formation (Principal Aquifer) and the shallow groundwater in the superficial glacial deposits to be the primary controlled waters sensitive receptors.
- The bedrock aquifer is considered vulnerable to pollution from contamination associated with the former site use. Whilst glacial Till affords some protection in the western part of the site, it is absent in the east. As groundwater flow in the superficial deposits is inferred to be to the east, there is a potential pollutant linkage via lateral and vertical migration pathways.
- The EA noted that remedial works carried out to date were constrained to the north of the site. Given the time elapsed since these works occurred, the EA recommend a series of planning conditions to assess potential risks to controlled waters and put mitigation measures in place, if required. This is because it cannot be guaranteed that the development will not be put at risk from, or be adversely affected by, unacceptable levels of water pollution.

WSP also visited site and inspected six deep monitoring wells, to assess their suitability for future sampling.

4.12 Hydrock - Report Review and Gap Analysis (November 2021)

Hydrock carried out a detailed review of all the available reports on the site to date and from this produced a data gap analysis which is summarised below.

They concluded that the investigations carried out had been focused on geo-environmental aspects. There is limited geotechnical investigation available, and if present, is typically focused on classification tests (predominantly of re-used fill material in remediated zones). Furthermore, there is limited in-situ strength information and, particularly so in the south of the site. There was limited information on the

depth to bedrock and no information on bedrock strength. In addition, there are multiple locations where underground obstructions remain in place and undefined.

Hydrock recommended further detailed site investigation specifically in the following areas:

Phases 1 & 2 (South)
Hydrock concluded that due to the former above-ground structure (Office Building) being in place at the time of the main series of investigations, there have been relatively limited investigations previously undertaken in this area.

Data gaps were considered present in the following areas:

- Former benzole plant and retort areas.
- General coverage beneath former office block and across the site.
- Additional round structure as shown on 1828 map within courtyard of the first gas works development.
- Post-remediation groundwater monitoring was also recommended.

In this area, Hydrock concluded that the majority of former contamination sources have been subject to historical investigation, and in some cases remediation. However, a number of potential source areas do not appear to have been subject to significant levels of investigation.

- Former sub-station in west of site.
- Limited investigation within former boilers area.
- Limited investigation within former condensers area.
- Purifiers and valve pits not investigated.
- The deep sewer (circa 11m bgl) that crosses the site. Hydrock noted that little was known about this sewer and that it could be a pathway for contaminant migration.

4.13 Hydrock - Ground Investigation Report (February 2022)

Hydrock undertook a further site investigation including a revised Desk Study in the southern area of the site (Development Phases 1 and 2). Pertinent points from these further investigations are summarised below.

- The Desk Study identified that from 1982 a depot with an associated fuel island including pumps and tanks is recorded within Phase 1 and 2.
- The site has a moderate UXO risk assessed via a non-specialist UXO assessment.

Ground Condition Summary

- Made ground encountered between 0.00m and 5.00m bgl, glacial Till encountered at 0.70m and 5.00m bgl up to 10.76m thickness comprising very stiff to stiff, very high to high strength dark brown sandy gravelly clay.
- Weathered Chester Formation - top encountered between 9.80m and 16.10m bgl up to 4.65m in thickness, comprising dense reddish orange gravelly to very gravelly silty sand or a dense light grey/light brown or reddish orange sandy clayey gravel.
- The intact Chester Formation was encountered underlying the weathered Chester Formation between 16.10m and 19.25m bgl. Described as weak to medium strong reddish orange medium to coarse sandstone or an extremely weak reddish orange medium to coarse sandstone.

- Localised and discontinuous perched waters were present within the made ground sat either on clayey layers or at the interface with the glacial Till between 1.46m and 3.37m bgl. There are also localised and discontinuous perched waters under a sub-artesian pressure within bands of sand in the glacial Till between 4.18m and 6.67m bgl and deeper perched waters at 9.87m and 12.06m bgl.
- Groundwater within the deeper Chester Formation indicated to be flowing from south/south west to north east towards the River Irk from 19.64m to 19.29m bgl.
- There is visual and olfactory evidence of petroleum hydrocarbon contamination encountered within the soils. There were sweet odours recorded within the made ground coupled with elevated PID readings above background of 20ppm, suggestive of VOC impact to the made ground. Shallow perched waters locally in the southeast of the site were found to be oily with a very weak hydrocarbon odour.
- Piled foundations were recommended with suspended floor slabs.
- Made ground was unstable during excavations.
- Buried obstructions were note to be likely.
- Soakaway drainage was considered unsuitable.

Human Health Assessment

- Pervasive arsenic and PAH in the made ground assessed against residential screening criteria.
- Asbestos fibres and suspected asbestos containing materials in the made ground.
- Petroleum hydrocarbons and visual evidence and odours in the made ground.
- Presence of benzene, 1-2-4-trimethylbenzene and concentrations of SVOCs in the made ground.
- Styrene hotspot present within WS704 at 1.20m bgl.
- Buried bituminous layer contains significant benzo(a)pyrene indictive of coal tar presence.

Controlled Waters

- Presence of elevated hydrocarbon, ammonium, total cyanide within deeper groundwater in BH301 close to the boundary of phases 1 and 3, plume appearing to migrate into the north west of phase 1.

Ground Gases and Vapours

- Site is provisionally classified as CS2 due to the vapour risk posed by VOCs and hydrocarbons within the made ground. Subject to completion of ongoing monitoring.
- Multiple occurrences of elevated PID readings within the made ground indicative of the presence of volatile contamination.
- Risk from VOC and hydrocarbon vapours from made ground remaining following enabling works.

Proposed Mitigation Measures

- The excavation and material management of the made ground containing petroleum hydrocarbons or visual or olfactory evidence of contamination.
- Targeted delineation and excavation of made ground present in WS704 at 1.20m and placement either below hardstanding outside of the building footprint or behind the retaining walls if geotechnically suitable.
- Examination of made ground soils in the vicinity of MPBH07A, hand picking of any visual suspected cement type asbestos and disposal offsite via a licensed waste contractor.
- The installation of a 450mm cover system in landscaped areas, comprising a high visibility geomembrane, subsoil and a minimum of 150mm of topsoil.
- Installation of Protectaline pipework.

- Installation of VOC vapour resistant membrane in buildings.

Further Work
To address the above points, Hydrock recommended the following further works:

- Demolition asbestos survey of existing structure.
- Obtain an updated CON29M report from the coal authority to confirm the conclusions of their report.
- Undertaking an additional two boreholes in the east of the site to complete detailed design of the piling. An additional borehole would also be beneficial along the NW side of the proposed westernmost apartment building.
- Specialist UXO/UXB risk assessment in accordance with CIRIA Report C681 with regard to construction risk.
- Completion and reporting of the ongoing gas monitoring, hence the conclusions in this report are provisional, subject to the completion of monitoring.
- Supplementary ground investigation and assessment in accordance with ADEPT & CWF Guidance (August 2019) to fully assess potential bituminous bound pavement arisings with regards to the presence of coal tar and waste disposal.
- Discussion and agreement with utility providers regarding the materials suitable for pipework.
- Discussions with regulatory bodies and the warranty provider regarding the conclusions of this report.
- Completion of further detailed risk assessment relating to groundwater to assess the risk to controlled waters posed specifically by ammonium, hydrocarbons, total cyanide and thiocyanate.
- Discussions with piling contractors regarding the conclusions of this report and the design of the piles.
- Provision of geotechnical design for the Category 2 structures (earthworks, retaining, floor slabs, foundations).
- Production of a Remediation Strategy and Verification Plan (and agreement with the regulatory bodies and the warranty provider).
- Production of a Materials Management Plan relating to reuse of soils at the site and import of soils to the site.
- Remediation and mitigation work; and verification of the earthworks, remediation and mitigation works.

4.14 Hydrock - Preliminary Risk Assessment and Outline Remediation Strategy (January 2022)

The above report summarised the remediation carried out on the site to date, primarily undertaken in the northern areas Phase 3 and 4.

With regards to human heath the report concluded that as the development will not feature private gardens, so the risk is that applicable to public open space. The likelihood is that this risk (measured by exceedance of GAC concentrations) will be mitigated by the placement of a clean cover system across the landscaped area. Service trenches will need to be over excavated and backfilled with clean material. The built environment will also break the pathway.

Vapour risk to site end users would be mitigated by vapour barriers subject to further assessment.

With regards to controlled waters, the risk from contaminants should be re-assessed based on site investigation data representing current conditions. If required, a detailed quantitative risk assessment (DQRA) will be applied to determine Remedial Target Values (RTVs) that are protective of controlled waters beneath a developed site. Hydrock concluded, given that a developed site drainage and the creation of a landscaped area will tend to reduce infiltration, it is possible that the RTVs will be less

stringent than those applicable to the 2010-2011 remediation works so it is considered unlikely that further remediation to protect controlled waters will be required in areas of previous remediation.

Remediation will be required in areas of known gross contamination, in particular Tar Tank No.1 and previously identified areas of known gross soil contamination.

They concluded that remediation is likely to comprise a mixture of:

- Pumping and/or excavation and ex-situ treatment or disposal of contaminated soils/waters.
- Backfill with treated site-won materials and/or imported clean materials.
- A programme of bedrock groundwater monitoring.
- A Piling Risk Assessment will be required.

4.15 Environment Agency Comments on Proposals to Date

The EA carried out a review of proposals submitted by Hydrock under a paid for review service (ref: ENVPAC/1/GMC/0055 dated 13 February 2024). Although the EA accept that the site can be developed, they have indicated it is their opinion that they do not consider the remedial works already carried out on site to be comprehensive.

They require more investigation in not only areas previously not investigated, but also in areas previously remediated; this would lead to a more refined and updated site conceptual model.

The EA accept that the work can only be carried out in a phased manner with the removal of the gas pipework, enabling access to previous inaccessible areas to unlock the site for redevelopment.

The EA welcomed proposals for further investigation, with the aim of facilitating the input parameters for a detailed assessment of risks to controlled waters, which will benefit the project going forwards. They also advised that the results of the ground investigations should be combined in a singular report and submitted prior to any separate detailed risk assessment (DQRA), and certainly a remediation strategy, to enable timely comments about the work and identify any queries should they arise.

5.0 PHASE 1 PRA SUMMARY AND RISK ASSESSMENT

5.1 Introduction

The section below has been produced in order to address element (b) of Condition 4 under MCC planning application 128248/FO/2020.The risk posed by any contaminants in soil or groundwater will depend on the nature and level of the source, the probability of exposure occurring, the potential pollution pathway and the likely effects on the receptors.

A contaminant is defined as a substance that has the potential to cause harm, a risk is considered to exist if such a substance is present at sufficient concentrations to cause harm and if a pathway is present through which a receptor could be exposed to the contaminant.

The following sections discuss the identified potential on-site and off-site sources, and any pollution that could impact receptors via the pathways associated with the proposed development. Pollution linkages are assessed which may represent a risk to human health and/or controlled water receptors from the information gained from the Phase I Assessment searches. The assessment has been carried out on a qualitative basis and aims to produce a complete and comprehensive Preliminary Conceptual Site Model.

Three potential impacts exist for any given site and all three need to be considered in the qualitative risk assessment, these are:

- On-site impacts.
- The site impacting its surroundings.
- Off-site sources impacting the subject site.

5.2 Potential Contaminative Sources

On-Site

With respect to the former gas works, a number of former gasometers and/or tar tanks have been identified and numbered during the previous phases of investigation and remediation which have taken place on site. A summary of the known gasometers / tar tanks and remedial works completed to date is indicated on Remediation Summary drawing reference C5962/05.

A summary of the historical gasworks features is provided below:

Feature Name	Comments
Tar Tank No. 1	• No evidence of any remediation undertaken to date. • Site investigation by Amec in 2011 demonstrated the tar tank has a 'dumpling' profile with made ground encountered to circa 3-3.5m in the centre, but is in excess of 8m towards the edge of the feature. • Gross contamination in the form of highly viscous liquid tar is present at the base of the tank, likely present largely as a 'halo' in the deepest areas of the tank around the perimeter. • TP601 (Amec, 2011) proved the presence of a brick sidewall to the tank. BH601A and BH602 (Amec 2011) encountered evidence of obstructions towards the base of the made ground in both locations, suggesting the possible presence of a base structure.
Tar Tank No. 2	• Contents removed, brick side walls and base of tank were jetted to remove tar residue but remain in situ. • Tar tank backfilled with compacted imported clay, with pulverised fly ash (PFA) used to fill the void up to 1.2m bgl, with clean stone and asphalt to the surface • Adjacent areas immediately outside of gasholder subjected to shallow excavation of contaminated soils and replacement with imported or site won materials.

Feature Name	Comments
Gas Holder No. 1	• Contents removed and stabilised ex-situ for re-use, brick side walls and base of tank remain in situ. • Backfilled to 8m bgl with PFA, followed by stabilised materials to 3.3m bgl, followed by clean granular material to ground level. • Adjacent areas immediately to north and east of gasholder subjected to shallow excavation of contaminated soils and replacement with imported or site won materials.
Gas Holder No. 2	• Gasholder found to be filled with clinker and no leachable contaminants, therefore only limited remediation was completed, comprising excavation of a sump to 8.7m bgl and removal of water. • The brick walls were broken out to 1m bgl and removed, but otherwise the structure was left in situ. • Adjacent areas immediately to west of gasholder subjected to shallow excavation of contaminated soils and replacement with imported or site won materials.
Gas Holder No. 3	• Structure previously backfilled with contaminated gas works purifier wastes and PFA, to its base at 9m bgl. • The only remedial works known to have been completed have comprised excavation of a sump excavation of a sump to 8.7m bgl and removal of contaminated water to the on-site treatment plant prior to discharge. • The brick walls were broken out to 1m bgl and removed, but otherwise the structure was left in situ. • Adjacent areas immediately to west of gasholder subjected to shallow excavation of contaminated soils and replacement with imported or site won materials.
Gas Holder No. 5	• Structure previously backfilled with contaminated gas works purifier wastes and PFA, to its base at 9.2m bgl. • The remediation comprised in-situ stabilisation. A total of 1,110 overlapping 1.2m diameter columns of stabilised material were created, and 1530m3 of arisings were disposed off-site. • Brick side walls and base of tank remain in situ.
Tar Wells Area (Upper Level)	• 2 No. small circular brick lined tar wells were present beneath circa 3m of brick demolition fill retained by the retaining wall on site. The wells were 2.85m in diameter and 2.1m deep and brick lined. • The tar wells were treated by vacuum pumping of liquid tar and excavation of tar contaminated brick rubble. The intact brick walls and bases of the tar wells were left in situ. • The tar wells were backfilled with demolition materials containing a small quantity of asbestos cement fragments. • Shallow excavation of contaminated soils and replacement with imported or site won materials
Ammonia Plant Area (Upper Level)	• The area of the former ammonia plant was found to include a brick substructure, 6.9m x 12m x 2m depth, filled with rubble and some contaminated soil, which was removed • The brick base to the substructure was left in situ.
Ammonia Plant Area (Lower Level)	No evidence of any remediation undertaken to date.
Condensers / Purifiers Area (Lower Level)	No evidence of any remediation undertaken to date.

In summary, from the information obtained, the following sources have been identified which may affect the redevelopment of the site for mixed residential and commercial end use:

- General made ground associated with the former gas works, depot, former garage.
- Former gas works infrastructure (especially unremediated features Tar Tank 1, ammonia plant area, condensers / purifiers).
- Former tanks.
- Railway sidings.
- Telecoms mast.
- Current and former electricity substations.

Off-Site
The following off-site sources have been identified which may affect the redevelopment of the site:

- Railway (abutting the site NW and SE).
- Electrical sub-stations (nearest abutting the NW of the site).
- Depots/Garages (nearest abutting the site).
- Historical tobacco works (from 10m W).
- Unspecified works (from 10m NE).
- Asphalt works (40m N).
- Bolt works/ Foundry (50m N).
- Rubber works (50m N).
- Paper Works (95m N).
- Tanks (95m N).

Given the distance to the Rochdale Road Gas Works and the nature of the subject site as a gas works, this potential source has been discounted, especially in light of the postulated hydraulic gradient of that site to be downstream towards the River Irk further to the north west.

The telecommunication mast is not likely to be a significant source of ground contamination, similarly the police station approximately 80m east is only considered due to any on-site vehicle maintenance or refuelling which may have taken place, but following its removal it is unlikely these sources remain and would not be distinguishable amongst likely on-site contamination. Neither is considered further.

Associated Contaminants
The contaminants commonly associated with the potential sources of contamination identified are tabulated below:

Contaminative Sources	Department of the Environment Industry Profile or Other Source	Commonly Associated Contaminants
On Site		
General Made Ground	AGS Guides BS8485 and BS8576	Heavy metals, polycyclic aromatic hydrocarbons (PAHs), asbestos, ground gases (carbon dioxide, methane, hydrogen sulphide, carbon monoxide).
Former gas works below ground structures inc. gasholders, tar tanks and other tanks	Industry profile - Gas works CL: AIRE – Soil and Groundwater Remediation Technologies on former Gasworks and Gasholder sites	PAHs, petroleum hydrocarbons inc. BTEX and phenols, metals, ammoniacal liquor (chlorides, thiocyanate, ammonia), hydrogen sulphide, spent oxide (blue billy, cyanide, thiocyanates), asbestos., VOCs.
Electricity Substation	Electrical Works	Poly-chlorinated biphenyls (PCBs), asbestos.
Depot	Road vehicle fuelling, service and repair	Heavy metals, petroleum hydrocarbons, asbestos.
Railway	Railway Land Engineering works-Railway	Poly-chlorinated biphenyls (PCBs), heavy metals, polycyclic aromatic hydrocarbons (PAHs), asbestos.
Off Site		
Depot	Road vehicle fuelling, service and repair	Heavy metals, petroleum hydrocarbons, asbestos.
Railway	Railway Land Engineering works-Railway	Poly-chlorinated biphenyls (PCBs), asbestos.
Electricity Substation	Electrical Works	Poly-chlorinated biphenyls (PCBs).
Unspecified Works	-	Heavy metals, PAHs, petroleum hydrocarbons, asbestos.
Tobacco Works	-	Heavy metals, PAHs, petroleum hydrocarbons, asbestos.
Asphalt Works	Ceramics, Cement and Asphalt	Heavy metals, inorganic compounds, asbestos, bitumen, petroleum hydrocarbons, PAHs, SVOCs, PCBS, solvents.

Contaminative Sources	Department of the Environment Industry Profile or Other Source	Commonly Associated Contaminants
Bolt works/ Foundry	Manufacturing, refining, and finishing works. Metal-Iron and Steel LQM Land Contamination at Foundry Sites	Heavy metals, PAHs, petroleum hydrocarbons, asbestos, sulphates, inorganic compounds, BTEX, SVOCs, PCBs.
Rubber Works	Chemical works- rubber processing works	Hydrocarbons, SVOCs, BTEX, PCBs, asbestos, inorganic compounds, PFAS.
Paper Works	Pulp and paper manufacturing works	Heavy metals, inorganic compounds, aliphatics, SVOCs PCBs, asbestos, solvents.
Tanks	Road vehicle fuelling, service and repair	Petroleum hydrocarbons, BTEX, MTBE, VOCs.

5.3 Pathways

A pathway is defined as a medium by which a contaminant comes into contact with, or otherwise impacts a receptor.

At this stage, the potential contaminants identified above are considered to present potential risks to site end users and controlled waters through the following pathways:

Potential Pathways	
Pathways in respect to Human Health	• Ingestion of contaminated soils. • Dermal contact with contamination. • Inhalation of dusts. • Inhalation of gases or vapours in both indoor and outdoor air.
Pathways in respect to Controlled Waters – Surface water	• Surface run-off /over land flow. • Drainage discharge. • Base flow from groundwater.
Pathways in respect to Controlled Waters – Groundwater	• Leaching of mobile contamination into groundwater via the unsaturated zone. • Migration of perched groundwater in any permeable soils or along existing or proposed service runs. • Migration into the saturated zone and flow through the aquifers underlying the site.
Pathways in respect to Property/structures/water pipes	• Direct contact with substances deleterious to building materials and potable water supply pipelines. • Migration of ground gases (methane) into confined spaces (explosion and damage to property).

5.4 Receptors

The identified receptors are listed below:

- Residential/Commercial end users (human health).
- Structures/Property/Potable water supply pipes.
- Nearest watercourse. River Irk, 117m NW (Controlled waters).
- Superficial Aquifer. Glacial Till, Secondary Undifferentiated Aquifer (Controlled waters).
- Bedrock Aquifer. Chester Formation, Principal Aquifer (Controlled waters).

Under current UK health and safety legislation, employers are required to carry out their own appropriate site-specific risk assessments and mitigation to protect employees. It has been assumed

that any future construction works onsite will be undertaken in compliance with these requirements. Therefore, construction workers have not been specifically considered as part of this assessment.

5.5 Preliminary Conceptual Site Model (CSM)

The information obtained in the previous sections has been used to compile a Preliminary pre-development CSM and the identified potential contaminants and receptors have been assessed in the table below as to whether a plausible source-pathway-receptor pollutant linkage for the proposed end use of the site exists. The risk classification has been estimated in accordance with information in the BSL Guidance and Methodology in Appendix A.

The Preliminary CSM's are presented in the tables overleaf, any assessed risk above moderate will possibly require further action:

PSCM Human Health						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
On site **General Made Ground** Metals, petroleum hydrocarbons, PAHs, asbestos.	Root uptake, ingestion, direct contact, inhalation of dusts/vapours	End-users	Likely	Medium	Moderate	The presence of contaminants has been confirmed during previous Site Investigations across all phases, although there is some uncertainty over the current state of the site given the variable and localised remediation which has taken place, particularly Phases 3 and 4. The presence of buildings and hard standing and earthworks which will be completed are likely to reduce the potential for contaminant linkages to be present to an extent, although further investigation and assessment will be required to confirm the risk.
On site **Made Ground** Metals and organic contamination	Migration into/chemical attack of water supply pipelines	Water Pipelines / End users	Highly likely	Medium	High	Contaminants within the soil/groundwater could potentially attack the clean potable water supply pipe, contaminants should be assessed to determine the correct pipe material and level of precautions required.
On site **Former Gas Works underground structures including gasometers and tanks** PAHs, petroleum hydrocarbons inc. BTEX and phenols, metals, ammoniacal liquor (chlorides, thiocyanate, ammonia), hydrogen sulphide, spent oxide (blue billy, cyanide, thiocyanates), asbestos	Ingestion, direct contact, inhalation of dusts/vapours	End-users	Likely	Medium	Moderate to High	The presence of contaminants has been confirmed during previous Site Investigations, although there is some uncertainty over the current state of the site given the variable and localised remediation which has taken place. The lack of remediation of Tar Tank 1 in particular increases the potential for greater concentrations of contaminants within this footprint, making the risk from this source as high. The base of Tar Tank No. 1 is known to contain free phase hydrocarbons comprising liquid tar. Further assessment will be required to confirm the risk; this lies within a Cadent compound and there are stringent H&S requirements that may limit intrusive investigation.
On site **Made ground** Ground Gas (carbon dioxide, methane, hydrogen sulphide, carbon monoxide)	Migration into confined spaces, inhalation and asphyxiation/ explosion	End-users / property / structures	Likely	Severe	High	Significant thicknesses of made ground are known to be present on site based on the historical ground investigations given the historic use as a gas works its likely ground gas is present and will need to be assessed including trace gases such as hydrogen sulphide and carbon monoxide. The latest ground gas monitoring data for the southern portion of the site resulted in these areas being provisionally classified as CS2 due to concentrations of carbon dioxide and carbon monoxide.

PSCM Human Health						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
						At this stage the risk is assessed as high and further monitoring is required in the northern portion of the site to supplement the existing dataset for the southern portion.
On site Made Ground Vapours	Migration into confined spaces, inhalation and asphyxiation/ explosion	End-users /Property/ Structures	Likely	Severe	High	Given the previous uses of the site and evidence from previous investigations there are potential sources of VOCs. The 2022 Hydrock ground investigation on the southern portion of the site identified concentrations of VOCs above the GACs and vapour protection measures were recommended for the southern portion. Further monitoring and assessment are required in order to fully assess the risk across the site as a whole, but the risk is considered to be high at this stage.
On site Electrical Sub-station PCBs	Ingestion, direct contact, inhalation of vapours/dusts	End-users	Low likelihood	Medium	Moderate/ low	Whilst the mobility of this contaminant is low, the presence of both historical and current electrical sub-stations pose a risk from polychlorinated biphenyls. The risk is assessed as moderate/ low.
Off site Depot/Garages Heavy metals, petroleum hydrocarbons, PAHs, Asbestos, Ground Gas	Ingestion, direct contact, inhalation of vapours/dusts.	End-users	Likely	Medium	Moderate	WS04A conducted on the site by ENTEC in 2002 has shown shallow hydrocarbon contamination at the southeast edge of the site adjacent to the series of depots and garages extending from the southwest of the site. In 2022, adjacent Hydrock trial pit TP720 encountered perched groundwater containing a sheen and diesel odour at the base of the made ground. It is possible these observations relate to the off-site garages which are immediately adjacent to this area of the site, these off-site sources are still present and due to their proximity to the site the risk from off-site garages has been assessed as moderate.
Off site Electricity Substation PCBs	Ingestion, direct contact, inhalation of dusts.	End-users	Unlikely	Medium	Low	The mobility of this contaminant is very low, and the substation adjacent to the site is also present at a lower elevation to the site, further reducing the potential for migration of any contaminants onto the subject site. The overall risk is assessed as low.
Off site Unspecified Works Heavy metals, PAHs, petroleum hydrocarbons, asbestos.	Ingestion, direct contact, inhalation of dusts.	End Users	Unlikely	Medium	Low	Whilst these works have no specified use on historical mapping, some are still present to the northeast of the site and may provide a source for off-site contamination. However, based on the anticipated ground conditions comprising glacial Till, in addition to the presence of hard standing across large areas of the proposed development, the risk from off-site source contamination is generally assessed as low.

PSCM Human Health						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
Off site Tobacco Works Heavy metals, PAHs, petroleum hydrocarbons, asbestos.	Ingestion, direct contact, inhalation of vapours/dusts	End Users	Unlikely	Medium	Low	Whilst the presence of contamination is possible associated with the former tobacco works, based on the anticipated ground conditions comprising glacial Till, in addition to the presence of hard standing across large areas of the proposed development, the risk from off-site source contamination is generally assessed as low.
Off site Asphalt Works Heavy metals, inorganic compounds, asbestos, bitumen, petroleum hydrocarbons, PAHs, SVOCs, PCBS, solvents.	Ingestion, direct contact, inhalation of vapours/dusts.	End Users	Unlikely	Medium	Low	Whilst an Asphalt works was present towards the north of the site the age, distance and underlying glacial till has likely limited the amount of contamination migrating beneath the site, the risk is assessed as low.
Off site Bolt Works/ Foundry Heavy metals, PAHs, petroleum hydrocarbons, asbestos, sulphates, inorganic compounds, BTEX, SVOCs, PCBs.	Ingestion, direct contact, inhalation of vapours/dusts.	End Users	Unlikely	Medium	Low	Whilst a Bolt works was present towards the north of the site the age, distance, lower elevation relative to the site, and underlying glacial till has likely limited the amount of contamination migrating beneath the site, the risk is assessed as low.
Off site Rubber Works Petroleum hydrocarbons, SVOCs, BTEX, PCBs, asbestos, PFAS.	Ingestion, direct contact, inhalation of vapours/dusts.	End Users	Unlikely	Medium	Low	Whilst a rubber works was present towards the north of the site the age, distance, lower elevation relative to the site, and underlying glacial till has likely limited the amount of contamination migrating beneath the site, the risk is assessed as low.
Off site Paper Works Heavy metals, petroleum hydrocarbons, SVOCs, PCBs, asbestos.	Ingestion, direct contact, inhalation of vapours/dusts.	End Users	Unlikely	Medium	Low	Whilst a paper works was present towards the southwest of the site the age, its change of use since the 1950s, its distance and the underlying glacial till has likely limited the potential for contaminants to migrate beneath the site, the risk is assessed as low.

PSCM Human Health						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
Off site **Tanks** Petroleum hydrocarbons, BTEX, MTBE, VOCs	Ingestion, direct contact, inhalation of vapours	End Users	Unlikely	Medium	Low	Whilst various were present towards the north of the site associated with the adjacent works, the age, having been removed post 1965 mapping, distance and underlying glacial till has likely limited the amount of contamination migrating beneath the site, the risk is assessed as low.

PSCM Controlled Waters						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
General Made Ground Metals, petroleum hydrocarbons, PAHs	Overland flow, / migration through saturated zone	River Irk, 117m away (Surface waters)	Low likelihood	Medium	Moderate / Low	Areas of gross contamination are likely to be localised to the former gasometers and tanks in the northern areas, and significant gross contamination was largely absent across the southern portion of the site investigated by Hydrock in 2022. The redevelopment of the site will involve a significant period of earthworks and site turnover alongside removal of any grossly contaminated soils, in addition to renewed hard surfacing and drainage systems. The distance between the site and the river will also provide an opportunity for attenuation and degradation of any mobile contaminants.
	Leaching through unsaturated zone / Migration through saturated zone	Secondary (Undifferentiated) Aquifer (Groundwater)	Low likelihood	Medium	Moderate / Low	As contamination has been observed within perched groundwater it is possible contaminant could leach through pockets of granular material into the secondary aquifer, the risk has been assessed as moderate.
	Migration through saturated zone	Principal Aquifer (Groundwater)	Unlikely	Medium	Low	Based on the Hydrock investigation in the southern portion of the site, the general made ground is expected to be up to 4-5m in thickness and is underlain by glacial Till comprising clays with only minor occurrences of granular soils. The glacial Till is expected to minimise migration of shallow groundwater and/or leachate towards the Principal Aquifer. The overall risk is considered to be low at this stage, subject to further investigations which are required in the northern area of the site. A Piling Risk Assessment will be required should piles be used for the proposed development to assess the potential of creating pathways for contaminants.
Former Gas Works underground structures including gasometers and tanks PAHs, petroleum	Overland flow, migration through saturated zone, migration via existing redundant drainage	River Irk, 117m away (Surface waters)	Low likelihood	Medium	Moderate / Low	The northern area of the site has been subject to some remediation, focusing predominantly on source removal of heavily contaminated soils, with some former gasometers treated in situ or infilled with ex-situ stabilised soils. Further investigation is required in these areas to confirm the current nature of the site, in addition to investigation in some areas in which no remediation is recorded to have taken place; in these areas there is an elevated potential for gross contamination to be present. Non aqueous contaminants associated with gasworks are typically DNAPL, i.e. greatest concentrations would be expected towards the base of the gasholders.

PSCM Controlled Waters						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
hydrocarbons, metals, chlorides, thiocyanate, ammonia), spent oxide						The gas holders are understood to be brick lined and some were historically lined with clay at the base, and the underlying superficial soils are indicated to comprise glacial Till (i.e. low permeability clay). These factors are likely to contribute to a reduced potential for contaminants to migrate towards the river, especially as overland flow is unlikely to encounter the greatest concentrations of contaminants, although further investigation is required to confirm the nature of contaminants, nature of the made ground, current condition of the gasholder structures, and thickness and nature of the superficial deposits to allow a complete assessment. The depth, extent and condition of the existing drainage networks on site and in the surrounding area should be established. Production of a DQRA may also be required.
	Leaching through unsaturated zone / Migration through saturated zone	Secondary (Undifferentiated) Aquifer (Groundwater)	Likely	Medium	Moderate	As stated above, despite the partial remediation which has been carried out to date, there is an elevated potential for gross contamination associated with the former gasworks structures, and further investigation is required in order to confirm the nature of contaminants, nature of the made ground, current condition of the gasholder structures, and thickness and nature of the underlying superficial deposits. The overall risk has been assessed as moderate at this stage.
	Migration through saturated zone	Principal Aquifer (Groundwater)	Likely	Medium	Moderate	As stated above, despite the partial remediation which has been carried out to date, there is an elevated potential for gross contamination associated with the former gasworks structures, and further investigation is required in order to confirm the nature of contaminants, nature of the made ground, current condition of the gasholder structures, and thickness and nature of the underlying superficial deposits. The overall risk has been assessed as moderate at this stage.

Human Health Risk – Soils Contamination Summary
Based on the preliminary CSM and the current use of the site, the overall risk from land contamination at the site is considered to be moderate to high for a redeveloped site. This would need to be confirmed by appropriate intrusive investigation, testing and assessment.

Human Health Risk – Ground Gas and Vapours Summary
A potential on-site gas and vapour source has been identified associated with deep made ground. Potentially viable linkages are considered to exist and the preliminary CSM considers these sources to be of high risk.

In accordance with BS8576 and CIRIA C665 as set out in Appendix A of this report, the gas generation potential (methane and carbon dioxide) is considered to be very low to low. The sensitivity of the development is moderate on account of the proposed high-rise apartments use.

In line with current guidance, it is recommended that ground gas monitoring should comprise 6 visits over a 3 month period, this will supplement the existing Hydrock data.

Ground gas monitoring and future site investigations should also include use of a Photo Ionisation Detector (PID) given the potential for volatile hydrocarbons for use as an initial screen to determine if further detailed testing and assessment is required.

Controlled Waters Risk - Summary
Based on the preliminary CSM, BSL believes the overall risk to controlled waters at the site is moderate.

The above assessed level of risk will need to be confirmed by intrusive investigation and quantitative risk assessment.

6.0 PRELIMINARY GEOTECHNICAL ASSESSMENT

6.1 Hazard Identification

A preliminary geotechnical hazard identification exercise has been undertaken in general accordance with the Highways England document CD 622, 'Managing geotechnical risk'. Potential geotechnical hazards based on the expected ground conditions are listed below:

- Made ground of unknown nature; if placed in a non-engineered manner may cause excessive settlement of foundations, highways and infrastructure.
- Presence of obstructions in the ground from historical developments (e.g. relict foundations, gasholders, tanks etc still in situ) causing difficulties with excavations or penetrative works (e.g. piling).
- Deep drainage features and other relict utilities related to the former gas works.
- Attack of buried concrete by aggressive ground conditions; the site may contain unknown made ground and potentially sulphate bearing soils.
- Shrink / swell of clay; settlement / heave of foundations and floor slabs when located within the influence of trees and vegetation.
- Running sands or loose fill materials leading to difficulty with excavation due to trench collapse.
- Shallow groundwater/groundwater rise causing resulting in difficulties with excavations due to trench collapse.
- UXO; parts of the site lie within areas at moderate risk from unexploded ordnance.

Whilst the site lies within a Coal Authority reporting area, based on the available information, the risk from mining induced instability is considered to be very low and needs no further consideration.

Retaining walls are present on the northern site boundary and across the centre of the site. These are comprised of variable construction (predominantly brick or stone masonry). BSL understand a substantial programme of earthworks is proposed during enabling works at the site, which will include the removal of some if not all of the retaining walls. The integrity of the wall and any requirements during future construction activities should be confirmed by a suitably qualified structural engineer.

The above identified geotechnical hazards will need to be considered as part of further investigations and assessments.

6.2 Foundation and Geotechnical Design

The proposed development will comprise fifteen 3 to 34 storey mixed commercial and residential blocks. The type of foundation solution should be informed by an onsite intrusive investigation to confirm ground conditions and obtain geotechnical parameters for preliminary foundation and floor slab design. At this stage, given the likely magnitude of column loads, known deep made ground and proposed earthworks, a piled solution will be required, extending into bedrock. Intrusive investigation should also obtain data to allow appropriate concrete classification in accordance with BRE SD1 and for preliminary highways / pavement design.

6.3 Drainage

Given the site history, presence of widespread and locally deep made ground and suspected pervasive contamination, coupled with the anticipated low permeability clays underlying the made ground, it is unlikely that drainage to SuDS such as traditional soakaways will be suitable.

6.4 Recommendations

To confirm the ground conditions in respect to the identified potential geotechnical hazards and risks, an appropriate intrusive investigation will need to be undertaken.

7.0 METHOD OF INVESTIGATION

7.1 Context and Objectives

The investigation within this report has been conducted in general accordance with the BSL Ground Investigation Scoping Report (reference AJS/C5692/13232 dated June 2024) was produced in order to ascertain the requirements for further ground investigation and address the first half of the condition 4(c) i.e. the requirement for a Site Investigation Proposal.

Following a review of the existing ground investigation information, BSL consider that the site investigation works completed over the site as a whole to date is reasonably comprehensive, but there are a number of areas that require further assessment in order to address EA concerns and discharge the imposed planning conditions, these areas are listed below:

- Undertake a site wide detailed gap analysis to inform the DQRA.
- Produce a site wide PRA to summarise all existing data in one report (chapters 2.0 – 6.0 within this report).
- Confirm the design of the supplementary site investigation targeting the areas not previously investigated – Phases 3 and 4.
- Carry out some confirmatory investigation in areas previously investigated and remediated by trial pitting (Phase 1).
- Carry out supplementary trial pitting along the route of new gas pipeline filling in data gaps in this area.
- Carry out a detailed drainage risk assessment of the deep sewer that crosses the northern part of the site, to identify if it is part of the wider Water Authority drainage or a standalone localised historic feature.
- Refine the existing site conceptual model based on the supplementary site investigation.
- Carry out subsequent rounds of groundwater sampling and analysis (min 2 No. rounds), enabling detailed comparisons to be made with the groundwater monitoring undertaken prior to the remedial works undertaken in the north of the site. It is envisaged that this will likely show the betterment of the contaminant plumes previously identified in the superficial and bedrock aquifers.
- Refinement of the hydrogeological model.
- Produce a DQRA for controlled waters, encompassing the latest groundwater and soil data. This would be based on the original model, but with updated parameters and soil concentrations where required.
- Design the remedial strategy and RTCs driven by the DQRA target levels. This would likely encompass a site over dig and extensive on-site testing and validation ensuring any areas not identified during the site investigation are picked up.
- Produce a Piling Risk Assessment to demonstrate piling/penetrative works would not pose a risk to identified receptors.
- Conduct ongoing regulatory liaison in aid of transparency and to ensure LPA/EA queries are resolved in a timely manner.
- Installation of sentinel monitoring wells for longer term compliance and re-assurance, if required.
- In addition to the above, obtain sufficient geotechnical information for design purposes (i.e. detailed pile design).

In order to address the above, supplementary investigations and assessments will be undertaken in general accordance with the following guidance (list is not exhaustive):

- Environment Agency guidance - Land Contamination: Risk Management (LCRM).
- BS 10175:2011+A2:2017 Investigation of Potentially Contaminated Sites.
- BS5930: 2015+A1:2020 Code of Practice for Ground Investigations.
- BS EN 1997-1:2004+A1:2013 Eurocode 7. Geotechnical design. General rules plus UK National Annex.
- BS EN 1997-2:2007 Eurocode 7 Geotechnical design. Ground investigation and testing plus UK National Annex.

The supplementary investigation will be undertaken using cable percussive and rotary cored boreholes, trial pitting, hand pitting, windowless sampling, infiltration testing, gas and groundwater monitoring, laboratory chemical and geotechnical testing, with reporting on the findings.

7.2 Coverage and Method of Site Investigation

At this stage, in due consideration of the requirements listed above, the anticipated possible depths of made ground, the nature and distribution of likely contaminants, multi storey nature of development and the constraints that existing utilities hold over investigatory techniques/positions, we have allowed for the following works at the site:

- Provision of Health and Safety documentation in accordance with CDM 2015 regulations.
- Liaison with Cadent regarding investigatory positions in relation to live assets.
- Service/utility clearance survey utilising EM and GPR techniques.
- Setting out/surveying of exploratory locations by GPS (at least 1cm accuracy) to National Grid coordinates and mOD elevations.
- Provision of a detailed UXO Desk Study and UXO supervision in required areas.
- 15 No. deep boreholes; given the spatial extent of the development comprising five separate multi storey buildings within phases 3 and 4, we consider this is the minimum required to provide sufficient geotechnical design information for the proposed development. This provides a coverage of 3 deep boreholes per development block. Hydrock drilled 16 No. deep boreholes on the area of Phase 2 and 3. The proposed deep boreholes are presented on the appended Proposed Exploratory hole location plan.
- 22 No. days to drill 15 No. boreholes via cable percussive methods to rockhead estimated to be at 20m bgl with SPTs and sampling. These boreholes would be started in 200mm diameter casing and tooling and reduced to 150mm to help ensure rockhead is reached.
- Provision of rotary casing to install into cable percussive boreholes. Clean drilling techniques to be employed in areas where no prior remediation has been carried out and/or where significant contamination is anticipated/encountered where required.
- An allowance for 16 No. days of conventional rotary drilling to follow on from the cable percussive boreholes, obtaining rock core which will be logged and sampled for geotechnical testing to inform geotechnical pile design from all 15 No. boreholes.
- The schedule of borehole depths and core to be obtained is presented in the table further below.
- The installation of monitoring wells in 10 No. of the rotary follow-on boreholes.
- 10 No. days allowed for UXO on site supervision due to the possible presence of UXOs, the number of day's supervision to be reviewed on results of the detailed desk study.
- The drilling of up to 22 No. circa. 4.00-5.00m deep dynamic windowless sample boreholes is proposed to provide additional coverage.
- Installation of 12 No. shallow ground gas installations within windowless sample boreholes, to circa 5.00-6.00m bgl. This results in 30 monitoring wells in total.
- 5 No. days of a JCB 3CX excavator and breaker for breaking out of locations for the boreholes and window sampling, alongside increase the exploratory hole density across the site.
- Well development of all standpipes prior to sampling.
- 2 No. rounds of groundwater sampling via low flow methods.
- 6 No. rounds of confirmatory ground gas monitoring to supplement the existing Hydrock dataset.
- In-situ permeability testing of selected boreholes including the bedrock to enable parameters for a controlled waters DQRA to be obtained.
- 25 No. days on site engineering supervision.

Given the site extends to circa 2.8 hectares, the above scope of works provides an approximate 65-70 No. positions, which equates to a grid spacing of circa 20m and falls under the description of a detailed investigation in accordance with BS10175. This excludes the previous Entec and Hydrock exploratory positions which will provide further increased coverage and confidence. In addition, it is already known

that a full site wide turnover during remediation is required, therefore there is very high likelihood that all significant sources of contamination will be identified and addressed in due course.

Method	No.	Target Depths (m bgl)	Purpose
Trial pits – JCB 3CX	18-28	~3.00-4.00	Establish general ground conditions and gain good coverage. Undertake hand shear vanes in cohesive strata to determine soil strengths for preliminary foundation design.
Hand excavated Foundation Pits	5	<1.20	Establish general shallow ground conditions and increase coverage in areas around pipelines/limited access.
Cable percussive boreholes / Rotary cored boreholes	15	Schedule in below table	Assess deeper ground conditions, carry out SPTs and obtain samples for contamination and geotechnical testing. Determine soil strengths/densities for preliminary foundation design. Installation of ground gas and ground water monitoring wells. Obtain rock core for geotechnical testing and parameters for preliminary foundation design. Detailed rationale for position locations is presented in the table further below.
Window sample boreholes – Tracked WS rig	22	4.00 – 5.00	Establish general ground conditions on site. Allow Standard Penetration Tests (SPTs) to be carried out and obtain samples for contamination and geotechnical and testing. Determine soil strengths/densities for preliminary foundation design. Installation of ground gas and water monitoring wells.
Infiltration tests (in boreholes)	3-5	TBC	Obtain infiltration rates to inform DQRA and drainage design.

Proposed Deep Borehole Schedule

Our proposed schedule for borehole depth, cored sections and number of tests on rock core is presented below*:*

Phase	Block Name	Height of Proposed Building in Storeys	BH No.	Est CP BH depth (m)	Rotary follow on core (m)	Total BH Depth (m)	Mon. Well Install Depth (m)	Rock Testing UCS	Rock Testing Point Load
3	E	8	BH801	20	6	26	25	1	3
3	E	8	BH802	20	6	26	N/A	1	3
3	E	7	BH803	20	6	26	20	1	3
3	F	14	BH804	20	15	35	20	3	4
3	F	14	BH805	20	15	35	20	3	4
3	F	12	BH806	20	12	32	N/A	2	4
4	G	10	BH807	20	12	32	25	2	4
4	G	10	BH808	20	12	32	N/A	2	4
4	G	8	BH809	20	6	26	20	1	3
4	H	8	BH8010	20	6	26	N/A	1	3
4	H	10	BH8011	20	12	32	20	2	4
4	H	12	BH8012	20	12	32	25	2	4
4	I	30	BH8013	20	20	40	N/A	5	8
4	I	30	BH8014	20	30	50	20	7	10
4	I	30	BH8015	20	20	40	25	5	8
Totals					190	490	220	38	69

Rationale for Proposed Exploratory Hole Positions
Our rationale for proposed locations and targets is provided in the table below:

Phase	BH No.	Position Rationale
3	BH801	Foundation Design for Block E and Deep Soil and Groundwater Data in area of Tar Tank 2
3	BH802	Foundation Design for Block E and Deep Soil and Groundwater Data in area of Ammonia Plant
3	BH803	Foundation Design for Block E and Deep Soil and Groundwater Data in Area of Ammonia Plant
3	BH804	Foundation Design for Block F and Deep Soil and Groundwater Data in area of Gas Holder 5
3	BH805	Foundation Design for Block F and Deep Soil and Groundwater Data in area of Tar Tank 1
3	BH806	Foundation Design for Block F and Deep Soil and Groundwater Data
4	BH807	Foundation Design for Block G and Deep Soil and Groundwater Data in area of Tar Tank 1
4	BH808	Foundation Design for Block G and Deep Soil and Groundwater Data in area of Condensors/Purifiers
4	BH809	Foundation Design for Block G and Deep Soil and Groundwater Data Data in area of Condensors/Purifiers
4	BH810	Foundation Design for Block H and Deep Soil and Groundwater Data Data in area of Condensors/Purifiers
4	BH811	Foundation Design for Block H and Deep Soil and Groundwater Data in area of Gas Holder 3
4	BH812	Foundation Design for Block H and Deep Soil and Groundwater Data
4	BH813	Foundation Design for Block I and Deep Soil and Groundwater Data in area of Gas Holder 2
4	BH814	Foundation Design for Block I and Deep Soil and Groundwater Data in area of Gas Holder 1
4	BH815	Foundation Design for Block I and Deep Soil and Groundwater Data Gas Holder 1

7.3 Site Works

The following site works have been undertaken as part of the intrusive investigation between the dates of 24th June and 3rd September 2024.

Method	No.	Range Depths (m bgl)	Purpose
Hand excavated trial pits	6	0.55 – 1.70	Establish general ground conditions on site. HP809 was undertaken to gain information within the cadent compound standoff zone, specifically to target an area which had not undergone prior remediation works. HP811 was also undertaken to gain information within the cadent compound standoff zone, specifically to target a historical ammonia washing plant. HP815 and HP817 were undertaken in areas where access with a 3CX excavator proved difficult due to the active car park. BH805 was undertaken as a hand pit to gain information within the cadent compound.
Machine excavated trial pits – JCB 3CX	17	3.00 – 4.30	Establish general ground conditions and gain good coverage. Undertake hand shear vanes in cohesive strata to determine soil strengths for preliminary foundation design.
Window sample boreholes – Tracked WS rig	22	0.80 – 5.45	Establish general ground conditions on site. Allow Standard Penetration Tests (SPTs) to be carried out and obtain samples for contamination and geotechnical and testing. Determine soil strengths/densities for preliminary foundation design. Installation of ground gas and water monitoring wells.

Method	No.	Range Depths (m bgl)	Purpose
Cable percussive boreholes (12 No. with rotary core follow on, 1 No. with rotary openhole follow on, 7 terminated due to ground obstructions)	20	0.80 – 50.00	Assess deeper ground conditions, carry out SPTs and obtain samples for contamination and geotechnical and testing. Determine soil strengths/densities for preliminary foundation design. Installation of ground gas and water monitoring wells. Twelve boreholes progressed into bedrock with rotary cored methods to obtain rock core for geotechnical testing and parameters for preliminary foundation design. BH807 progressed into bedrock with rotary openhole methods to allow installation of groundwater monitoring wells.
Infiltration tests (in Boreholes)	5	-	Obtain indicative infiltration rates for drainage design.

The surveyed locations of the exploratory holes are indicated on the Post-Remediation Exploratory Hole Plan, Drawing No C5692/02 and the Combined Exploratory Hole Location Plan, Drawing No C5692/03 Rev D. The exploratory hole logs are presented in Appendix F.

The exploratory holes were logged by an experienced geo-environmental engineer in general accordance with the following guidance:

- BS 5930:2015+A1:2020 Code of Practice for Site Investigations.
- BS EN 14688-1:2018 Geotechnical Investigation and Testing – Identification and classification of soil.
- BS EN ISO 14689:2018 Geotechnical investigation and testing – Identification and classification of rock.

A specialist UXO study (EOD Contracts reference EOD/24/24210/DTS/REV1/Gould Street, Manchester, M4 4BH dated 12 June 2024) identified areas at moderate risk of UXO and order to minimise the risk to operatives during the ground investigation works, all exploratory locations were scanned with a hand-held magnetometer and works supervised by a specialist UXO surveyor within discrete areas of the site as summarised in section 4.16 of this report.

Whilst undertaking the drilling of BH814, a magnetic anomaly was encountered at 4.45m bgl. The hole was then terminated and moved at least 5.00m away from the original location to BH814A and agreed with the UXO Engineer onsite.

During the site investigation, contamination was encountered to varying degrees both within the made ground soils and groundwater with exploratory holes. To prevent the spread of potential contaminated arisings onsite or the spillage of potentially contaminated groundwater into local infrastructure and drainage, clean drilling techniques were used when deemed appropriate. These techniques included washing down equipment after drilling, using visqueen bunds to contain the spread of arisings and stockpile excess arisings/groundwater and using powdered bentonite to absorb groundwater.

Consideration was also taken in respect to potentially creating pathways from the potentially contaminated made ground/groundwater into the natural underlying strata and aquifers, therefore, bentonite seals were installed at the interface between made ground and natural soils around the outside of the casing during the drilling process. Further seals were installed when the holes were installed/backfilled to prevent leaching to the natural strata.

The below table shows where clean drilling techniques were used onsite:

Location	Contamination	Techniques
BH801	Made Ground & Groundwater – Strong hydrocarbon and solvent odour	Visqueen bund, bentonite seal and washing down of equipment.
BH803	Made Ground & Groundwater – Strong hydrocarbon odour and oily sheen	
BH804	Made Ground – Rancid solvent odour (suspected blue billy)	
BH806A	Made Ground and Groundwater – Very strong hydrocarbon odour, oily sheen and coal tar	
BH807	Made Ground, Glaciofluvial Deposits & Groundwater – Strong hydrocarbon and chlorinated solvent odour with moderate sheen	
BH811B	Made Ground and Groundwater – Moderate hydrocarbon odour	
BH813	Made Ground and Groundwater – Moderate hydrocarbon odour and sheen	
BH814A	Made Ground and Groundwater – Slight hydrocarbon odour	
BH815	Made Ground and Groundwater – Strong hydrocarbon odour and oily sheen	
WS817	Made Ground and Groundwater – Hydrocarbon odour and sheen. Bituminous material/coal tar	

It should be noted that the contaminated groundwater referenced within the above table refers to groundwater encountered within the made ground strata, and is likely perched and not representative of the natural groundwater table within the sandstone bedrock. Groundwater encountered within the bedrock strata did not display any visual or olfactory signs of contamination. BH807 was the only exploratory hole where visual or olfactory evidence of contamination was encountered within the natural superficial soil, further details are provided in Section 8.0.

At the end of the site works undertaken by BSL, the potentially contaminated excess arisings were stockpiled onto visqueen sheeting in the north-east corner of the site (lower car park) and subsequently fenced off with heras fencing as per the client's request.

Cadent PRS Compound Site Works – 2nd & 3rd September 2024

As described in Section 2.0, a Cadent PRS gas compound is present in the centre of the site, a number of additional holes were proposed to be undertaken in this area, including a borehole and three hand excavated trial pits. As this section of the site is owned and operated by Cadent, a permit and additional supervision was required to undertake any intrusive works, as well as adherence to specific requirements with regards to health and safety. Due to the risk of potential damage to assets within the compound, a cadent pipeline inspector and separate competent person for working in gas compounds were required to be in attendance, and the borehole was required to be 15m standoff away from any infrastructure. A hand pit, excavated to 1.20m depth and of a 1.0x1.0m area was also required to be excavated prior to the borehole being undertaken using an insulated shovel only, no insulated scissor shovels or insulated breaking bars were permitted. During the excavation of the hand pit, groundwater was encountered at 0.50m bgl, and due to the water being black and cloudy in nature, the base of the pit could not be observed and therefore it was deemed unsafe to continue excavating by hand pitting methods. Using a pump and a 1000L IBC, BSL attempted to lower the head of water enough to enable the hand excavating to continue.

The IBC was filled in circa 15 minutes, and during this time the head of water was unable to be lowered and therefore the pit was not able to be completed and the borehole was subsequently terminated.

A 15m standoff was also enforced around the area surrounding the compound for any holes BSL undertook during the site works. Further representative investigation would not be viable until the Cadent infrastructure in these areas is removed, although data from historical investigation positions are also available for this area.

7.4 Sampling Strategy

Soil Sampling
Representative samples were taken from exploratory holes at regular intervals to assist in the identification of the soils and to allow subsequent laboratory testing. They were stored and transported in general accordance with BS 10175:2011+A2:2017.

The type of sample was dependent upon the stratum and the purpose of analysis in accordance with current environmental and geotechnical guidance. The distribution of samples taken across the site is recorded on the exploratory logs.

Investigatory hole locations were determined by reference to the conditions identified in the preliminary risk assessment. Certain specific features such as former gas holders, tar tanks, ammonia washing plants and electrical substations were targeted for specific investigation and the remainder of the site was based off a circa 20m grid spacing.

7.5 Monitoring

Ground gas and groundwater monitoring standpipes were installed in a number of boreholes as detailed in the table further below.

A total of 6 monitoring visits have been undertaken by BSL as part of the current scope, in line with the recommendations of BS8485.

All gas monitoring was undertaken using either a GA5000 or GFM436 infrared gas meter with integral electronic flow analyser and a Photo Ionisation Detector (PID).

Flow measurements on each standpipe (l/hr) were taken. Measurements of the percentage volume in air (%v/v) of oxygen (O_2), carbon dioxide (CO_2) and methane (CH_4) were recorded in addition to the percentage Lower Explosive Limit (%LEL) of methane (Note: 100% LEL equates to 5% by volume), the atmospheric pressure (mb) and average temperature during the visit (°C), and trace gases including carbon monoxide and hydrogen sulphide. Total volatile organic compounds (TVOCs) were measured with a Photo Ionisation Detector (PID).

Standpipes were constructed in general accordance with the relevant guidance. A summary of the installation construction is presented in the table below:

Location	Internal Diameter Pipe	Response Zone (m bgl)	Targeted Strata	Purpose
BH801	50mm HDPE	12.00 - 21.00	SANDSTONE	Groundwater
BH802A	50mm HDPE	15.00 - 24.00	SANDSTONE	Groundwater
BH804	50mm HDPE	14.00 - 24.00	SANDSTONE	Groundwater
BH807	35mm PVC 50mm HDPE	4.00 - 9.00 15.00 - 20.00	CLAY SANDSTONE	Ground Gas & Groundwater Groundwater
BH810	50mm HDPE	17.00 - 23.00	SANDSTONE	Groundwater

Location	Internal Diameter Pipe	Response Zone (m bgl)	Targeted Strata	Purpose
BH811B	50mm HDPE	12.00 - 20.00	SANDSTONE & MUDSTONE	Groundwater
BH812	50mm HDPE	10.00 - 25.00	SANDSTONE	Groundwater
BH814A	50mm HDPE	10.00 - 30.00	SANDSTONE	Groundwater
BH815	50mm HDPE	4.00 - 7.00	MADE GROUND	Ground Gas & Groundwater
WS801	35mm PVC	2.00 - 5.00	CLAY	Ground Gas & Groundwater
WS802	35mm PVC	1.00 - 3.00	MADE GROUND	Ground Gas & Groundwater
WS803	35mm PVC	2.00 - 5.00	MADE GROUND	Ground Gas & Groundwater
WS805	35mm PVC	1.20 - 2.60	MADE GROUND	Ground Gas & Groundwater
WS806	35mm PVC	2.50 - 4.50	MADE GROUND	Ground Gas & Groundwater
WS807	35mm PVC	1.00 - 2.00	MADE GROUND	Ground Gas & Groundwater
WS808	35mm PVC	0.50 - 1.50	MADE GROUND	Ground Gas & Groundwater
WS809A	35mm PVC	1.00 - 2.50	MADE GROUND	Ground Gas & Groundwater
WS810	35mm PVC	1.00 - 5.00	MADE GROUND	Ground Gas & Groundwater
WS812	35mm PVC	1.00 - 1.50	MADE GROUND	Ground Gas & Groundwater
WS814	35mm PVC	1.20 - 4.00	MADE GROUND	Ground Gas & Groundwater
WS815	35mm PVC	1.00 - 4.00	MADE GROUND	Ground Gas & Groundwater
WS816	35mm PVC	2.00 - 5.00	MADE GROUND	Ground Gas & Groundwater
WS817	35mm PVC	1.50 - 2.00	MADE GROUND	Ground Gas & Groundwater
WS818	35mm PVC	2.00 - 5.00	MADE GROUND	Ground Gas & Groundwater
WS819	35mm PVC	0.50 - 1.50	MADE GROUND	Ground Gas & Groundwater
WS821	35mm PVC	1.00 - 5.00	MADE GROUND	Ground Gas & Groundwater
WS822	35mm PVC	1.00 - 2.00	MADE GROUND	Ground Gas & Groundwater
HP811	35mm PVC	0.20 - 1.70	MADE GROUND	Ground Gas & Groundwater

The following historical boreholes from previous site investigations have also been monitored as part of the site investigation and subsequent monitoring.

Location	Internal Diameter Pipe	Response Zone (m bgl)	Targeted Strata	Purpose
WS11	35mm PVC	1.00-1.50	MADE GROUND	Ground Gas & Groundwater
WS310	35mm PVC	0.50-0.80	MADE GROUND	Ground Gas & Groundwater
WS701	35mm PVC	1.00-4.00	CLAY	Ground Gas & Groundwater
WS702	35mm PVC	0.50-3.00	MADE GROUND	Ground Gas & Groundwater
BH301	50mm HDPE	18.50-24.50	SANDSTONE	Ground Gas & Groundwater
BH303A	50mm HDPE	19.00-26.50	SANDSTONE	Ground Gas & Groundwater
BH305	50mm HDPE	7.50-9.50	CLAY & SAND	Ground Gas & Groundwater
BH507	50mm HDPE	N/A	N/A	Ground Gas & Groundwater
MPBH710	50mm HDPE	10.00-16.00	CLAY, GRAVEL & SAND	Ground Gas & Groundwater

The gas monitoring visits recorded peak and steady state conditions. Peak results are those that occur on opening the valve on the borehole tap. Steady state conditions are those that occur a period of time afterwards when the initial (accumulated) gases have been purged from the borehole.

Ground gas monitoring results are presented in Appendix I of this report.

Installation Development and Groundwater Sampling
BSL attended site on 25th July 2024 to undertake development on all installed BSL boreholes.

Development of the installation was undertaken using a peristaltic pump, removing 3 times the volume of the installation, utilising fresh pipe in-between holes to prevent cross contamination and cleaning of all equipment down with de-ionised water.

After development, BSL re-attended site on 6th and 7th August 2024 to collect 13 No. water samples from BS installations. Water was collected via low flow methods using a peristaltic pump to gain representative samples once key parameters had stabilised.

BSL undertook an additional sampling visit on 19th and 20th August 2023 to collect a further 13 No. water samples. On the second visit, it was possible to retrieve samples from WS801, which was dry during the first sampling visit; this sample was scheduled for testing in preference over WS806 given WS801 was installed within the natural superficial deposits. A sample was not able to be retrieved from HP811 during the second round, therefore sample from WS815 was tested instead. Otherwise, the same monitoring wells were sampled and scheduled for the same suite of testing on both the first and second rounds of monitoring.

Further sampling was undertaken by BSL on 3rd September 2024 to collect a shallow water sample at circa 0.6m depth from BH805, located within the Cadent PRS compound, as access to this area of the site had not been possible during the main phase of investigation works.

7.6 Laboratory Testing

As part of the further assessment for potential contamination of the site, selected samples were taken for the purpose of chemical contamination testing.

Based on the potential contaminative processes on site identified, the following suite of determinands were analysed at a UKAS approved laboratory to screen for potential site impacts:

Made Ground Strata Testing

Determinand	No of Samples
BSL Default Soil Suite: Arsenic, Cadmium, Chromium (III), Chromium (VI), Copper, Nickel, Mercury, Lead, Zinc, Selenium, speciated polycyclic hydrocarbons (PAH 16), water soluble sulphate (2:1 Extract), soil organic matter (SOM) and pH.	30
Petroleum Hydrocarbons (TPH CWG) inc BTEX and MTBE.	23
Asbestos Screen.	26
PCB Compounds (7 Congeners).	2
Volatile Organic Compounds (VOCs) by GC-MS (Ex TIC).	27
Semi Volatile Organic compounds (SVOCs) by GC-MS (Ex TIC).	25
Cyanides, Ammoniacal Nitrogen, Thiocyanate, Speciated Phenols	26
Fraction Organic Carbon (FOC)	9

Natural Strata Testing

Determinand	No of Samples
BSL Default Soil Suite: Arsenic, Cadmium, Chromium (III), Chromium (VI), Copper, Nickel, Mercury, Lead, Zinc, Selenium, speciated polycyclic hydrocarbons (PAH 16), water soluble sulphate (2:1 Extract), soil organic matter (SOM) and pH.	2
Petroleum Hydrocarbons (TPH CWG) inc BTEX and MTBE.	4
Volatile Organic Compounds (VOCs) by GC-MS (Ex TIC).	4
Semi Volatile Organic compounds (SVOCs) by GC-MS (Ex TIC).	9
Cyanides, Ammoniacal Nitrogen, Thiocyanate, Speciated Phenols	5
Fraction Organic Carbon (FOC)	5

Sandstone Bedrock Testing

Determinand	No of Samples
Fraction Organic Carbon (FOC)	2

The following tests were scheduled on groundwater samples (two rounds in total as per EA requirements) at a UKAS approved laboratory:

Determinand	No of Samples
Site Specific Suite: Silver, Aluminium, Arsenic ,Boron, Barium, Calcium, Cadmium, Cobalt, Chromium - III, Chromium - Hexavalent, Chromium, Copper, Iron, Mercury, Manganese, Sodium, Nickel, Lead, Antimony, Selenium, Tin, Zinc, Vanadium, Cyanide - Total, Cyanide - Free, Cyanide - Complex, Phenols – Speciated, Ammoniacal Nitrogen as N, Ammoniacal Nitrogen as NH3, Ammoniacal Nitrogen as NH4, Dissolved Organic Carbon (DOC), Bromate, Chloride, Fluoride, Nitrate, Nitrite, Sulphate as SO4, PAH - Speciated (EPA 16) Inc total, pH, Electrical Conductivity, Hardness - Total (as CaCO3), Thiocyanate (as SCN).	27
Petroleum Hydrocarbons (TPH CWG) inc BTEX and MTBE.	27
Volatile Organic Compounds (VOCs) by GC-MS	6
Semi Volatile Organic compounds (SVOCs) by GC-MS	21
Enhanced Degradation Suite for Water: Nitrate (as N03), Nitrite (as N02), Iron Species (Fe 2+ / Fe 3+), Manganese II & Manganese IV, Sulphate as SO4, Sulphide, Redox Potential, pH, Alkalinity (as CaCO3), Electrical Conductivity.	10

The Chemical Laboratory Testing Results are presented in Appendix H.

Representative disturbed samples were obtained for all soil types encountered. Selected samples were scheduled for testing at an approved laboratory in accordance with BS 1377 'Method of Test for Soils for Civil Engineering Purposes' and BS EN ISO 17892- Parts 1-12:2018 'Geotechnical investigation and testing. Laboratory testing of soil'.

The following tests were scheduled for geotechnical purposes:

Description	No of Samples
Natural Water Content.	16
Plasticity Index Analysis.	16
Particle Size Distribution (PSD) wet.	18
pH Value.	12
Water Soluble Sulphate Contents.	12
SD1 BRE Full Suite.	12
Determination of One-Dimensional Consolidation properties.	7
Point Load Testing.	65
Unconfined Compressive Strength (UCS).	38
Determination of Undrained Shear Strength in Triaxial Compression.	11

The following tests were scheduled for earthworks purposes:

Description	No of Samples
Determination of dry density/moisture content relationship (2.5kg).	6
Determination of dry density/moisture content relationship (4.5kg).	9
Determination of dry density/moisture content relationship (vibrating hammer).	6
Laboratory Hand Shear Vane.	13
CBR in lab: at received MC.	6
CBR in Lab: OMC.	6

The Geotechnical Laboratory Testing Results are presented in Appendix H.

8.0 GROUND CONDITIONS

8.1 Summary

A brief summary of the ground conditions encountered is presented in the table below:

Stratum	Range Depths - Top (m bgl)	Range Depths - Base (m bgl)	Range Thickness' (m)	Brief Description
Made Ground – Hardstanding	0.00	0.08 – 0.30	0.08 – 0.30	Tarmacadam, Bricks & Concrete.
Made Ground	0.08 – 0.30	0.55 – 10.00	0.30 – 9.90	Gravelly SAND, Silty SAND (PFA), sandy GRAVEL, gravelly clayey SAND, sandy gravelly CLAY.
Natural Superficial Strata – Cohesive	1.00 – 10.00	3.50 – 15.00	0.60 – 9.90	Slightly gravelly CLAY.
Natural Superficial Strata – Granular	7.90 – 9.00	9.00 – 9.16	0.16 – 1.10	Gravelly SAND.
Solid Geology – Sandstone	9.00 – 16.50	13.00 – 33.00	2.10 – 23.80	SANDTONE.
Solid Geology – Mudstone	12.00 – 33.00	13.10 – 50.00	0.04 – 17.00	MUDSTONE.

Details are provided in the logs in Appendix F and the individual strata are described in the sections below.

It should be noted that the details provided in the above table only include the ground conditions encountered during the BSL site investigation.

8.2 Made Ground

Made Ground – General
Made ground was encountered within all the exploratory holes across the site and was observed from ground level to depths between 0.55m and 10.50m bgl.

Hardstanding surfacing of tarmacadam was present across the majority of the site recorded between 0.08m and 0.30m thick.

Hardstanding concrete was found in TP821 and TP822 to a depth of 0.10m bgl.

The composition of the made ground beneath the tarmacadam was fairly consistent across the site and represented sub-base material comprising gravelly sand with gravels of brick and sandstone.

Across the wider site, the composition of the made ground below the sub-base was mainly classified as granular, comprising of gravelly sand with varying amounts of ash as a minor constituent, with the exception of areas where large proportions of PFA was encountered within the made ground, as detailed below. The gravel included anthropogenic inclusions of slag, brick, concrete, glass, clinker, coal, metal, timber and suspected blue billy.

Cohesive made ground was also encountered locally across the site, most commonly encountered below the granular made ground strata. The cohesive made ground comprised of a sandy gravelly clay.

The locations and depths of the cohesive made ground are presented in the table below:

Cohesive Made Ground		
Location	Depth (m)	Historic Feature Name
TP802	1.30-1.70	Gas Holder No. 2
TP803	1.10-4.00	-
TP809	2.40-2.60	-
TP818	2.50-3.70	-
TP819	0.90-1.30	-
WS801	1.00-2.00	-
WS802	0.50-1.00	-
WS802	3.00-4.00	-
WS803	1.00-5.45	Gas Holder No. 2
WS804	0.50-1.80	Gas Holder No. 2
WS806	1.50-5.45	-
WS807	0.50-2.43	Gas Holder No. 2
WS808	1.50-1.78	-
WS817	2.10-3.00	-
HP811	1.00-1.70	-
BH804	7.00-8.50	Gas Holder No. 5
BH807	2.80-3.50	-
BH808	0.90-3.10	-
BH813	2.00-8.00	Gas Holder No. 2

Concrete associated with previous developments (basements and cellars) was encountered within TP820 and TP821 at 3.50m bgl. Further obstructions were encountered within the boreholes and are detailed in Section 8.6.

Pulverised Fly Ash (PFA) was encountered within the made ground across the site predominantly within the former gas holders, locations can be found in the table below:

Pulverised Fly Ash (PFA)		
Location	Depth (m)	Historic Feature Name
BH801	0.80 – 8.00	Tar Tank No. 2
BH811	1.00 – 3.50	Gas Holder No. 3
BH811A	1.00 – 3.00	Gas Holder No. 3
WS805	1.20 – 2.82	Gas Holder No. 1
WS810	1.00 – 5.45	Gas Holder No. 5
WS816	1.20 – 5.45	Tar Tank No. 2
WS818	2.00 – 5.45	Tar Tank No. 2
WS822	1.00 – 2.18	Gas Holder No. 3
TP804	1.40 – 4.00	Gas Holder No. 5
TP806	1.80 – 4.00	Gas Holder No. 1

The depth of the made ground varied greatly across the site, due to the presence of historical gas holders and tanks associated with the former gas works. Within the holes completed within the gas holders, the made ground ranged in depths between 6.00m and 10.00m bgl, which is typically in line with the depths of the gas holders, from historical records and previous site investigations. The made ground depths outside the gas holders/tanks ranged from 1.00m to 7.00m bgl. The depth of made ground across the site is shown on the Depth to Made Ground Plans, Drawing Nos. C5692/09 and C5692/10.

8.3 Natural Superficial Strata

The natural strata underlying the site was encountered in just 22 out of 65 locations and was generally a firm to stiff clay with varying amounts of sand and gravel as minor constituents. This is interpreted to represent glacial Till.

The encountered thickness of the natural strata across the site varied due to the presence of the historical gas holders/tanks. Within the gas holders/tanks the natural superficial strata was limited, and was encountered between 0.60m and 4.00m in thickness. Within BH813, no superficial strata was found between the base of the made ground and the natural bedrock strata, although the interface between the granular made ground and the bedrock strata was separated by a concrete slab, which is likely to represent the base of the gas holder/tank. Natural superficial strata was encountered below the made ground in the areas of the gas holders in 5 locations; BH801 (Tar Tank No.2), BH804 (Gas Holder No.5), BH811B (Gas Holder No.3), BH814A (Gas Holder No.5) and BH815 (Gas Holder No.5).

Outside of the areas of the gas holders, the natural superficial strata was slightly more abundant, and was encountered to between 3.50m and 15.00m bgl within 17 exploratory holes undertaken by BSL, in the following locations and thicknesses:

Location	Thickness (m)
BH802A	9.90
BH803	8.00
BH806A	8.70
BH807	7.40
BH808	9.10
BH810	5.50
BH812	6.90
TP801	1.40
TP808	2.50
TP809	1.70
TP812	1.60
TP819	2.70
TP822	2.30
WS801	3.45
WS802	1.45
WS814	0.85
WS817	2.45

Shear vane readings (where available) in the cohesive soils indicate the clays are generally medium and high strength. The full results are provided on the borehole logs.

The presence of granular strata was relatively limited and only encountered sporadically at the below locations and depths within the boreholes:

Granular Strata		
Location	Depth (m bgl)	Strata
BH807	7.20 – 8.70	Lenses of black sand.
BH811B	9.00 – 9.16	Very dense slightly gravelly sand.
BH812	7.90 – 9.00	Dense slightly gravelly sand.

8.4 Solid Geology

Sandstone
Very weak sandstone bedrock was encountered from depths of between 9.00m and 16.50m. This was proven to a maximum depth of 33.00m across the site and is interpreted to represent the Chester Formation. The discontinuities described generally ranged from being extremely close to medium spaced, rough, being horizontal to sub-horizontal in orientation. Localised vertical to sub-vertical factures were also encountered.

The overall percentage of Total Core Recovery (TCR) in sandstone over each core run within an individual borehole varied from 0% to 100%, although averaged at 74%. Similarly, Solid Core Recovery (SCR) ranged between 0% to 100% and averaged 57%.

Rock Quality Designation (RQD) percentages ranged between 0% up to 100%, although considerable variation in the RQD was recorded with depth and averaged at 44%. Thirteen of the twenty-four data points were recorded at 50% or above in the sandstone, however, overall there was little consistent pattern to recorded RQD values with depth, with no trend apparent.

Mudstone
Extremely weak to weak mudstone was encountered in localised areas of the site. Discontinuities described generally ranged from being extremely close to closely spaced, rough and horizontal to sub-horizontal in orientation. Localised vertical to sub-vertical factures were also encountered. Locations and depths can be found in the table below:

Mudstone Strata	
Location	**Depth (m)**
BH811B	19.35 – 19.78
	25.71 – 26.00
BH812	25.30 – 23.50
BH814A	33.00 – 50.00

The overall percentage of Total Core Recovery (TCR) in mudstone over each core run within an individual borehole varied from 66.7% to 100%, although averaged at 93%. Similarly, Solid Core Recovery (SCR) ranged between 50% to 100% and averaged 88%.

Rock Quality Designation (RQD) percentages ranged between 32% up to 100% and averaged at 80%.
The majority of the core runs within the mudstone were recorded with a RQD of 70% or above, with only two runs being recorded between 32% and 70% at 31.00m and 39.00m bgl respectively. Overall there was little consistent pattern to recorded RQD values with depth, with no trend apparent.

8.5 Groundwater

The depths to groundwater and locations present within the made ground strata during site works are shown in the tables below:

Groundwater – Made Ground			
Location	Depth During Site Works (m)	Depth During Site Works (mAOD)	Comments
BH801	7.70	34.864	Strong hydrocarbon and solvent odour
BH803	4.50	40.868	Strong hydrocarbon odour and oily sheen
BH806A	4.50	41.014	Very strong hydrocarbon odour, oily sheen.
BH807	2.80 & 3.50	39.937 & 39.237	Strong hydrocarbon and chlorinated solvent odour with moderate sheen
BH811	2.80	40.132	Moderate hydrocarbon odour
BH811A	3.70	39.2	Moderate hydrocarbon odour
BH811B	2.80	40.036	Moderate hydrocarbon odour
BH813	8.00 & 8.20	34.366 & 34.166	Moderate hydrocarbon odour and sheen.
BH815	4.50	37.818	Strong hydrocarbon odour and oily sheen.
WS806	2.50 & 3.00	39.853 & 39.353	-
WS814	3.70	38.757	-
WS816	2.00	40.424	-
WS818	3.00	39.693	-
TP801	2.60	39.774	-
TP805	2.60	39.831	-
TP809	2.45	40.442	Hydrocarbon odour and sheen.
TP810	2.00	40.644	Hydrocarbon odour and sheen.
TP812	2.40	39.991	-
TP821	1.20	44.91	-
HP811	1.70	40.952	-

Groundwater – Superficial / Bedrock			
Location	Depth During Site Works (m bgl)	Depth During Site Works (mAOD)	Comments
BH801	14.30	28.264	Sandstone bedrock
BH802	18.10	26.62	
BH803	23.00	22.368	
BH804	15.10	27.275	
BH806A	18.50	27.014	
BH807	7.20	35.537	Superficial sand
BH807	16.50	26.237	Sandstone bedrock
BH810	18.70	26.866	
BH811B	15.00	27.836	
BH812	17.00	25.497	
BH813	15.40	26.966	
BH814A	15.00	27.281	

Post site works monitoring has revealed the following depths to groundwater:

Location	Depth During Monitoring Period (range) (m)		Depth During Monitoring Period (range) (mAOD)	
	Min	Max	Min	Max
Overall min/max	0.37	19.20	26.517	43.787
WS801	2.09	3.15	40.228	39.168
WS802	2.59	2.88	39.756	39.466
WS803	NGW	3.90	NGW	38.545
WS805	0.37	1.27	41.919	41.019
WS806	1.82	2.54	40.533	39.813
WS807	NGW	1.18	NGW	41.155
WS808	NGW	NGW	NGW	NGW
WS809A	2.10	2.35	43.815	43.565
WS810	0.83	3.22	45.081	42.691
WS812	NGW	NGW	NGW	NGW
WS814	3.20	3.36	39.257	39.097
WS815	0.80	0.87	41.718	41.648
WS816	1.40	1.66	41.024	40.764
WS817	1.60	1.80	40.991	40.791
WS818	1.50	1.92	41.193	40.773
WS819	NGW	NGW	NGW	NGW
WS821	NGW	NGW	NGW	NGW
WS822	1.34	1.72	41.511	41.131
BH801	12.00	15.94	30.564	26.624
BH802A	18.10	19.20	26.517	25.417
BH804	14.83	15.46	27.545	26.915
BH807D	12.80	16.23	29.937	26.507
BH807S	NGW	NGW	NGW	NGW
BH810	18.60	18.86	26.966	26.706
BH811B	14.88	14.93	27.956	27.906
BH812	15.41	15.6	27.087	26.897
BH814A	14.00	15.40	28.281	26.881
BH815	1.10	1.36	41.218	40.958
HP811	1.10	1.35	41.552	41.302
WS11	NGW	NGW	NGW	NGW
WS310	NGW	NGW	NGW	NGW
WS701	0.90	1.30	44.187	43.787
WS702	NGW	NGW	NGW	NGW
BH301	18.1	18.6	26.924	26.424
BH303A	18.7	19.04	27.078	26.738
BH305	3.40	8.80	42.068	36.668
BH507	11.50	11.63	32.725	32.595

Based on the post site works monitoring data from the 5th and 6th August 2024, the groundwater levels have been modelled using surfer contouring software, as displayed on the Bedrock Groundwater Level Contour Plan, BSL drawing reference C5692/16, which is presented in the drawings section. The groundwater dataset was consistently obtained from groundwater depths within the same stratum, the Chester Formation Sandstone bedrock, and therefore is considered to represent a continuous groundwater body within the sandstone bedrock. Whilst groundwater levels are relatively flat especially in the far north of the site, the data demonstrates an overall trend of groundwater levels decreasing towards the south-west, which is concurrent with observations made by Hydrock in 2022 for the southern half of the site.

Within the content of the wider hydrogeological area the groundwater gradient seems to be trending parallel to the River Irk present to the north-west of the site, perhaps reflecting an overall wider hydrogeological gradient towards the River Irwell which lies approximately 800m to the west of the site at its closest approach, and therefore the groundwater onsite is likely being influenced by the Irwell's potentially more influential catchment area. Furthermore, the Bedrock Groundwater Level Contour Plan has been based on data obtained over the same groundwater monitoring visit in August 2024 to give a present-day snapshot. This avoids the potential variation of groundwater levels associated with using data over different visits or phases of investigation which could introduce seasonal and annual variance and compromise an accurate assessment of the dataset.

8.6 Observations

Contamination

During the works undertaken by BSL, observations for both visual and olfactory evidence of contamination were undertaken. The below table shows the locations and depth of the suspected contamination observations during the site works:

Contamination		
Location	Depth (m bgl)	Type
BH801	0.80-8.00	Made Ground & Groundwater – Strong hydrocarbon and solvent odour
BH803	4.50-5.00	Made Ground & Groundwater – Strong hydrocarbon odour and oily sheen
BH804	0.20-8.50	Made Ground – Rancid solvent odour (suspected blue billy)
BH806A	4.50-4.90	Made Ground and Groundwater – Very strong hydrocarbon odour, oily sheen and coal tar.
BH807	0.50-2.80 3.50-4.00 7.20-8.70	Made Ground, Glaciofluvial Deposits & Groundwater – Strong hydrocarbon and chlorinated solvent odour with moderate sheen
BH811	1.00-3.50	Made Ground and Groundwater – Moderate hydrocarbon odour
BH811A	1.00-3.00	Made Ground and Groundwater – Moderate hydrocarbon odour
BH811B	1.00-3.50	Made Ground and Groundwater – Moderate hydrocarbon odour
BH813	4.00-9.90	Made Ground and Groundwater – Moderate hydrocarbon odour and sheen.
BH814A	1.50-8.60	Made Ground and Groundwater – Slight hydrocarbon odour
BH815	1.70-8.00	Made Ground and Groundwater – Strong hydrocarbon odour and oily sheen.
WS802	0.30-0.50	Made Ground - Hydrocarbon odour
WS803	0.10-1.00 1.80-5.00	Made Ground - Hydrocarbon odour
WS805	1.20-2.60	Made Ground - Hydrocarbon odour
WS806	0.30-1.50	Made Ground - Hydrocarbon odour
WS807	0.30-0.50	Made Ground - Hydrocarbon odour
WS808	0.50-1.50	Made Ground - Hydrocarbon odour
WS810	1.00-5.00	Made Ground - Hydrocarbon odour
WS814	0.60-4.60	Made Ground - Hydrocarbon odour

Location	Contamination	
	Depth (m bgl)	Type
WS815	1.00-5.45	Made Ground - Hydrocarbon odour
WS816	0.30-5.45	Made Ground - Strong hydrocarbon odour
WS817	1.60-3.00	Made Ground and Groundwater – Hydrocarbon odour and sheen. Bituminous material/coal tar.
WS818	0.50-0.60 2.00-5.00	Made Ground - Hydrocarbon odour
WS822	0.50-1.00	Made Ground - Hydrocarbon odour
TP801	1.50-2.60	Made Ground - Hydrocarbon odour
TP802	0.70-1.30	Made Ground - Hydrocarbon odour
TP803	0.60-1.10	Made Ground - Hydrocarbon odour
TP804	1.40-4.00	Made Ground – Sharp hydrocarbon odour (suspected blue billy)
TP805	1.70-3.00	Made Ground - Hydrocarbon odour
TP806	1.80-4.00	Made Ground - Weak hydrocarbon odour
TP808	0.70-1.00	Made Ground - Hydrocarbon odour
TP809	0.50-0.80	Made Ground and Groundwater – Hydrocarbon odour and sheen.
TP810	0.50-3.50	Made Ground and Groundwater – Hydrocarbon odour and sheen.
TP812	0.60-1.40 2.40-4.00	Made Ground - Hydrocarbon odour
HP811	0.60-1.70	Made Ground - Strong hydrocarbon odour

Varying amounts of ash, clinker and slag were also encountered within the majority of the granular made ground soils encountered across the site.

Stability of Excavations/Boreholes
The sides of the trial pits were generally stable however spalling of the made ground strata was observed in TP813 and TP805.

Casing was required to prevent collapse with the granular materials during drilling of the window sample boreholes, cable percussive and rotary boreholes. Casing was also used to seal off the superficial deposits within the rotary boreholes and to prevent collapse within the made ground.

Obstructions
There are numerous obstructions throughout the made ground on site. The obstructions identified are summarised in the table below:

Location	Depth (m bgl)	Comments
BH803	5.00	Concrete obstruction encountered at 5.00m bgl, bentonite seal created.
BH806	2.00	Concrete obstruction encountered at 2.00m and chiselled down to 2.50m bgl.
BH809	1.00	Concrete obstruction encountered at 1.00m bgl and hole terminated.
BH809A	0.80	Concrete obstruction encountered at 0.80m bgl and hole terminated.
BH811	4.00	Concrete obstruction encountered at 4.00m bgl and hole terminated.

Location	Depth (m bgl)	Comments
BH811A	4.00	Concrete obstruction encountered at 4.00m bgl and hole terminated.
BH811B	4.40	Concrete obstruction encountered between 4.40m and 6.00m bgl.
HP815	0.55	Concrete obstruction encountered at 0.55m bgl and hole terminated.
TP809	2.50	Pit extended southwards at 2.50m bgl due to concrete obstruction.
TP820	3.50	Hard obstruction encountered at 3.50m bgl thought to be concrete. Trial pit terminated.
TP821	3.50	Hard obstruction encountered at 3.50m bgl thought to be concrete. Trial pit terminated.

UXO

During the drilling of BH813, a positive magnetometer reading was encountered at 9.00m bgl. The magnetic anomaly was likely associated with the base of a historic gas holder / tank.

During the drilling of BH814, a positive magnetometer reading on was encountered at 4.45m bgl. The hole was subsequently moved approximately 5 metres to the south.

No further magnetic anomalies were encountered during the works.

9.0 TEST RESULTS

9.1 Geotechnical Laboratory Testing

Plasticity Index Analysis
Plasticity index results ranged between 19% and 28%. Associated water contents ranged between 15% and 28%.

After modification of particle size in accordance with BRE 240 the modified plasticity indices are in the range 16% to 26%, indicating the cohesive soils to be of low to medium volume change potential.

Particle Size Distribution (PSD) Analyses
PSD tests were undertaken on eleven samples of the made ground. The findings generally indicate the made ground is predominantly granular, comprising of gravelly sandy with varying amounts of silt and cobbles as minor constituents.

PSD tests were also undertaken on seven samples of the natural superficial strata. The findings indicate these strata are cohesive clays with varying amounts of sand and gravel as minor constituents.

Undrained Shear Strength
The results of the tests are shown in the table below:

Location	Depth (m)	Shear Strength (kPa)	Undrained Shear Strength to EC7
BH801	9.00-9.45	207	High
BH802A	6.00-6.45	94	High
BH802A	7.50-7.95	146	High
BH806A	10.50-10.95	79	High
BH807	5.00-5.45	101	High
BH807	9.00-9.45	143	High
BH808	4.00-4.45	106	High
BH808	11.00-11.45	122	High
BH810	7.50-7.95	122	High
BH810	10.50-10.95	107	High
BH812	5.00-5.45	121	High

Laboratory HSV Results
The results of the tests are shown in the table below:

Location	Depth (m)	HSV Reading (kN/m^2)	Soil Strength
BH801	8.00-8.50	112	Stiff
BH802A	3.60	62	Firm
BH804	8.50-9.00	91	Stiff
BH806A	5.00-5.50	38	Soft
BH807	3.50-4.00	36	Soft
BH807	8.70-8.90	115	Stiff
BH808	3.50-4.00	120	Stiff
TP801	2.60-3.00	34	Soft
TP808	1.10-1.50	17	Very soft
TP809	2.60-3.00	12	Very soft
TP812	2.40-3.00	41	Firm
TP819	1.30-2.00	138	Stiff
TP822	1.70-2.70	126	Stiff

One Dimensional Consolidation Properties

The one-dimensional consolidation properties were as follows:

Location	Depth (m)	Mv Range (m^2/MN)	Cv Range (m^2/yr)	Compressibility at Approx Over-Burden Pressure
BH802A	6.00-6.45	0.08-0.51	1.93-2.97	Low to medium
BH802A	7.50-7.95	0.08-0.97	2.24-3.37	Low to high
BH806A	7.50-7.95	0.17-0.35	3.47-29.45	Medium to high
BH806A	10.50-10.95	0.06-0.76	1.51-2.86	Low to high
BH810	7.50-7.95	0.10-0.38	1.43-2.79	Medium to high
BH810	10.50-10.95	0.02-0.80	2.97-7.27	Very low to high
BH812	5.00-5.45	0.02-0.25	1.90-7.16	Very low to medium

Dry Density/Moisture Content

The results of the Dry Density/Moisture Content relationship testing are as follows.

Method	Location	Depth (m)	Brief Stratum Description	PD[1] (Mg/m^3)	MDD[2] (Mg/m^3)	IMC[3] (%)	OMC[4] (%)
2.5 / 4.5 kg compaction effort	BH802A	3.6	Sl gravelly CLAY	2.6	1.84	9.4	14
	BH811	1.00-2.00	MADE GROUND – Gravelly sand	2.5	1.8	8.9	13
	BH814A	0.30-1.20	MADE GROUND – Sandy gravel	2.65	2.03	6	10
	BH814A	2.50-3.00	MADE GROUND – Sl gravelly sand	2.4	1.66	10.4	15
	BH814A	0.10-0.30	MADE GROUND – Sandy gravel	2.5	1.94	6.8	10
	TP801	2.60-3.00	Sl gravelly sl sandy CLAY	2.6	1.75	13.2	17
	TP802	1.70-2.30	MADE GROUND - Gravelly sand	2.4	1.7	9.2	14
	TP803	1.10-2.00	MADE GROUND - Sl gravelly sl sandy clay	2.5	1.73	12.4	15
	TP804	1.40-2.00	MADE GROUND – Sl clayey sl gravelly sand	2.2	1.52	15.1	18
	TP806	1.80-2.30	MADE GROUND - Gravelly sand	2.2	1.5	15.8	19
	TP808	1.10-1.50	Sl gravelly sl sandy CLAY	2.6	1.84	10.5	14
	TP809	2.60-3.00	Sl gravelly CLAY	2.6	1.86	9.1	13
	TP812	2.40-3.00	Sl gravelly sl sandy CLAY	2.6	1.78	11.8	16
	TP822	1.70-2.70	Sl gravelly CLAY	2.6	1.73	13.7	18
	TP822	0.10-1.00	MADE GROUND – Sl clayey gravelly sand	2.65	2.03	6.3	10

[1] PD – Particle Density, [2] MDD – Maximum Dry Density, [3] IMC – initial Moisture Content, [4] *OMC – Optimum Moisture Content

Laboratory CBR Results

The laboratory California Bearing Ratio (CBR) results are summarised in the table below:

Method	Location	Depth (m)	Brief Stratum Description	CBR (%)	Moisture Content (%)
Laboratory CBR on recompacted sample	BH804	0.20-0.60	Made GROUND – Gravelly sand	6.8	15.7

Method	Location	Depth (m)	Brief Stratum Description	CBR (%)	Moisture Content (%)
(4.5 kg compaction effort at received MC)	BH814A	0.30-1.20	MADE GROUND – Sandy gravel	0.6	14.4
	BH814A	2.50-3.00	MADE GROUND – Sl gravelly sand	0.2	22.2
	TP801	2.60-3.00	Sl gravelly sl sandy CLAY	1.9	21.7
	TP802	1.70-2.30	MADE GROUND - Gravelly sand	2.5	16.2
	TP804	1.40-2.00	MADE GROUND – Sl clayey sl gravelly sand	1.2	29.6
Laboratory CBR on recompacted sample (4.5 kg compaction effort at OMC)	BH807	2.80-3.00	MADE GROUND – Gravelly clay	11.4	12.0
	BH814A	0.30-1.20	MADE GROUND – Sandy gravel	4.7	10.0
	BH814A	2.50-3.00	MADE GROUND – Sl gravelly sand	2.1	15.0
	TP801	2.60-3.00	Sl gravelly sl sandy CLAY	3.9	17.0
	TP802	1.70-2.30	MADE GROUND - Gravelly sand	22.8	14.0
	TP804	1.40-2.00	MADE GROUND – Sl clayey sl gravelly sand	7.7	18.0

Unconfined Compressive Strength (UCS) and Point Load Index

A summary of the information pertaining to the Unconfined Compressive Strength (UCS) of the intact rock material (not rock mass) related to the sandstone and mudstone bedrock at the site is shown in the tables below. The point load index results have been used to derive the UCS using the relationship of UCS=24*IS50 for sandstone and UCS=20*IS50 for mudstone (ISRM).

Sandstone Results

Point Load Index (MPa) (range)		UCS Range (MPa)	Method	No. of results
Is	IS50			
0.01-0.21	0.02-0.27	0.48-6.48	Point load (Diametral)	56
-		7.50-25.60	UCS test	26

Mudstone Results

Point Load Index (MPa) (range)		UCS Range (MPa)	Method	No. of results
Is	IS50			
0.01-0.19	0.02-0.24	0.48-5.76	Point load (Diametral)	13
-		7.80-25.40	UCS test	12

9.2 Aggressive Ground Conditions – Geotechnical Chemical Testing

The test results for the assessment of aggressive ground conditions are presented in Appendix H. The results are summarised and assessed within Section 10.10 of this report.

9.3 In Situ Geotechnical Testing

In Situ Hand Shear Vane Tests
Hand shear vane tests were carried out on suitable cohesive soils where possible. Each shear vane result recorded represents the mean value of three tests undertaken at the specified depth.

The results and distribution of the hand shear vane tests are recorded in kPa on the Exploratory Hole Logs which are presented in Appendix F.

In Situ Standard Penetration Tests
Standard Penetration Tests (SPTs) were carried out within the window sample and cable percussive boreholes at regular 1.0m to 1.5m intervals. The results of the individual blows and the N-values are recorded on the Exploratory Hole Logs in Appendix F.

All SPT N values are uncorrected. Density and strength descriptors are reported in accordance with the guidelines stated in BS 5930:2015+A1:2020, incorporating requirements of BS EN ISO 14688-1:2002, BS EN ISO 14688-2:2004 and BS EN ISO 14689-1:2003.

Permeability Test Results (Boreholes)
The results of permeability testing in boreholes using falling head methods are presented in the table below. These were carried out in general accordance with BS 5930 & BS 22282.

Location	Stratum Type	Response Zone (m)	Hydraulic Conductivity (m/sec)		
			Test 1	Test 2	Test 3
BH804	SANDSTONE	14.00 – 24.00	$4.02x10^{-5}$	$4.02x10^{-5}$	$4.02x10^{-5}$
BH811B	SANDSTONE	12.00 – 20.00	$6.60x10^{-6}$	-	-
BH815	MADE GROUND	4.00 – 7.00	$4.13x10^{-4}$	$4.13x10^{-4}$	$4.13x10^{-4}$
WS801	Gravelly CLAY	2.00 – 5.00	$5.33x10^{-6}$	$5.41x10^{-6}$	-
WS809A	MADE GROUND	1.00 – 2.50	$5.23x10^{-3}$	$5.23x10^{-3}$	$5.23x10^{-3}$

The full test results are presented in Appendix H.

9.4 Geo-Environmental Testing

Chemical Laboratory Testing
The chemical test results for soils and groundwater are presented in Appendix H. The results are summarised and assessed within Section 11 of this report.

Photo-Ionisation Detection (PID) Monitoring - Soils
PID head space monitoring was undertaken on all environmental soil samples taken during the ground investigation at the site, the results are recorded on the exploratory hole logs.

All of the samples tested recorded PID results of between 0.0ppm and 0.1ppm, indicating that no significant volatile vapour contamination was present. As a potential indication of significant volatile organic contamination, a summary of the locations where PID readings over 10ppm were recorded is provided below:

Location	Depth (m)	Stratum	PID Reading (PPM)
BH804	2.20	MADE GROUND - Sand	11.7
BH804	4.00	MADE GROUND - Sand	19.1
BH807	7.20	Gravelly sandy CLAY	386
WS817	1.60	MADE GROUND - Clay	34.2

Ground Gas Monitoring

Ground gas monitoring results are presented in Appendix I and are summarised and assessed within Section 11 of this report.

10.0 GEOTECHNICAL ASSESSMENT

10.1 Ground Model

The below table summarises the development onsite:

Architects Ltd in September 2020, as well as other drawings available on the Manchester City Council Planning Portal:

Phase	Building Ref.	Building Height	Lowest Level
1	A	6-7 (+ Ground Floor)	Level 0 (45.60m AOD)
	B	6-7 (+ Ground Floor)	
2	C	6-7 (+ Ground Floor)	Level 0 (45.60m AOD)
	D	6-7 (+ Ground Floor)	
3	E	9 (+ Ground Floor)	Level -2 (39.60m AOD)
	F	16 (+ Ground Floor)	
4	G	10 (+ Ground Floor)	Level -2 (39.60m AOD)
	H	13 (+ Ground Floor)	
	I	31 (+ Ground Floor)	

Level 0 refers to the proposed site levels within the central spine access through the site referred to as "The Lanes and Square". Relatively Level 0 for Phase 1 and Phase 2, is below the surrounding ground level to the south of the site, such that Level 0 can be considered to be below ground level. Level 0 at this central area of the site is proposed to be 45.60m AOD, with Phases 3 & 4 with sub-ground floor levels G-1 at 42.60m AOD and G-2 at 39.60m AOD.

The site currently comprises an active hardstanding car park split over two levels and is broadly split into two areas accordingly. A retaining wall runs broadly east to west across the centre of the site and divides the upper and lower levels of the car park. There are known gas holder structures, basements, walls and other associated foundation features associated with the previous uses at the site.

The ground conditions for the lower level which comprises the majority of the Phase 3 and 4 area can be succinctly summarised as below (top down):

- Made ground generally comprising gravelly sand, sandy gravel and gravelly clay from ground level to between 0.55m and 10.00m bgl.
- Natural superficial deposits comprising gravelly clay proven to depths between 3.50m and 12.00m bgl.
- Solid geology comprising sandstone and mudstone proven to depths ranging between 13.00m and 50.00m bgl.
- Groundwater levels (made ground) ranging between 1.20m and 8.20m bgl during site works.
- Groundwater levels (superficial/bedrock) ranging between 7.20m and 16.50m bgl during site works.
- Post site works monitoring levels ranging between 1.10m and 16.23m bgl (lower level) and 0.37m to 19.20m bgl (upper level).

The ground conditions for the upper level which comprises the entirety of Phase 1 and 2 and a small area of the Phase 3 and 4 area can be summarised as below (top down):

- Made ground generally comprising gravelly sand, sandy gravel and gravelly clay from ground level to between 1.65m and 7.00m bgl.
- Natural superficial deposits comprising gravelly clay proven to depths between 4.00m and 15.00m bgl.
- Solid geology comprising sandstone and mudstone proven to depths ranging between 19.00m and 27.00m bgl.

- Groundwater levels (made ground) ranging between 2.00m and 4.50m bgl during site works.
- Groundwater levels (superficial/bedrock) ranging between 18.10m and 23.00m bgl during site works.
- Post site works monitoring levels ranging between 0.37m and 19.20m bgl.

Plans showing the thickness of made ground across the site (ref. C5692/09 and C5692/10) are presented to the rear of the report.

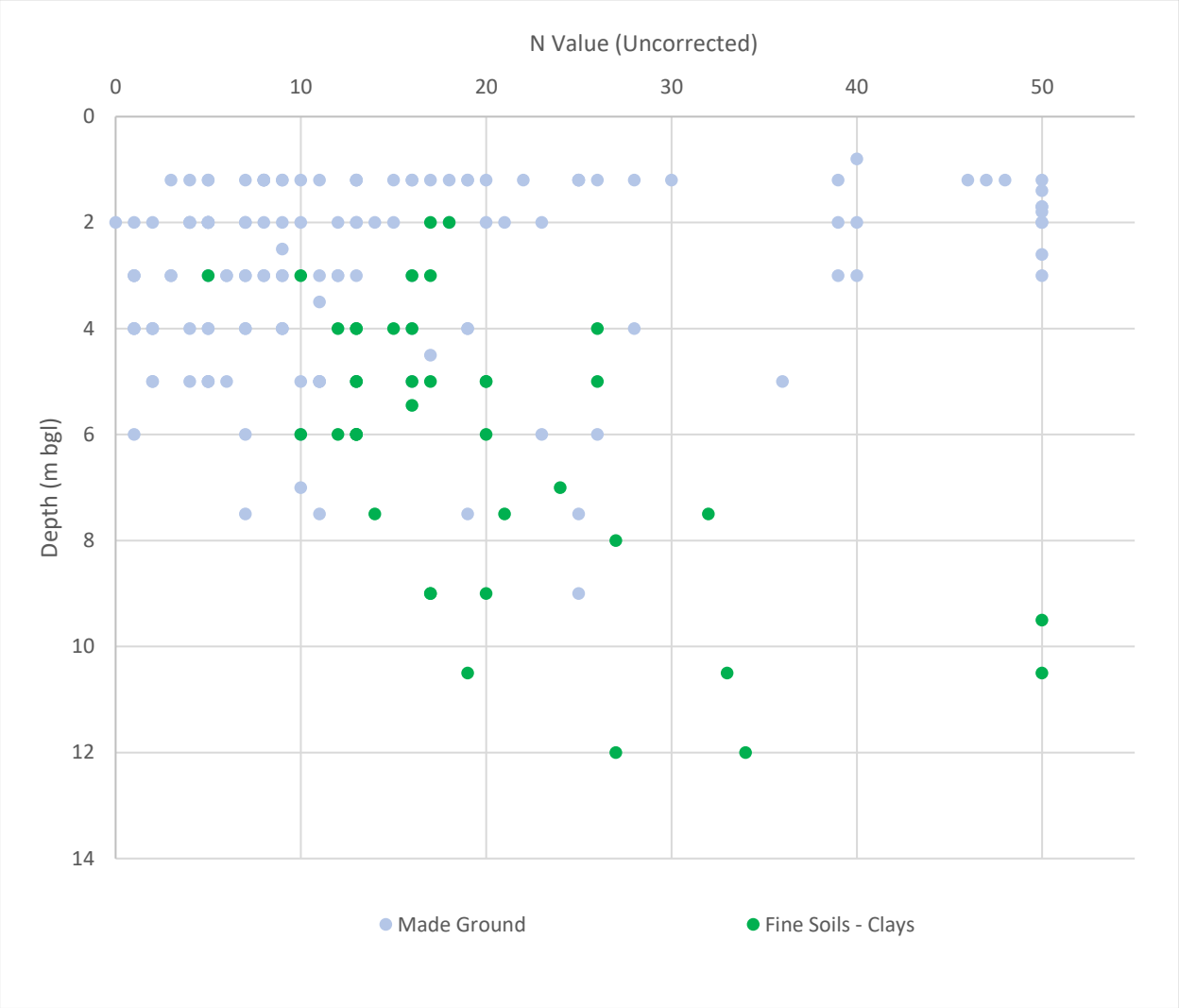
Numerous underground drainage / sewers run beneath the eastern section of the site and will need to be taken into consideration for foundation design. Historical mapping also indicates the presence of a deep sewer running across the lower car park area, within close proximity to the PRS compound.

Two moderate UXO risk zones are located in the north of the site covering roughly 50% of the total lower deck site area. There are also numerous concrete and brick obstructions throughout the made ground that will need removal during enabling works.

10.2 Design Soil Parameters

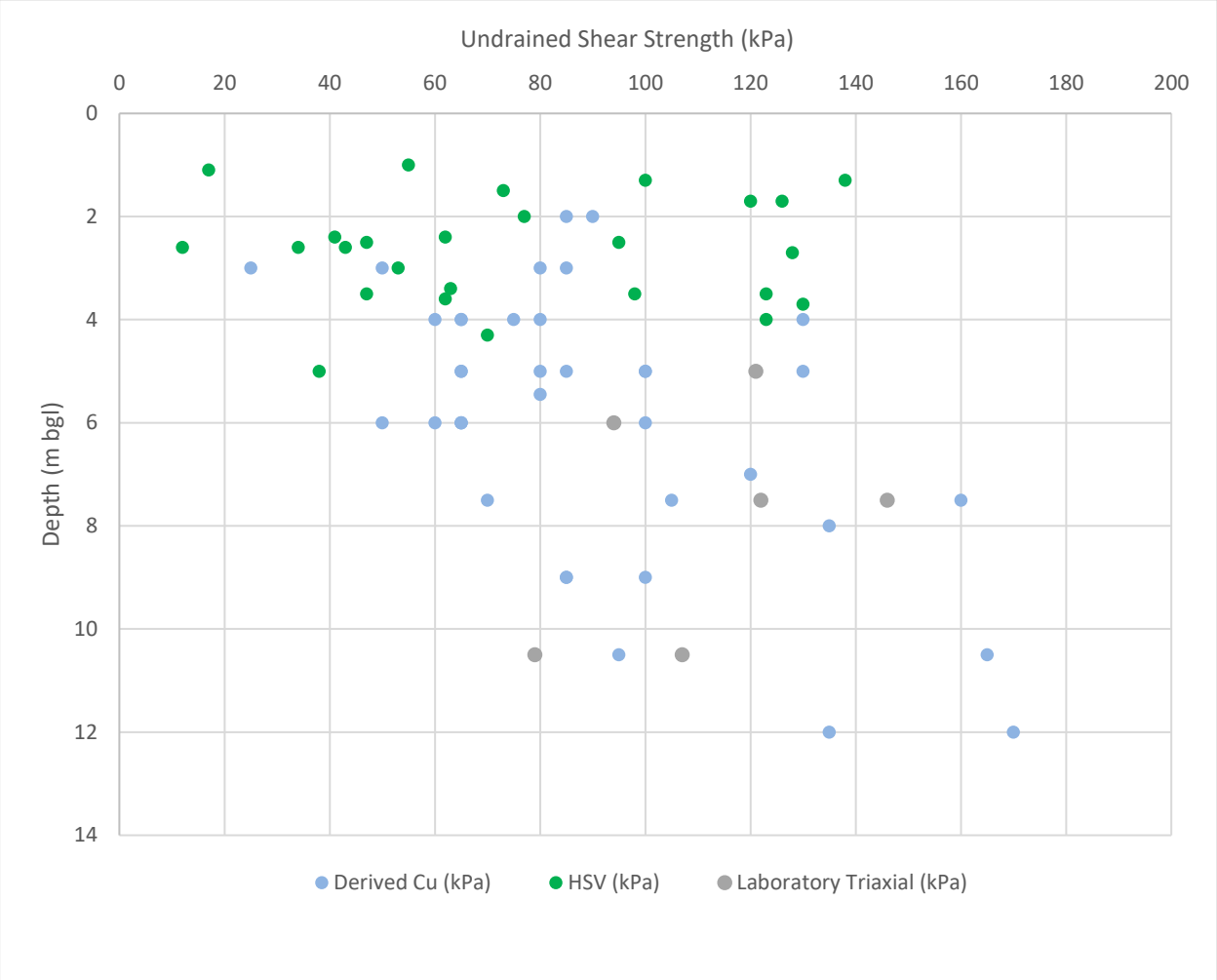
The relevant test results from the prior section have been evaluated to derive geotechnical soil parameters for the site.

Characteristic Values – Made Ground and Shallow Superficial Deposits
A depth (m bgl) vs SPT N value graph is provided below to provide a profile of the soils underlying the site.



The above graph shows a general increase in soils density as depth increases within the superficial cohesive strata, with some slight variability between borehole locations.

A depth (m bgl) vs derived shear strength (Cu) graph is provided below to provide a profile of the cohesive soils underlying the site.



The above graph shows a general increase in soils strengths as depth increases.

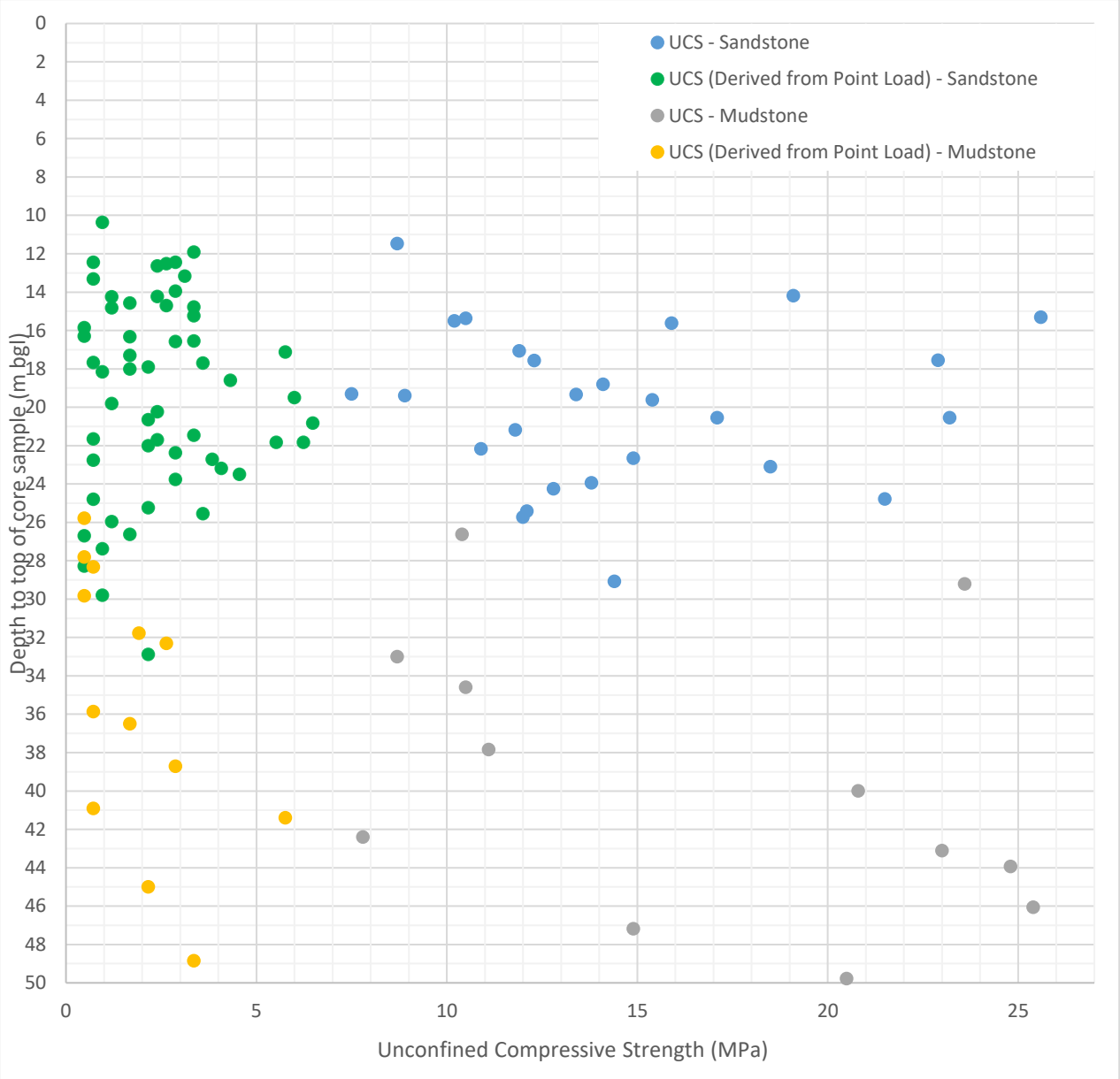
From the geotechnical parameters shown above, it is anticipated that shallow foundations are not suitable for the site due to areas of deep made ground and the variability of superficial deposits / depth to bedrock as well as the anticipated column loads of the building, therefore values have not been derived for the made ground strata in respect to a site wide generalised foundation design, especially given the variances in site levels. Whilst some locations contain deep made ground straight onto bedrock, or a very thin veneer of superficial deposits, other locations contain a thick enough layer where some skin friction would be achieved. For this, the characteristic values for the superficial strata are reported in the table below:

Stratum	Depth Range (m)	Characteristic N Value	Characteristic Cu Value (kN/m^2)
Slightly gravelly CLAY	3.10 – 13.60	21	100
Slightly gravelly slightly sandy CLAY	2.20 – 8.70	20	100
Slightly gravelly SAND	7.20 – 9.16	50	-

Characteristic Values – Solid Geology

All SPTs undertaken in bedrock refused with an N value of 50, except for BH810 at 12m bgl, where an SPT N value of 39 was recorded. At this depth, the rock was encountered as an extremely weak destructured mudstone, recovered as a gravel.

The Unconfined Compressive Strength (UCS) was determined by laboratory testing and was also derived from laboratory point load testing using the relationship of UCS=24*IS50 for sandstone (ISRM) and UCS=20*IS50 for mudstone (ISRM). A graph showing the variation in UCS and derived UCS vs depth is presented below to provide a profile of the variation in UCS of the bedrock with depth.

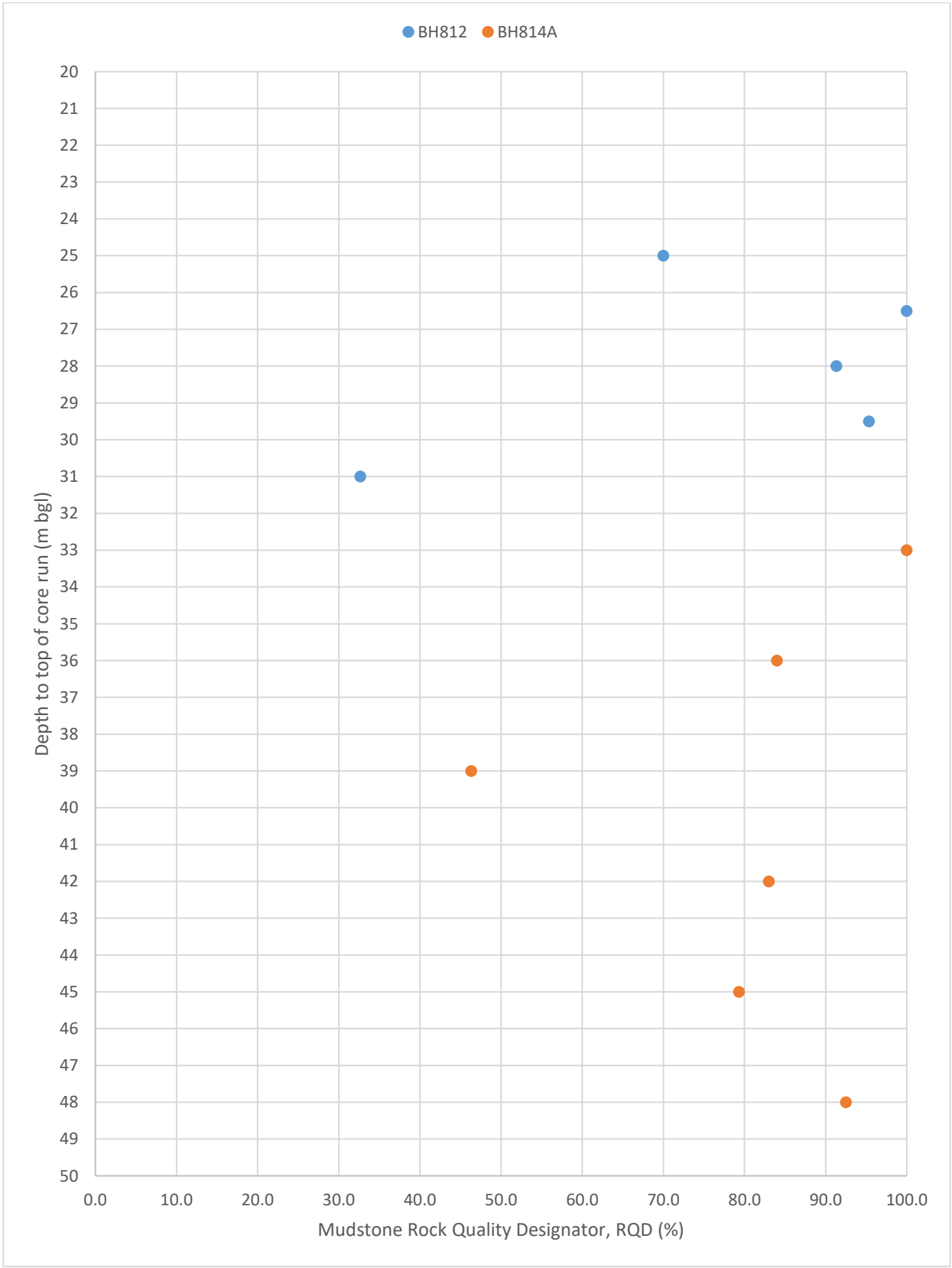


The above does not show any significant trend with depth. The mudstone is visibly stronger than the sandstone, with the unconfined compressive strength approximately double. There do not appear to be any significant or definitive lower strength zones within the UCS testing, with the entirety of the results being above 5MPa (weak rock) as can be expected of the Chester Formation. However, the vast majority of correlated UCS values from the point load testing are less than 5MPa (weak rock). Note there is a tendency for bias within the UCS and point load data; UCS is typically undertaken on more intact samples, whereas lower strength area of rock tend to provide samples of rock unsuitable for UCS analysis, hence point load data is used as a proxy for UCS strengths. This should be considered during estimation of characteristic values.

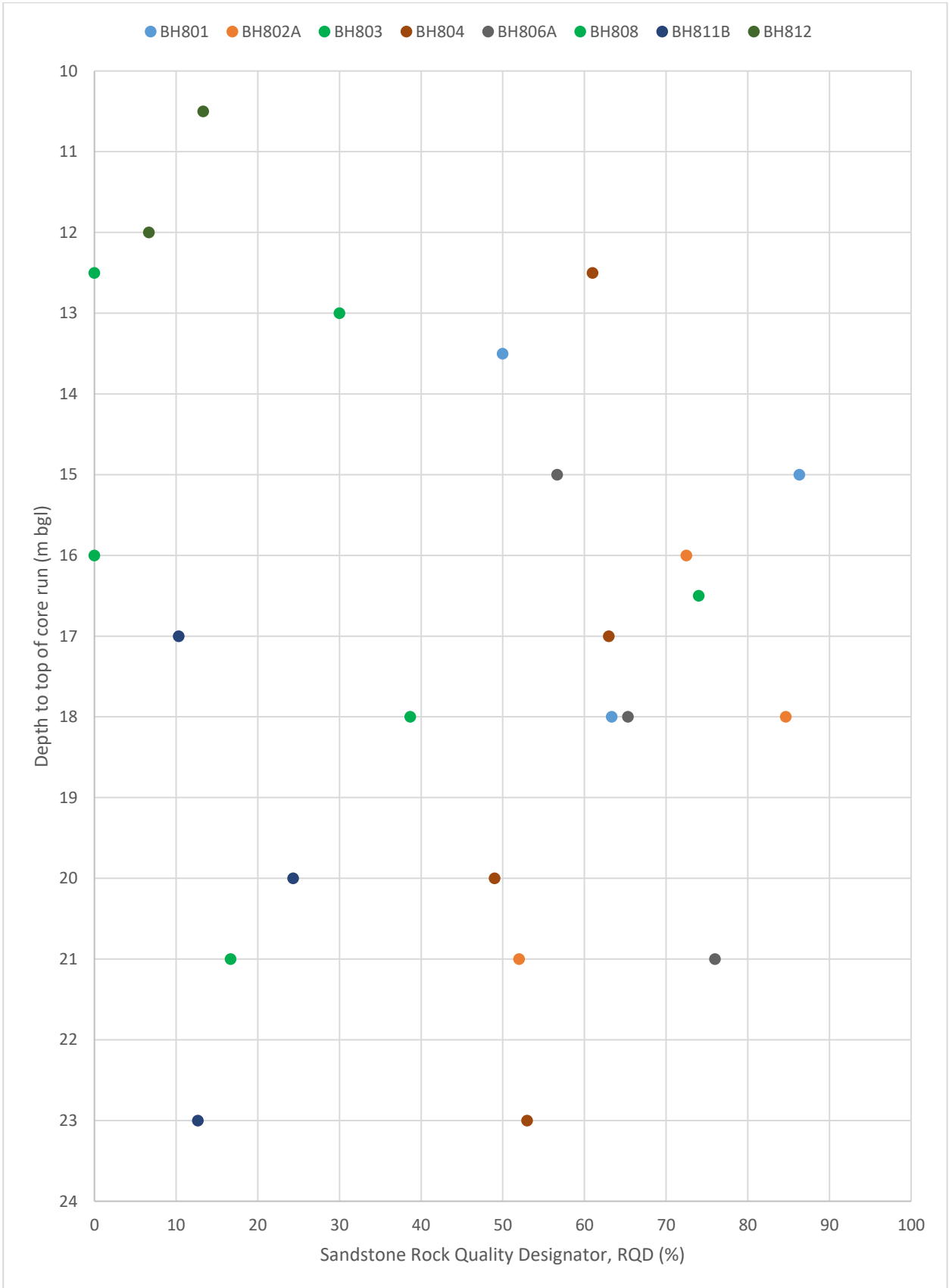
Based on field strength descriptions and the laboratory testing, the characteristic UCS for the bedrock underlying the site has been derived and summarised in the table below.

Block	Depth (m)	Characteristic UCS (MPa)
Lower Level		
E	13.83	7.15
	17.33	8.99
	18.33	1.84
F	12.2	16.82
	15.2	10.55
	18.2	7.22
G	10.2	8.29
	12.7	12.14
	15.2	8.87
H	17.20	4.18
	20.20	1.44
	25.20	7.66
I	20.50	14.70
	23.50	12.00
	26.50	14.40
Upper Level		
A	19	2.40
	20	4.08
	21	4.56
B	19	8.14
	20	7.80
	21	8.18
C	17.4	4.96
	18.4	6.46
	19.4	7.96
D	18.9	6.46
	19.9	7.96
	20.9	5.04

A graph showing the variations in RQD percentages with depth in each borehole is presented below for mudstone, where RQD should be considered in respect reduction factors for shaft resistance during detailed design (Rowe 2001).



A graph showing the variations in RQD percentages with depth in each borehole is presented below for sandstone, where RQD should be considered in respect reduction factors for shaft resistance during detailed design (Rowe 2001).



Based on the above, the characteristic RQD values for the solid geology underlying the site at various depths have been derived, taking into consideration the averages and are summarised in the table below, selected to the nearest 5% RQD:

Block	Depth (m)	Characteristic RQD (%)
Lower Level		
E	13.83	77.67
	17.33	59.5
	18.33	50.67
F	12.2	43.25
	15.2	44.33
	18.2	38.67
G	10.2	13.75
	12.7	30.5
	15.2	41.33
H	17.20	13
	20.20	9.33
	25.20	85
I	20.50	29.5
	23.50	56.5
	26.50	50
Upper Level		
A	19	8
	20	8
	21	8
B	19	44.5
	20	64
	21	63
C	17.4	24
	18.4	28.5
	19.4	17.5
D	18.9	28.5
	19.9	17.5
	20.9	17.5

10.3 Foundations

The development will comprise of nine buildings developed over four phases. The buildings vary in height from 6-7 storey plus ground floor to up to 13 storey plus ground floor, with one 31 storey (plus ground floor) block and is considered to be classed as Geotechnical Category 2 in accordance with Eurocode 7.

Building	Proposed Building
Block A	6-7 (+ Ground Floor)
Block B	6-7 (+ Ground Floor)
Block C	6-7 (+ Ground Floor)
Block D	6-7 (+ Ground Floor)
Block E	9 (+ Ground Floor)
Block F	16 (+ Ground Floor)
Block G	10 (+ Ground Floor)
Block H	13 (+ Ground Floor)
Block I	31 (+ Ground Floor)

Preliminary design by calculation has been undertaken to determine the design resistance of the bearing strata in the following section. No proposed structural loads were available at the time of writing,

therefore the following recommendations are provisional and should be reviewed at the detailed design stage by a suitably competent engineer.

Piles

Due to the magnitude of the column loads expected to be imposed by the proposed high rise multi-storey structures, the use of shallow foundations is not considered to be feasible. Therefore, the most suitable foundations are considered to be piles extending through the made ground and superficial deposits, socketed into the sandstone bedrock which was observed from varying depths across the site.

The selection of pile type and detailed design of pile foundations is typically completed by specialist piling contractors; the following general information is provided for guidance only. Based on the information from the site investigation, a replacement type piled solution will be required, such as CFA or rotary bored piles.

To provide a guide on potential requirements, preliminary calculations were undertaken for a circular concrete pile, taking into account shaft resistance, end bearing resistance and potential effects of negative skin friction.

The frictional contribution of the made ground has been omitted from these calculations for conservatism due to the variability, general loose nature and proposed level changes. Contribution from the superficial deposits has been estimated using the suggested pile calculations within Tomlinson (2001). Additionally, pile designs should be based on the final ground level, if any excavation is proposed, rather than the current ground elevations.

For piles socketed into bedrock, the ultimate shaft resistance for the portion of the pile embedded in the bedrock may be determined through the following equation:

$$q_s = k_1 p_{ref} \left(\frac{q_u}{p_{ref}} \right)^{k_2}$$

In this equation, q_s is the ultimate shaft resistance in kN/m^2, q_u is the UCS value of the bedrock, p_{ref} is a reference pressure of 100kPa and k_1 and k_2 are coefficients selected from the range presented in BS 8004 as 1.0 and 0.5 respectively.

The ultimate end bearing resistance of the competent bedrock has been determined using the following equation:

$$q_b = k_3 p_{ref} \left(\frac{q_u}{p_{ref}} \right)^{k_4}$$

In this equation, q_b is the ultimate base resistance in kN/m^2, q_u is the UCS value of the bedrock, p_{ref} is a reference pressure of 100kPa and k_3 and k_4 are coefficients identified in BS 8004 as 15 and 0.5 respectively for cemented materials. The design base resistance may be limited by the compressive strength of the concrete used to construct the pile or the structural capacity of the pile itself.

Based on the available information and methodology outlined above, preliminary calculations were undertaken to provide estimated factored allowable loads for a singular circular concrete pile, to be socketed into sandstone bedrock of variable lengths and a variety of diameters (based on standard rotary pile boring equipment). The proposed site levels of 45.60m AOD for Blocks A-D, and 39.60m AOD for Blocks E-I have been used to determine pile calculations; therefore proposed pile lengths and loads are based on proposed levels and not existing levels. A global factor of safety of 3 has been used in this assessment. The preliminary allowable loads are shown in the table below. Note these recommendations are provisional and subject to review at the detailed design stage.

Block	Pile Diameter (mm)	Allowable Axial Loads (MN)		
		19.00m (1m Embed)	20.00 (2m Embed)	21m (3m Embed)
Block A	600	1.1	1.4	1.7
	750	1.5	2.1	2.4
	900	2.1	2.8	3.2
		19.00m (1.4m Embed)	20.00 (2.4m Embed)	21m (3.4m Embed)
Block B	600	2.0	2.3	2.7[1]
	750	2.8	3.3[1]	3.7[1]
	900	3.9	4.4[1]	5.0[1]
		17.40m (1.5m Embed)	18.40m (2.5m Embed)	19.40m (3.5m Embed)
Block C	600	1.5	1.9[1]	2.3[1]
	750	2.2[1]	2.7[1]	3.2[1]
	900	3.0[1]	3.7[1]	4.3[1]
		18.90m (1m Embed)	19.90 (2.0m Embed)	20.90 (3.0m Embed)
Block D	600	1.6[1]	2.0[1]	1.9[1]
	750	2.4[1]	2.9[1]	2.7[1]
	900	3.3[1]	3.9[1]	3.6[1]
		13.80m (2.5m Embed)	17.30m (3.5m Embed)	18.30m (4.5m Embed)
Block E	600	2.4	3.1	2.2[2]
	750	3.4	4.3	3.0[2]
	900	4.5	5.6	3.8[2]
		12.20m (3m Embed)	15.20m (6.00m Embed)	18.20m (9.0m Embed)
Block F	600	3.3	3.7	4.4
	750	4.6	5.1	5.8
	900	6.3	6.7	7.4[1]
		10.20m (2.5m Embed)	12.70m (5.00m Embed)	15.20m (7.5m Embed)
Block G	600	2.0	2.3	2.2[2]
	750	2.9	3.4	3.2[2]
	900	4.0	4.7	4.4[2]
		17.20m (9.0m Embed)	20.20m (12.0m Embed)	25.20m (15.0m Embed)
Block H	600	2.5	2.4[2]	3.9
	750	3.4	3.3[2]	5.3
	900	4.4	4.1[2]	6.8
		20.50m (12.00m Embed)	23.50 (15.00m Embed)	26.50 (18.0m Embed)
Block I	600	5.8	7.5	9.0
	750	7.8	9.9	11.8
	900	10.1	12.5	14.8

[1] <5 pile diameters length below the proposed tow of the pile into bearing stratum recovered during SI.
[2] Allowable Axial Load decreases with depth as UCS and RQD values reduce compared to shallower depths.
NB: Only one rock core test has been undertaken in boreholes in Block D and RQDs for this block remained at zero, and therefore the characteristic UCS and RQD values have been taken from Block C, adjacent to Block D.

These calculations have been based on a single pile, it is likely that piles will be installed in groups and the group action of the piles should be considered.

During the construction phase supervision should be on a continuous basis to check the design assumptions are correct and construction conforms to design. Supervision should include inspections, Control Ground Investigations and monitoring. If the ground conditions encountered during the construction phase differ significantly to the conditions encountered during construction, work should cease and BSL contacted for further advice.

Trial piles are recommended to verify design assumptions including confirmation that a reasonable socket length into bedrock can be achieved using the proposed rig. Load testing can also be completed on trial

piles to confirm a final design, verify that the design resistance can be achieved and confirm settlements are within the required parameters.

Whilst detailed design is beyond the scope of this report, the following should be taken into consideration during the detailed design stage by a suitably competent contractor/engineer:

- Piles should extend a minimum of five pile diameters into the bearing stratum to fully mobilise end-bearing resistance and shaft resistance.
- Higher allowable loads than those listed in the table above could be achieved by increasing the diameter of the piles or by using pile groups.
- Obstructions in the ground (e.g. relict foundations) could cause piles to stop shallower than their anticipated design depth, or deviate from the vertical, therefore reducing their capacity.
- Bored piles through coarse soils will likely result in loosening, with resultant reduced shaft friction.
- The execution of bored cast-in-place piles should conform to BS EN 1536 and also any relevant standards associated with manufacturing the piles.
- In accordance with Eurocode 7 it would be prudent to verify the compressive resistance of the strata and the pile design should by static load testing on working piles 1.5 times the characteristic load on more than 1% of working piles. This will provide an accurate strength of the end bearing stratum.

Working Platform
Prior to the commencement of penetrative works (piling), a working platform will be required for tracked plant. This should be designed and installed in accordance with BR470 (BRE 2004) based on the plant requirements, data and rig loadings.

UXO
Based on the available information to date, specialist UXO advice and/or supervision will be required for all groundworks undertaken within the two separate UXO moderate risk areas onsite, as shown within the UXO Desk Study in Appendix F. Probing and clearance of all proposed piles within these locations is likely to be required.

Piling Risk Assessment
A risk assessment is likely to be necessary for piling, as there is a possibility that this could lead to creation of new pathways for migration of contamination.

10.4 Building Near Trees

The clay soils on site are of low to medium volume change potential and are only encountered locally, and generally at depths greater than 3.00m bgl. Where piles encounter cohesive strata in the vicinity of existing, proposed or recently removed trees, foundations should be adjusted in full accordance with BRE 298. Although earthworks will likely vary the locations of materials, the upper section of the pile (to the recommended minimum founding depth) should be sleeved or overbored to allow for clay volume change. Bored, cast-in-place piles are well suited to counteracting heave.

The vast majority of locations onsite where cohesive strata was encountered are not in influencing distance of existing trees, or the clay is at such a depth where no effects of heave would occur (i.e. greater than 3.00m bgl).

Furthermore, the few existing trees that are currently present onsite will be removed as part of development process and depths of cohesive strata locally to the tress is considered beyond the point where they would be at risk of heave after removal.

Consideration should be given to the placement of any new trees in close proximity to pile locations. Designs should take suitable precautions to protect against ground heave and the influence of trees if the

inclusion of trees is proposed as part of the design of the new development or if evidence of current or former trees is uncovered during construction.

10.5 Floor Slabs

Phase 1 and 2
A suspended floor slab should be adopted at the site, supported by piles. The final floor slab design should be of sufficient thickness and sufficiently reinforced to accept the envisaged applied loads, without unacceptable total or differential movement. Floor slabs should also be designed to incorporate any ground gas protection measures, where required.

Phase 3 and 4
Two sub-ground floor levels are due to be incorporated into the structure, whereby the sub-ground floor slab should effectively be supported by and suitably tied into piles. The following general criteria should be considered during design:

- Any fill beneath the slab is suitable, well-compacted granular material placed in an appropriate thickness in accordance with a suitable specification with the end performance validated.
- Any compressible or unsuitable materials are excavated and either improved or removed and replaced with suitable materials.
- The final floor slab design should be of sufficient thickness and sufficiently reinforced to accept the envisaged applied loads, without unacceptable total or differential movement.
- As the slab will be below ground level, waterproofing requirements will require consideration; the effects of hydrostatic uplift on the slab may also require consideration, with recorded post site works groundwater levels ranging between 2.45m and 16.23m bgl.
- Floor slabs should also be designed to incorporate any ground gas protections measures, where required.

10.6 Site Preparation and Construction

The existing structures, ramps and retaining walls will need to be demolished and relict foundations/infrastructure grubbed out.

There are a number of services crossing the site, including electricity, water, a deep sewer and BT assets, as well as the high pressure gas main which bisects the centre of the site, with associated facilities located within the existing Cadent gas compound in the centre of the site. To allow remediation and construction, all services will need to be disconnected and any suspected dead services are confirmed as dead by testing. BSL understand the Cadent gas compound and all associated assets will be re-located to two alternative PRS locations onsite under a separate planning application.

Instability of excavations through natural soils is not anticipated provided they are not exposed to adverse weather conditions for any substantial period of time. Instability of the made ground should be allowed for. All excavations should be carried out in accordance with CIRIA Report 97 'Trenching Practice'.

Excavation depths should generally be readily achieved using conventional plant (JCB or similar) although high specification plant (tracked 360° or similar) is recommended to maintain the build programme. Breaking equipment may also be required locally to penetrate old foundations associated with former construction.

The presence of substantial depths of made ground across the site may result in settlement of newly installed drainage. This should be taken into consideration during the design of drainage, which may include flexible joints to allow for some differential settlement.

It should be noted that undertaking treatment locally or using deepened foundations (i.e. focussing only on the footprint of structures) means that the surrounding areas (roads, gardens and landscaping) are likely to settle relative to the structures if disturbed. This risk can be mitigated by undertaking more widespread ground improvement through techniques such as dynamic compaction, surcharging or excavation and re-compaction.

To protect against the effects of heave, new drainage in cohesive soils should be designed to take account of potential ground movement, including where pipes and services which pass through substructure walls or foundations. The volume change potential on this site is low to medium and the potential ground movements that need to be considered for design are 100mm.

Recorded post site works groundwater levels ranged between 1.10m and 16.23m bgl (lower level) and 0.37m to 19.20m bgl (upper level) and therefore will be encountered within likely excavation depths. Based on the exploratory holes logs and monitoring, it is considered that methods such as sump pumping are likely to be sufficient to deal with anticipated flows. Further guidance is provided in CIRIA C750 "Groundwater Control: Design and Practice". It should be noted that groundwater levels will vary seasonally and the timing of construction may influence requirements.

Any water pumped from excavations is likely to need to be passed via settlement tanks and treated before being discharged to the sewer; discharge consents/permits will also be required. Any NAPL or grossly contaminated groundwater should be pumped out of excavations and treated and/or disposed off-site.

10.7 Basement Construction

A sub-ground floor level basement structure is proposed beneath Blocks E, F, G, H and I which comprise Phases 3 and 4. Depths of to the base of the structure are not currently known to BSL.

Based on the proposed basement levels, the lowest levels of Phase 3 and 4 will be approximately 6.00m shallower than the lowest levels of Phase 1 and 2 and therefore a degree of infilling will be required.

The following points need to be considered in the design and construction of the basement:

- The method of excavation of materials within the basement.
- Temporary and permanent support of the excavation.
- Groundwater levels, control and water proofing of basement sidewalls/base.
- Active pressures from groundwater and the surrounding earth acting on the sidewalls/base.
- Potential settlement of adjacent structures or infrastructure due to ground deformation or dewatering.
- Differential settlement between the basement structure and other foundations or floor slab elements.
- Cut and fill requirements across the wider site.
- Floor heave/settlement.

It is likely that embedded retaining walls would be the most suitable option for constructing the basement using temporary support, where one advantage is that they could be incorporated into the foundation design for the proposed structure. This could include either a contiguous or secant piled wall or a diaphragm wall.

The selection of the type of embedded retaining wall, will depend on a range of factors such as environmental constraints, including noise and vibration, as well as cost.

Alternatively, sheet piled walls could be utilised or the basement retaining walls could be constructed within an open excavation. However, the sides of the excavation would need to be sufficiently battered and supported for safety, and the available space on site may preclude this option.

Retaining walls which are incorporated in the design of the basement will need to be designed by an engineer, taking into account the ground conditions and the serviceability requirements of the scheme. Specialist advice should be sought on all aspects of the construction.

Methods of water proofing basements and below ground structures are detailed in BS 8102 (2009), "Code of practice for protection of below ground structures against water from the ground".

Any water from excavations should be treated either prior to construction or during the operation of the site in accordance with a Remedial Specification and discharged in accordance with the relevant permits and licences.

Temporary support (if adopted) should be designed in accordance with BS 5975 "Code of practice for temporary works procedures and the permissible stress design of falsework".

The design of the basement should also take into account ground gas protection measures, although ventilation within the basement may negate the requirement of these measures. A full assessment will be made upon completion of the ground gas monitoring programme.

If the materials excavated from the basement are to be re-used elsewhere on site, then an earthworks specification will be required to ensure the appropriate management and reuse of the existing soils. This may also need to be undertaken in accordance with a Materials Management Plan (MMP) under the CL:AIRE Code of Practice.

10.8 Concrete Classification

The soluble sulphate and pH test results have been assessed in accordance with BRE Special Digest 1 "Concrete in aggressive ground" 2005. The Design Sulphate (DS) classification and the Aggressive Chemical Environment for Concrete (ACEC) classification are presented in the table below.

For the purposes of this assessment, the made ground and natural strata is considered to be relatively permeable, therefore the groundwater has been classed as mobile.

Stratum	No. Samples	Characteristic SO_4 (g/l)	Characteristic pH	DS Class	ACEC Class
Made Ground	30	4.95	7.31	DS4	AC-4
Natural Superficial Strata	14	0.081	8.45	DS1	AC-1
Solid Geology – Chester Formation	12	0.038	8.8	DS1	AC-1

Based on the above, the results of laboratory pH and sulphate content, alongside the BRE full suite tests, indicate that sulphate class DS-4 and ACED Class AC-4 conditions prevail in the made ground strata in accordance with BRE Special Digest 1 "Concrete in aggressive ground" 2005, and DS-1 and ACEC Class AC-1 prevail in both the natural superficial strata and the solid geology of the Chester Formation.

The specific concrete mixes (the Design Concrete Class) to be used on site will be determined by the site-specific concrete requirements in terms of the durability and structural performance. These are assessed in terms of the Structural Performance Level (SPL) and any need for Additional Protective Measures (APM) detailed in Part D of BRE Special Digest 1 with further guidance in Pt E and F.

10.9 Highways

A site wide programme of earthworks will alter the properties of the existing made ground and providing these soils are placed to a suitable specification, CBR values in the range of 3 – 5% would likely be achieved in granular fill and 2% for cohesive fill.

To aid design proposals during construction of haul roads etc, based on Table 5.1 from DMRB IAN 73/06 Rev 1 equilibrium CBR values of 5% are likely to be achieved in undisturbed natural granular soils where they are encountered and 2% for made ground and natural clays soils for pavement design purposes, unless proven otherwise by in-situ testing at formation level by a specialist geotechnical engineer.

Where the CBR is found to be less than 2%, the sub-grade is unlikely to be suitable for both the trafficking of site plant and as a permanent highway foundation without improvement of the soils.

To achieve the required design CBR value, improvement works should be carried out in accordance with DMRB IAN 73/06 Rev 1 Chapter 5 and may include proof rolling, excavation and re-engineering / replacement of weaker soils, the inclusion of a geogrid or use of stabilisation techniques such as the addition of hydraulic binders (e.g. cement/lime).

Based on the fines content of the soils, they are considered to be frost susceptible, therefore highway construction should be a minimum thickness of 450mm to mitigate against the risk.

Care should be taken to ensure the stratum at formation level is protected against inclement weather, as this is likely to lead to surface deterioration and a decrease in soils strengths.

10.10 Site Drainage

Falling head tests were carried out in five locations with the made ground, superficial cohesive strata and sandstone bedrock, with Hydraulic Conductivity results in the range of 10^{-3} m/s to 10^{-6} m/s being calculated.

However, the use of sustainable drainage systems, such as traditional soakaways within the natural ground, is not likely to be feasible over large areas of the site due to the presence of low permeability cohesive strata underlying the site, alongside the presence of variable and potentially contaminated made ground near the surface and extending to depths in excess of 10.00m bgl.

Much of the site will be covered by structures/hardstanding, which may also preclude the use of large scale soakaway drainage with attenuation. SuDS features such as permeable paving may be feasible in areas underlain by granular strata providing a form of mitigation can be included to minimise contaminant leaching, otherwise surface water would need to be positively drained into the off-site existing sewer network, subject to agreement with the local utility provider.

10.11 Retaining Walls

A large retaining wall approximately 3m height of concrete and brick construction is present onsite bisecting approximately the centre, running west to east across the entire width of the site, with two ramp features to provide access between the upper and lower levels. It was outside the scope of this investigation to undertake a detailed inspection of the construction or a structural inspection of the walls. BSL recommends inspection of the walls by a structural engineer to assess their condition and determine what, if any, specialist requirements there are in respect to demolition and removal. Inadequate demolition may result in the instability of soils behind the wall, potentially resulting in dangerous collapse.

Where existing retaining walls are to be retained, care should be taken in the design of the proposed development to ensure that the safety and stability of retaining walls is not compromised. This work should be undertaken by a suitably competent engineer, particularly where they form, or could influence, site boundaries.

Any retaining walls which are to be incorporated in the development will need to be designed by an engineer, taking into account the ground conditions and the serviceability requirements of the scheme. Retaining wall design should also incorporate suitable drainage as appropriate.

10.12 Earthworks

Given the variability of existing site levels and development layout requirements, earthworks will be required in order to achieve the desired development platform levels.

Design of the earthworks, particularly in the north and north-western part of the site, should consider the stability of any cut or fill slopes. Any fill should be placed in accordance with an appropriate specification, discussed further below. Designs should allow for incorporation of suitable drainage to prevent the build-up of pore water pressure which could lead to slope instability.

An initial assessment reveals spoil resulting from excavations within the superficial deposits should generally be suitable for re-use as general fill subject to further testing and specification or may be disposed off site.

However, the made ground soils have generally found to be contaminated (e.g. hydrocarbon impacted soils) and will likely require extensive treatment before they become geotechnically suitable; further testing would be required on such soils (e.g. bench trials for lime/cement stabilisation). Alternatively, they could be disposed off site to a suitably licenced facility.

Where it is proposed to re-use site won materials as an engineered fill, it will be necessary to develop an appropriate Earthworks Specification. The basis for the Specification should be BS 6031:2009 and the latest version of the SHW, Series 600 Earthworks.

If site-won material is to be re-used on site, it is recommended this is carried out under the CL:AIRE Development Industry Code of Practice (DoWCoP CL:AIRE March 2011).

As a guide, the following materials could be expected to be encountered onsite for re-use in an appropriately designed cut and fill exercise:

Stratum	Range Depths - Top (m bgl)	Range Depths - Base (m bgl)	Range Thickness' (m)	Brief Description
Made Ground – Hardstanding	0.00	0.08 – 0.30	0.08 – 0.30	Tarmacadam, Bricks & Concrete.
Made Ground	0.08 – 0.30	0.55 – 10.00	0.30 – 9.90	Gravelly SAND, Silty SAND (PFA), sandy GRAVEL, gravelly clayey SAND, sandy gravelly CLAY.
Natural Superficial Strata – Cohesive	1.00 – 10.00	3.50 – 15.00	0.60 – 9.90	Slightly gravelly CLAY.

64 samples were taken and tested for a suite of geotechnical earthworks testing. The results of the testing have been used to inform the materials classification, as discussed below, and the full testing results are presented in Appendix H.

Grading/Particle Size Distribution Testing
PSD testing was scheduled on 18 samples with the results outlined below:

Location	Strata	Classification Type	Classification Use
HP815A	MADE GROUND	6A	Selected well graded granular material
BH807	Slightly gravelly CLAY	2C	Stony cohesive material
HP817	MADE GROUND	6F1	Selected granular material – fine grading
TP822	Slightly gravelly CLAY	2A/2B	Wet/Dry cohesive material

Location	Strata	Classification Type	Classification Use
BH802A	Slightly gravelly CLAY	2A/2B	Wet/Dry cohesive material
TP809	Slightly gravelly CLAY	2A/2B	Wet/Dry cohesive material
TP808	Slightly gravelly slightly sandy CLAY	2A/2B	Wet/Dry cohesive material
TP812	Slightly gravelly slightly sandy CLAY	2C	Stony cohesive material
TP822	MADE GROUND	6F1	Selected granular material – fine grading
TP801	Slightly gravelly slightly sandy CLAY	2A/2B	Wet/Dry cohesive material
BH814A	MADE GROUND	6F1	Selected granular material – fine grading
BH814A	MADE GROUND	2C	Stony cohesive material
BH811	MADE GROUND	2C	Stony cohesive material
TP802	MADE GROUND	2C	Stony cohesive material
TP804	MADE GROUND	2C	Stony cohesive material
TP806	MADE GROUND	2C	Stony cohesive material
TP803	MADE GROUND	2C	Stony cohesive material
BH814A	MADE GROUND	2C	Stony cohesive material

Compaction testing carried out on samples of the made ground soils indicate Optimum Moisture Contents (OMC) of between 10% and 19%, with corresponding Maximum Dry Density (MDD) values between 1.50 Mg/m^3 and 2.03 Mg/m^3.

Recorded water contents of the made ground soils range from 6.0% to 15.8%, with an average of 10.1%, indicating that they are on the 'wet' side of OMC, but may be suitable for re-use following the addition of binders to control the moisture content (i.e. stabilisation).

Compaction testing carried out on samples of the natural soils indicate Optimum Moisture Contents (OMC) of between 13% and 17%, with corresponding Maximum Dry Density (MDD) values between 1.73 Mg/m^3 and 1.86 Mg/m^3.

Recorded water contents of the natural soils range from 9.1% to 13.7%, with an average of 11.3%, indicating that they are 'dry' of OMC, but may be suitable for re-use following the addition of some moisture.

Due to the high sulphate contents that have been identified in the made ground, discissions should be held with a specialist Remediation Contractor over the suitability of stabilisation and improvement by the inclusion of binders. However, the natural soils may be suitable for stabilisation and improvement by the inclusion of binders, subject to further detailed design and testing.

Results Interpretation

Based on the testing results all of the samples fall within the requirements for re-use onsite as general fill, but it is likely areas of gross contamination will require extensive treatment prior to re-use or would require removal from site as unsuitable materials.

The grading of the material is based on the as received sample and therefore any gradings of granular materials may be altered through onsite re-grading / processing.

The concrete and brick hardstanding onsite are most likely able to be crushed and re-used as 6F2/5 type material.

Therefore, it can be seen that the materials tested are suitable for reuse as fill in many areas of the site, albeit with some minor limitations.

Where it is proposed to re-use site won materials as an engineered fill, it will be necessary to develop an appropriate Earthworks Specification. The basis for the Specification should be BS 6031:2009 and the latest version of the SHW, Series 600 Earthworks.

11.0 GEO-ENVIRONMENTAL RISK ASSESSMENT

11.1 Introduction

The samples were tested for an assessment of the chemical contamination that may pose a risk to human health. The results were examined with reference to a selection of guidance documents as detailed in Appendix A.

In this case, in the first instance the LQM/CIEH S4ULs and DEFRA C4SLs for a Residential Public Open Space end use have been adopted as Tier 1 generic screening values. Whilst the ground floor levels of the proposed development will comprise a combination of commercial units and townhouses, we understand there are no private or communal gardens being incorporated into the development. Landscaped areas will be accessible to the general public and therefore a residential public open space scenario is considered the most applicable scenario for the site whilst still being relatively conservative. Some contaminants have been assessed more conservatively depending on the identified potential pollutant pathways.

BSL have also considered testing results from the previous investigations completed at the site within this section, with the results presented as summary tables within Appendix C and summary comments where relevant provided in this chapter.

The apparent exceedance of the relevant screening value is taken as indicating further detailed assessment or remedial action is required.

A summary assessment sheet is presented in Appendix C alongside the chemical test results. Results are discussed in detail in the sections below. Drawings detailing the distribution of key contaminants on site are presented (drawing Nos C5692/11-15)

11.2 Soils Test Results and Risk Assessment – Human Health

Metals
The following elevated metals were detected during the recent works completed by BSL:

Exploratory Hole	Depth (m)	Stratum	Metal	Concentration (mg/kg)	Adopted Screening Value (mg/kg)
TP803	0.60-1.00	Made Ground	Arsenic	100	79
BH801	7.50-8.00	Natural	Arsenic	82	79

The previous investigations have also identified elevated concentrations of arsenic, as well as some areas (including Tar Tank No. 1) affected by lead and, to a lesser extent, chromium (III), mercury and nickel contamination in the made ground. It should be noted that the vast majority of metals contamination was identified during the Entec investigation in 2003, which was undertaken prior to any site-wide remediation took place. The elevated concentrations of lead encountered by Amec during investigation of Tar Tank No. 1 represent soils which have not previously been remediated.

The concentrations of metals identified within the made ground soils during subsequent investigations are significantly less widespread, including BSL's investigation.

Asbestos

The locations where asbestos has been detected or suspected in the made ground, alongside the results of quantification (where carried out) are summarised in the table below:

Exploratory Hole	Depth (m)	Strata Type (depth m bgl)	Asbestos ID	Concentration by Weight (%)
Entec 2003				
WS21	2.00-3.50	Made ground (2.00 – 3.50)	'Possible asbestos fibres' identified as visual / olfactory observation during site works	Sample tested, no asbestos detected
WYG 2015				
HP1002	0.40	Made ground (0.00 – 0.50*)	Free fibres (chrysotile)	N/Q
HP1004	0.20	Made ground (0.00 – 0.40*)	Free fibres (amosite)	N/Q
HP1005	0.35	Made ground (0.00 – 0.40*)	Free fibres (chrysotile)	N/Q
HP1008	0.45	Made ground (0.15 – 0.60*)	Asbestos Insulating Board Debris (amosite & chrysotile)	N/Q
Hydrock 2021				
MPBH703A	0.20-0.40	Made ground (0.20 – 0.40*)	Suspected Asbestos Cement (60x80mm, 20x30mm and 10x15mm)	N/Q
MPBH703A	0.20-0.40		Chrysotile	<0.001
TP704	0.90-1.10	Made ground (0.25 – 0.95)**	Loose fibrous debris (chrysotile)	0.013
TP711	0.65	Made ground (0.60 – 1.60*)	Loose fibres (amosite)	<0.001
TP715	0.75	Made ground (0.65 – 0.90)	Loose fibres (chrysotile)	<0.001
WS701	0.50	Made ground (0.40 – 0.70)	Loose fibres (chrysotile)	<0.001
WS704	0.90	Made ground (0.65 – 1.50)	Loose fibres (amosite)	<0.001
BSL 2024				
TP818	0.10-0.50	Made Ground	Loose Fibres (amosite and chrysotile)	0.014
TP816	0.10-0.50	Made Ground	Loose Fibres (amosite and chrysotile)	0.003
WS815	1.30 - 1.50	Made Ground	Loose Fibres (amosite)	<0.001
WS816	3.50-4.00	Made Ground	Loose Fibres (amosite)	<0.001

NB: * base of strata not proven. ** strata assumed based on incomplete data. N/Q = Not Quantified.

Poly Aromatic Hydrocarbons (PAHs)

The chemical testing completed as part of the current scope has confirmed the presence of widespread PAH contamination across phases 3 and 4, which is consistent with previous investigations in the northern area of the site, as well as the recent Hydrock investigations in Phases 1 and 2 in the south of the site, which also identified widespread pervasive PAH contamination present in soils.

The locations, depth and concentrations of elevated species of PAHs are presented in full within the laboratory testing data and summary assessment sheets in Appendix C.

BSL consider the main risk drivers for PAHs to be benzo(a)pyrene (B(a)P) and naphthalene. This is due to B(a)P being one of the most toxic of the PAHs, and naphthalene the most volatile and soluble. Given the potential volatility of naphthalene and to ensure potential contaminative pathways with respect to volatile vapours are considered within the Tier 1 Human Health Risk Assessment, for this determinand, the S4UL for a residential without plant uptake scenario will be used to initially screen the dataset.

A summary of the locations where benzo(a)pyrene (B(a)P) and naphthalene have exceeded the S4ULs during the recent site investigation works undertaken by BSL is presented below:

Exploratory Hole	Depth (m)	Stratum	Species	Concentration (mg/kg)	Adopted Screening Value (mg/kg)
BH801	7.50-8.00	Made ground	Benzo(a)pyrene	25	5.7
			Naphthalene	120	5.6
BH801	8.10-8.60	Natural CLAY	Naphthalene	16	5.6
BH803	4.50 - 5.00	Made Ground	Benzo(a)pyrene	74	5.7
BH804	7.00 - 7.50	Made Ground	Benzo(a)pyrene	45	5.7
			Naphthalene	400	5.6
BH805	0.30-0.60	Made Ground	Benzo(a)pyrene	44	5.7
			Naphthalene	7.4	5.6
BH806A	4.50- 4.80	Made Ground	Benzo(a)pyrene	470	5.7
			Naphthalene	1300	5.6
BH807	7.20-8.00	Natural CLAY	Benzo(a)pyrene	49	5.7
			Naphthalene	460	5.6
BH807	8.70-9.50	Natural CLAY	Naphthalene	8.1	5.6
BH810	2.20-3.00	Made Ground	Benzo(a)pyrene	57	5.7
BH811B	6.00	Natural CLAY	Benzo(a)pyrene	9.5	5.7
BH813	7.00-7.60	Made Ground	Benzo(a)pyrene	84	5.7
			Naphthalene	16	5.6
BH814	1.80 - 2.20	Made Ground	Benzo(a)pyrene	32	5.7
			Naphthalene	13	5.6
BH815	1.80 - 2.20	Made Ground	Benzo(a)pyrene	21	5.7
			Naphthalene	8.4	5.6
BH815	8.10-8.50	Natural CLAY	Benzo(a)pyrene	7.5	5.7
			Naphthalene	20	5.6
HP811	1.00 - 1.70	Made Ground	Benzo(a)pyrene	40	5.7
			Naphthalene	6.8	5.6
TP803	0.60-1.00	Made Ground	Benzo(a)pyrene	410	5.7
			Naphthalene	18	5.6
TP804	1.40 - 1.80	Made Ground	Naphthalene	190	5.6
TP806	3.00 -3.10	Made Ground	Naphthalene	44	5.6
TP808	0.70 - 0.90	Made Ground	Benzo(a)pyrene	43	5.7
			Naphthalene	28	5.6
TP809	0.50 - 0.70	Made Ground	Benzo(a)pyrene	15	5.7
			Naphthalene	8.2	5.6
TP810	0.50 - 0.70	Made Ground	Benzo(a)pyrene	28	5.7
TP812	0.60 -1.00	Made Ground	Naphthalene	38	5.6
WS801	1.50 - 2.00	Made Ground	Benzo(a)pyrene	18	5.7
			Naphthalene	8.1	5.6
WS803	1.80-2.00	Made Ground	Benzo(a)pyrene	26	5.7
WS815	1.30 - 1.50	Made Ground	Benzo(a)pyrene	17	5.7
			Naphthalene	270	5.6
WS816	3.50-4.00	Made Ground	Naphthalene	72	5.6
WS817	1.60 - 1.90	Made Ground	Benzo(a)pyrene	240	5.7
			Naphthalene	990	5.6
WS817	3.00 - 3.40	Natural CLAY	Naphthalene	7.2	5.6

Some of the greatest concentrations of PAHs have been encountered within BH603 (located within Tar Tank No. 1) on material which is representative of free phase tar contamination. Concentrations of

naphthalene (22,100 mg/kg) are the highest recorded on site and benzo(a)pyrene (935 mg/kg) among the highest concentrations recorded on site.

Total Petroleum Hydrocarbons (TPH CWG)
The locations, depths and elevated ranges of petroleum hydrocarbons identified above the adopted screening criteria are shown in the table below:

Exploratory Hole	Depth (m)	Stratum	Range / Fraction	Concentration (mg/kg)	Adopted Screening Value (mg/kg)
BH806A	4.50- 4.80	Made Ground	Petroleum Hydrocarbons Aromatic >EC12-EC16	6800	5100
BH806A	4.50- 4.80	Made Ground	Petroleum Hydrocarbons Aromatic >EC16-EC21	14000	3800
BH806A	4.50- 4.80	Made Ground	Petroleum Hydrocarbons Aromatic >EC21-EC35	14000	3800
TP803	0.60-1.00	Made Ground	Petroleum Hydrocarbons Aromatic >EC16-EC21	5900	3800
TP803	0.60-1.00	Made Ground	Petroleum Hydrocarbons Aromatic >EC21-EC35	13000	3800
WS817	1.60 - 1.90	Made Ground	Petroleum Hydrocarbons Aromatic >EC12-EC16	5400	5100
WS817	1.60 - 1.90	Made Ground	Petroleum Hydrocarbons Aromatic >EC16-EC21	4100	3800
WS817	1.60 - 1.90	Made Ground	Petroleum Hydrocarbons Aromatic >EC21-EC35	7800	3800

Speciated TPH-CWG testing was not carried out during Amec's 2011 investigation of Tar Tank No. 1. However, total petroleum hydrocarbon concentrations were the highest recorded on site; the highest recorded was 486000 mg/kg (TP601, 0.2-0.4m bgl) but in all borehole locations concentrations exceeded 25000 mg/kg in at least 1 sample tested.

BTEX and MTBE
No BTEX or MTBE compounds have been identified above the adopted screening criteria during the recent ground investigation undertaken by BSL.

Previous investigations have identified the following elevated concentrations of benzene which may require further consideration:

Exploratory Hole	Depth (m)	Stratum	Compound	Concentration (mg/kg)	Adopted Screening Value (mg/kg)
Entec 2003					
BH02A	8.3	Natural SAND	Benzene	210	72
BH02A DPUP	8.3	Natural SAND	Benzene	230	72
Entec 2009					
TP307	4.3-4.5	Made Ground	Benzene	340	72
Amec, 2011					
BH603	3.8-4.0	Made Ground	Benzene	261	72
BH603	4.5-4.7	Made Ground	Benzene	262	72
Hydrock 2022					
TP713	1.40-1.6	Made Ground	Benzene	3700	72
WS704	1.20-1.20	Made Ground	Benzene	550	72

SVOCs/VOCs

The concentrations of VOCs encountered during the BSL investigation were generally very low and the majority of compounds were not present above laboratory lower limits of detection. There have been no exceedances of chlorinated solvents during BSLs investigation with the vast majority of compounds not detected.

A number of SVOC compounds listed below have been detected above laboratory detection limits, however no generic screening values are available for these compounds. The vast majority of concentrations are noted to be very marginally above laboratory limits of detection.

- Styrene.
- n-Propylbenzene.
- 1,3,5-Trimethylbenzene.
- 1,2,4-Trimethylbenzene.
- Aniline.
- 2-Methylphenol.
- Hexachloroethane.
- 2,4-Dimethylphenol.
- 2-Methylnaphthalene.
- Dibenzofuran.
- Carbazole.
- Anthraquinone.
- Butyl benzyl phthalate.

Cyanide and Phenols

The locations and depths where cyanide and phenols have been identified above the adopted screening criteria are shown in the table below:

Exploratory Hole	Depth (m)	Stratum	Compound	Concentration (mg/kg)	Adopted Screening Value (mg/kg)
BH814	1.80 - 2.20	Made Ground	Cyanide (free)	86	34
TP809	0.50 - 0.70	Made Ground	Cyanide (free)	170	34
TP806	3.00 -3.10	Made Ground	Cyanide (free)	220	34
TP804	1.40 - 1.80	Made Ground	Cyanide (free)	940	34
BH803	4.50 - 5.00	Made Ground	Phenol (total)	793	690

The greatest concentrations of cyanide and phenols on site have been detected within Amec's 2011 investigation of Tar Tank No.1, in which a maximum concentration of total phenols was recorded in BH603 at 4.5-4.7m (17,200 mg/kg) and the maximum concentration of cyanide recorded in TP601 at 0.2-0.4m (1,400 mg/kg).

Poly-Chlorinated Biphenyls (PCBs)

Samples of made ground recovered from BH801 and TP819 were tested for the presence of PCBs (targeted at approximate former substation areas), but no PCBs were detected above laboratory limits of detection in these samples. Hydrock also carried out testing for PCBs and did not identify any exceedances.

11.3 Summary – Human Health Risk Assessment

Based on the testing and assessment undertaken there is pervasive contamination within the made ground, predominantly in the form of metals and PAHs attributed to ash within the made ground strata.

Petroleum hydrocarbons, benzene, SVOCs, cyanide and phenols are present locally within the made ground, likely associated with industrial processes relating to the former gasworks.

Asbestos fibres have been detected at trace levels in numerous samples across phases 1-3 and trace concentrations should be assumed across these areas of the site. Concentrations of asbestos has been found to exceed trace concentrations in three locations in phases 1 and 3.

The above pose a risk to human health and will require further consideration.

11.4 Former Gas Holders – Soils Testing Assessment

The chemical testing carried out on the made ground demonstrates the materials within gas holders is pervasively impacted with PAHs in addition to localised areas of petroleum hydrocarbon contamination. However, in contrast, the chemical testing carried out on samples of natural clay underlying the gasholders suggests relatively low concentrations of contaminants within the natural soils, appearing to suggest that downwards migration of contamination towards the underlying Principal Aquifer at depth is being significantly restricted by the superficial deposits.

Locations below investigated by BSL are broadly described west to east as opposed to numerically.

Tar Tank No. 2:

- Investigated by BH801 (within tank) and with BH807, WS814 and WS817 in nearby vicinity encountering both made ground and natural soils.
- BH801 encountered made ground to 8.00m bgl containing ash, PFA and a slight hydrocarbon odour, reporting to become strong at 8.00m bgl.
- No evidence of a basal brick or concrete layer denoting base of the tar tank.
- From 8.00m bgl, a firm brown gravelly CLAY was encountered, with no visual or olfactory evidence of contamination.
- PID readings within the made ground in BH801 peaked at 7ppm (7.50m bgl) but were 0.0ppm in underlying clay in the same borehole.
- Chemical testing of the made ground from BH801 at 7.5-8.0m bgl identified significantly elevated concentrations of PAHs and some SVOCs. Chemical testing of the natural soils from BH801 at 8.1-8.6m bgl did not identify any elevated concentrations of contaminants. Whilst PAHs were detected during laboratory testing, concentrations were typically an order of magnitude lower than the made ground directly overlying the natural clay.
- Similar observations were made in adjacent locations. In WS817, elevated concentrations of PAHs and aromatic hydrocarbons (C12-C35) were recorded in the made ground, with no elevated concentrations of contaminants in soils in the underlying natural soils, with concentrations of some SVOCs an order of magnitude lower in the natural soils vs the overlying made ground stratum.

Gas Holder No. 5:

- Investigated by BH804 (within holder) and with WS814 and WS817 in nearby vicinity encountering both made ground and natural soils.
- BH801 encountered made ground to 8.50m bgl containing ash and a strong rancid odour. Blue billy (spent oxide) widely encountered.
- No evidence of a basal brick or concrete layer denoting base of the tar tank.
- From 8.50m bgl, a firm brown slightly gravelly CLAY was encountered, with no visual or olfactory evidence of contamination.
- PID readings within the made ground in BH804 peaked at 19.1ppm (4.00m bgl) but were 0.0ppm in underlying clay in the same borehole.

- Chemical testing of the made ground from BH804 at 7.0-7.5m bgl identified significantly elevated concentrations of PAHs and some SVOCs. Chemical testing of the natural soils from BH804 at 8.50-9.00m bgl did not identify any elevated concentrations of contaminants. Whilst PAHs were detected during laboratory testing, concentrations were typically an order of magnitude lower than the made ground directly overlying the natural clay.
- Similar observations were made in adjacent locations. In WS817, elevated concentrations of PAHs and aromatic hydrocarbons (C12-C35) were recorded in the made ground, with no elevated concentrations of contaminants in soils in the underlying natural soils, with concentrations of some SVOCs an order of magnitude lower in the natural soils vs the overlying made ground stratum.

Gas Holder No. 1:

- Investigated by BH814A and BH815 within holder.
- Made ground encountered to between 8.00m and 8.60m bgl containing ash and evidence of hydrocarbon contamination. Slight hydrocarbon odour noted in BH814A throughout made ground, whereas in BH815 there was groundwater ingress at 4.50m bgl with moderate odour and oily sheen, and a strong hydrocarbon odour noted from 6.50m to 7.50m bgl.
- Basal brick layer denoting base of the tar tank at 8.00m bgl in BH815 but not present in BH814A.
- Natural clay encountered from 8.60m to 9.20m bgl in BH814A, and from 8.15m to 9.10m bgl in BH815. In both boreholes there was no visual or olfactory evidence of contamination reported.
- PID readings were very low in both the made ground and natural soils.
- Elevated concentrations of cyanide encountered in the made ground in BH814A, and the made ground in both BH814A and BH815 contained elevated concentrations of PAHs. The natural clay sampled from BH815 contained significantly elevated concentrations of PAHs, concentrations were higher than the shallow made ground sampled from the same location, and further consideration is required.
- In contrast, concentrations of cyanide were below laboratory limits of detection in the natural soils underlying the made ground in BH815.

Records indicate this is one of the few locations where the made ground in the holder has been remediated by source removal, so elevated concentrations in the BH815 natural strata could be relict cross contamination, but it is noted that it was backfilled with PFA to 8mbgl, then ex-situ stabilised materials to 3.3m bgl, essentially leaving impacted material below.

Gas Holder No. 2:

- Investigated by BH813 within holder and BH812 and WS802 in in nearby vicinity encountering both made ground and natural soils.
- Made ground in BH813 encountered to 10.30m bgl bgl, containing ash and evidence of hydrocarbon contamination. Slight hydrocarbon odour noted in BH813 throughout made ground. Groundwater ingress at 8.20m bgl with moderate odour.
- Basal concrete layer denoting base of the gas holder at 10.20m bgl.
- No natural soils were encountered at the base of the holder, with sandstone encountered directly underneath the concrete slab.
- In adjacent location WS802, relatively low concentrations of PAHs were recorded in both the made ground and natural strata.

Gas Holder No. 3:

- Investigated by BH811B (within holder).
- BH811B encountered made ground to 6.00m bgl with moderate hydrocarbon odour between 1.00m and 3.50m bgl.

- No evidence of a basal brick layer denoting base of the tar tank, although various obstructions were encountered including concrete between 5.00m and 6.00m bgl.
- From 6.00m bgl, a firm brown gravelly CLAY was encountered, with no visual or olfactory evidence of contamination.
- PID readings were very low in both the made ground and natural soils.
- The made ground in BH811B was not scheduled for testing. However, the made ground in TP810 was scheduled for chemical testing, located within the same holder.
- Elevated concentrations of PAHs were encountered in both the made ground and natural soils, although the concentrations present in the natural soils are significantly lower suggesting some attenuation of contaminants may be occurring.
- It is also noted that made ground was much shallower within Gas Holder No. 3, resulting in 3m of clay cover overlying the sandstone bedrock, which was encountered from approximately 9m bgl in BH811B. However, this may be due to the gas holder potentially having a convex base, as is the case for Tar Tank No. 1, described below.

Tar Tank No. 1:

- Investigated by BH805 (within holder).
- Limited information was obtained during the current phase of work for Tar Tank No. 1 due to a very high groundwater table and safety restrictions imposed by Cadent preventing deepening of BH805 below 0.60m bgl.
- Previous investigation by Amec (2011) with of BH601, BH601A, BH602, BH603 and TP601, which indicate the tar tank has a convex basal profile
- Within the central areas of the tank (investigated by BH601A and BH603), the depth of made ground is only 3.1-3.5m in thickness whereas the depth of the tank towards the edges (investigated by BH603) is at least 8m.
- Where the base of the made ground was proven in BH601A and BH602, there appeared to be evidence of obstructions at the base, suggesting a base structure, which in turn was underlain by natural clay.
- BH603 confirms there is at least a circa 4m thickness of free phase tar located at the base of the tank, which is assumed to extend around the perimeter of the dumpling.
- Testing results indicate significantly elevated concentrations of benzene, PAHs (naphthalene, benzo(a) pyrene and others), ammonium and lead. Contaminant concentrations generally increase towards the base of the made ground in each location, but in general concentrations of contaminants reduce significantly in the underlying natural soils (where encountered in the central areas) compared to the overlying made ground.

Limited information was obtained during the current phase of work for Tar Tank No. 1 due to a very high groundwater table and safety restrictions imposed by Cadent preventing deepening of BH805 below 0.60m bgl or relocating due to safety stand-off distance from their assets, even whilst under full time supervision of a Cadent pipeline inspector, a separate competent person and a BSL engineer holding SHEA gas qualifications.

However, the previous investigation of Tar Tank No. 1 carried out by Amec in 2011 included the drilling / excavation of BH601, BH601A, BH602, BH603 and TP601. Exploratory Hole Logs and chemical testing data which had previously been redacted has recently been made available to BSL for assessment as part of this report, and the original data is presented in Appendix K for completeness.

In summary, the available records within Tar Tank 1 demonstrate a convex basal profile to this tank within the central areas of the tank (investigated by BH601A and BH603), the depth of made ground is only 3.1-3.5m in thickness whereas the depth of the tank towards the edges (investigated by BH603) is at least 8m. BH603 confirms there is at least a circa 4m thickness of free phase tar located at the base of the tank, which is assumed to extend around the perimeter of the dumpling.

Amec obtained samples during the drilling works and the results of chemical testing are also presented within Appendix K. The results indicate significantly elevated concentrations of benzene, PAHs (naphthalene, benzo(a) pyrene and others), ammonium and lead. Contaminant concentrations generally increase towards the base of the made ground in each location, but in general concentrations of contaminants reduce significantly in the underlying natural soils (where encountered in the central areas) compared to the overlying made ground.

11.5 Water Test Results – Controlled Waters

A total of 2 rounds of groundwater monitoring were undertaken at the site and samples were recovered from installations from the Phase 3 and 4 areas. This supplements the existing Hydrock dataset from Phases 1 and 2, where 2 No. rounds of sampling were also undertaken during early 2022. Samples were obtained from boreholes via low flow sampling techniques.

In the first instance, results were compared to UK drinking water standards (DWS) given the presence of a Principal Aquifer underlying the site which is considered the most sensitive controlled waters receptor based on the Preliminary CSM. In absence of DWS values, Environmental Quality Standard (EQS) values have been adopted for the Tier 1 Assessment.

Metals
The locations and concentrations of metals identified above the adopted screening criteria are shown in the table below:

Exploratory Hole	Response Zone	Metal	Concentration Visit 1 (ug/l)	Concentration Visit 2 (ug/l)	Adopted Screening Criteria (ug/l)
BH805	Made Ground	Lead	Not tested	15*	10
BH805	Made Ground	Manganese	Not tested	87*	50
HP811	Made Ground	Calcium	710	Not tested	250
HP811	Made Ground	Manganese	8300	Not tested	50
WS806	Made Ground	Calcium	300	Not tested	250
WS806	Made Ground	Manganese	3400	Not tested	50
WS810	Made Ground	Arsenic	120	140	10
WS810	Made Ground	Boron	Not tested	1500	1000
WS810	Made Ground	Calcium	990	930	250
WS810	Made Ground	Calcium	930	Not tested	250
WS810	Made Ground	Selenium	100	91	10
WS815	Made Ground	Arsenic	Not tested	150	10
WS815	Made Ground	Calcium	Not tested	1200	250
WS815	Made Ground	Nickel	Not tested	490	20
WS818	Made Ground	Arsenic	34.5	59.9	10
WS818	Made Ground	Boron	1100	1100	1000
WS818	Made Ground	Calcium	700	710	250
WS818	Made Ground	Manganese	720	840	50
WS818	Made Ground	Selenium	Not tested	11	10
BH815	Superficial CLAY	Boron	1500	1400	1000
BH815	Superficial CLAY	Calcium	540	430	250
BH815	Superficial CLAY	Manganese	20000	18000	50
BH815	Superficial CLAY	Selenium	72	14	10
WS801	Superficial CLAY	Manganese	-	730	50
BH801	Bedrock	Boron	1300	1500	1000

Exploratory Hole	Response Zone	Metal	Concentration Visit 1 (ug/l)	Concentration Visit 2 (ug/l)	Adopted Screening Criteria (ug/l)
BH801	Bedrock	Calcium	570	470	250
BH801	Bedrock	Manganese	700	990	50
BH802A	Bedrock	Manganese	880	820	50
BH804	Bedrock	Manganese	650	1600	50
BH807(D)	Bedrock	Manganese	3000	3100	50
BH810	Bedrock	Calcium	150	310	250
BH810	Bedrock	Manganese	460	410	50
BH811B	Bedrock	Calcium	330	360	250
BH811B	Bedrock	Manganese	310	710	50
BH812	Bedrock	Selenium	17	11	10
BH814A	Bedrock	Manganese	1500	5500	50

*BH805 sampled during standalone visit on 03/09/24.

Inorganics/Non-metals

The locations and concentrations of inorganics/non-metals identified above the adopted screening criteria are shown in the table below:

Exploratory Hole	Response Zone	Compound	Concentration Visit 1 (ug/l)	Concentration Visit 2 (ug/l)	Adopted Screening Criteria (ug/l)
BH805	Made Ground	Cyanide (Hydrogen cyanide)	Not tested	230*	50
BH805	Made Ground	Total Ammonia (as NH4) plus ammonia (NH3)	Not tested	40000*	50
BH805	Made Ground	Ammonium (NH4)	Not tested	21000*	500
BH815	Made Ground	Cyanide (Hydrogen cyanide)	1200	760	50
BH815	Made Ground	Total Ammonia (as NH4) plus ammonia (NH3)	67000	27000	50
BH815	Made Ground	Ammonium (NH4)	34000	14000	500
BH815	Made Ground	Chloride	300000	300000	250000
HP811	Made Ground	Cyanide (Hydrogen cyanide)	790	Not tested	50
HP811	Made Ground	Total Ammonia (as NH4) plus ammonia (NH3)	163000	Not tested	50
HP811	Made Ground	Ammonium (NH4)	84000	Not tested	500
WS806	Made Ground	Cyanide (Hydrogen cyanide)	2600	Not tested	50
WS806	Made Ground	Total Ammonia (as NH4) plus ammonia (NH3)	68000	Not tested	50
WS806	Made Ground	Ammonium (NH4)	35000	Not tested	500
WS810	Made Ground	Cyanide (Hydrogen cyanide)	350000	300000	50
WS810	Made Ground	Chloride	1500000	1800000	250000
WS815	Made Ground	Cyanide (Hydrogen cyanide)	Not tested	370000	50
WS815	Made Ground	Total Ammonia (as NH4) plus ammonia (NH3)	Not tested	310000	50
WS815	Made Ground	Ammonium (NH4)	Not tested	160000	500
WS815	Made Ground	Chloride	Not tested	1700000	250000
WS818	Made Ground	Cyanide (Hydrogen cyanide)	42000	37000	50

Exploratory Hole	Response Zone	Compound	Concentration Visit 1 (ug/l)	Concentration Visit 2 (ug/l)	Adopted Screening Criteria (ug/l)
WS818	Made Ground	Total Ammonia (as NH4) plus ammonia (NH3)	9500	8400	50
WS818	Made Ground	Ammonium (NH4)	4900	4300	500
WS818	Made Ground	Chloride	310000	320000	250000
WS801	Natural CLAY	Cyanide (Hydrogen cyanide)	Not tested	450	50
WS801	Natural CLAY	Total Ammonia (as NH4) plus ammonia (NH3)	Not tested	5600	50
WS801	Natural CLAY	Ammonium (NH4)	Not tested	2900	500
BH801	Bedrock	Cyanide (Hydrogen cyanide)	7400	8000	50
BH801	Bedrock	Total Ammonia (as NH4) plus ammonia (NH3)	37000	76000	50
BH801	Bedrock	Ammonium (NH4)	19000	39000	500
BH801	Bedrock	Chloride	260000	290000	250000
BH802A	Bedrock	Cyanide (Hydrogen cyanide)	80	72	50
BH802A	Bedrock	Total Ammonia (as NH4) plus ammonia (NH3)	6000	72000	50
BH802A	Bedrock	Ammonium (NH4)	31000	37000	500
BH802A	Bedrock	Nitrate (as N03)	Below ASC	52500	50000
BH802A	Bedrock	Nitrate (as N02)	3000	570	100
BH804	Bedrock	Cyanide (Hydrogen cyanide)	6700	2700	50
BH804	Bedrock	Total Ammonia (as NH4) plus ammonia (NH3)	7800	7600	50
BH804	Bedrock	Ammonium (NH4)	4000	3900	500
BH807	Bedrock	Cyanide (Hydrogen cyanide)	260	120	50
BH807	Bedrock	Total Ammonia (as NH4) plus ammonia (NH3)	260000	350000	50
BH807	Bedrock	Ammonium (NH4)	130000	180000	500
BH807	Bedrock	Nitrate (as N03)	269000	270000	50000
BH807	Bedrock	Nitrate (as N02)	4500	8600	100
BH810	Bedrock	Cyanide (Hydrogen cyanide)	730	290	50
BH810	Bedrock	Total Ammonia (as NH4) plus ammonia (NH3)	105000	51000	50
BH810	Bedrock	Ammonium (NH4)	54000	26000	500
BH811B	Bedrock	Cyanide (Hydrogen cyanide)	2000	2400	50
BH811B	Bedrock	Total Ammonia (as NH4) plus ammonia (NH3)	210000	210000	50
BH811B	Bedrock	Ammonium (NH4)	110000	110000	500
BH812	Bedrock	Cyanide (Hydrogen cyanide)	53	Below ASC	50
BH812	Bedrock	Total Ammonia (as NH4) plus ammonia (NH3)	250	450	50
BH814A	Bedrock	Cyanide (Hydrogen cyanide)	940	1600	50
BH814A	Bedrock	Total Ammonia (as NH4) plus ammonia (NH3)	144000	46000	50

Exploratory Hole	Response Zone	Compound	Concentration Visit 1 (ug/l)	Concentration Visit 2 (ug/l)	Adopted Screening Criteria (ug/l)
BH814A	Bedrock	Ammonium (NH4)	74000	24000	500

*BH805 sampled during standalone visit on 03/09/24.

Thiocyanate was detected within all monitoring locations with the exception of BH812 and WS801. There are no available DWS or EQS levels for initial screening, therefore a summary of the concentrations where thiocyanate was present within groundwater is presented below:

Exploratory Hole	Response Zone	Concentration Visit 1 (ug/l)	Concentration Visit 2 (ug/l)
BH805	Made Ground	Not tested	300*
BH815	Made Ground	190000	160000
HP811	Made Ground	1400	Not tested
WS806	Made Ground	2100	Not tested
WS810	Made Ground	1300000	1300000
WS815	Made Ground	Not tested	1600000
WS818	Made Ground	140000	170000
BH801	Sandstone	70000	49000
BH802A	Sandstone	280	280
BH804	Sandstone	42000	2200
BH807	Sandstone	740	290
BH810	Sandstone	32000	3900
BH811B	Sandstone	2700	18000
BH814A	Sandstone	130000	46000
BH802A	Sandstone	280	280

*BH805 sampled during standalone visit on 03/09/24.

Poly Aromatic Hydrocarbons (PAHs)

There were widespread incidences of the DWS for PAH compounds being exceeded (or EQS where no DWS value exists). Results are summarised in the following tables:

Exploratory Holes Exceeding	Response Zone	Species	Max Concentration (ug/l)	Adopted Screening Criteria (ug/l)	Screening Criteria Source
BH815, HP811, WS806, WS810, WS818	Made ground	Anthracene	2.7 (BH815)	0.1	EQS
BH805, BH815 WS818	Made ground	Benzo(a)pyrene	1.7 (BH815)	0.01	DWS
BH805, BH815 HP811	Made ground	Benzo(b)fluoranthene	2.0 (BH815)	0.1	DWS
BH805, BH815 HP811, WS818	Made ground	Benzo(k)fluoranthene	0.8 (BH815)	0.10	DWS
BH815, HP811 WS818	Made ground	Benzo(ghi)perylene	1.4 (BH815)	0.1	DWS
BH805, BH815, HP811, WS806, WS810, WS815, WS818 [1]	Made ground	Fluoranthene	4.6 (BH815)	0.0063	EQS
BH815, HP811, WS818	Made ground	Indeno(1,2,3,cd)pyrene	0.98 (BH815)	0.1	DWS
BH815, WS806, WS810, WS815,	Made Ground	Naphthalene	2200 (WS815)	2.0	EQS

Exploratory Holes Exceeding	Response Zone	Species	Max Concentration (ug/l)	Adopted Screening Criteria (ug/l)	Screening Criteria Source
WS818					
BH807	Bedrock	Acenaphthylene	240	5.8	EQS
BH801, BH802A BH807, BH812	Bedrock	Anthracene	35 (BH807)	0.1	EQS
BH801, BH802A BH812	Bedrock	Benzo(a)pyrene	0.53 (BH812)	0.01	DWS
BH801, BH802A, BH807, BH812	Bedrock	Benzo(b)fluoranthene	8.0 (BH807)	0.1	DWS
BH801, BH807, BH812	Bedrock	Benzo(ghi)perylene	3.3 (BH807)	0.1	DWS
BH801, BH802A BH807, BH812	Bedrock	Benzo(k)fluoranthene	3.4 (BH807)	0.1	DWS
BH801, BH802A BH804, BH807, BH810, BH811B BH812, BH814A	Bedrock	Fluoranthene	38 (BH807)	0.0063	EQS
BH801, BH807, BH812	Bedrock	Indeno(1,2,3,cd)pyrene	3.0 (BH807)	0.1	DWS
BH804, BH807	Bedrock	Naphthalene	3500 (BH807)	2.0	EQS

Note: EQS value for fluoranthene is less than the laboratory limit of detection, therefore additional areas cannot be disproved to have exceeded this value despite being below laboratory limits of detection but are not listed here.

Phenols

Elevated concentrations of Phenols have been detected at the following locations:

Exploratory Hole	Response Zone	Compound	Concentration Visit 1 (ug/l)	Concentration Visit 2 (ug/l)	Adopted Screening Criteria (ug/l)
WS815	Made Ground	Total Phenols	Not tested	44000	7.7
BH802A	Bedrock	Total Phenols	65	<3.5	7.7
BH807	Bedrock	Total Phenols	7500	<3.5	7.7

Petroleum Hydrocarbons

The locations elevated ranges of petroleum hydrocarbons identified above the adopted screening criteria are shown in the table below:

Exploratory Holes	Response Zone	Range / Fraction	Max. Concentration (ug/l)	Adopted Screening Criteria (ug/l)
HP811, WS815	Made Ground	Aromatic >C5 - C6	150 (WS815)	10
BH815, WS810, WS810, WS815	Made Ground	Aromatic >C10 - C12	2300 (WS815)	90
BH805, BH815, HP811, WS806, WS810, WS810, WS815	Made Ground	Aromatic >C12 - C16	5100 (WS815)	90
BH805, BH815, HP811, WS810, WS815	Made Ground	Aromatic >C16 - C21	1600 (WS815)	90
BH805, HP811	Made Ground	Aromatic >C21 - C35	130 (HP811)	90

Exploratory Holes	Response Zone	Range / Fraction	Max. Concentration (ug/l)	Adopted Screening Criteria (ug/l)
BH807, BH814A	Bedrock	Aromatic >C5 - C6	440 (BH807)	10
BH807	Bedrock	Aromatic >C8 - C10	820 (BH807)	300
BH807	Bedrock	Aromatic >C10 - C12	8300 (BH807)	90
BH801, BH804, BH807	Bedrock	Aromatic >C12 - C16	8400 (BH807)	90
BH807	Bedrock	Aromatic >C16 - C21	5200 (BH807)	90
BH804, BH807	Bedrock	Aromatic >C21 - C35	1100 (BH807)	90

BTEX Compounds

The locations elevated ranges of BTEX compounds identified above the adopted screening criteria are shown in the table below:

Exploratory Hole	Response Zone	Compound	Concentration Visit 1 (ug/l)	Concentration Visit 2 (ug/l)	Adopted Screening Criteria (ug/l)
HP811	Made Ground	Benzene	20.4	Not tested	1
WS815	Made Ground	Benzene	Not tested	148	1
BH807	Bedrock	Benzene	439	128	1
BH807	Bedrock	Xylene	692	609	500
BH814A	Bedrock	Benzene	<3	54.2	1

Note: DWS values for Benzene are less than the laboratory limit of detection (3 ug/l), therefore additional areas cannot be disproved to have exceeded this value despite being below laboratory limits of detection but are not listed here. Note the EQS for benzene in Freshwater of 10ug/l is above the LLD.

VOCs / SVOCs

With the exception of BTEX compounds and PAHs already detailed in this chapter, the vast majority of VOCs and SVOCs were not detected above the laboratory lower limits of detection.

11.6 Controlled Waters Risk Assessment

The results of groundwater testing indicate the Principal Aquifer underlying the site is impacted by elevated concentrations of the following:

- Metals; in particular manganese elevated in numerous locations (up to 62 times DWS in BH807) as well as boron, calcium and selenium to a lesser extent.
- Various inorganic compounds:
  - Cyanide; concentrations detected up to 160 times the DWS in BH801. It is noted that concentrations representative of the Principal Aquifer are significantly lower that the concentrations within perched shallow groundwater in the made ground, which have been detected up to 7400 times the DWS (WS815).
  - Ammonium; concentrations detected up to 360 times the DWS in BH807, with concentrations generally similar to those recorded in areas of the perched groundwater body.
  - Chloride; marginally exceeding DWS in BH801 (1.16x)
  - Nitrates; exceeding the DWS in BH802 and BH807, detected up to 86 times the DWS in BH807.
  - Thiocyanate; detected across the site in both shallow perched groundwater and in the Principal Aquifer.
- Various PAH species, with maximum concentrations typically at least one order of magnitude above the relevant DWS or EQS.
- Phenols are elevated within BH802A and BH807; in BH807 concentrations are almost 2 orders of magnitude above the EQS.
- Aromatic petroleum hydrocarbons are elevated across all fractions (C5-35) with the greatest elevations on site recorded within BH807.
- BTEX compounds:

- Benzene elevated in BH814 and BH807, up to two orders of magnitude above the DWS.
- Xylene also marginally elevated in BH807.

Whilst elevated concentrations of the contaminants detailed above have been identified at various sampling points representative of the Principal Aquifer across the site, it is noted that the concentrations of contaminants within the shallow installations, representative of perched groundwater within the made ground and limited superficial deposits, are generally higher and in many locations significantly higher than concentrations in the Principal Aquifer.

As detailed within section 11.4, this trend also appears to be present within soils testing of the made ground compared to testing of the deeper superficial deposits underlying the gasholders / tar tanks present on site. Almost all of the gasholders and tar tanks remaining on site include either a basal brick or concrete layer, and/or are underlain by superficial clay deposits, chemical testing of which indicates a generally consistent reduction in contaminant concentrations between the made ground and the underlying natural soils. Only Gas Holder No. 2 is not underlain by any superficial deposits, although a basal concrete layer is present.

A summary of the comparative dataset available with respect to individual contaminative sources on site, is detailed as follows:

Feature	Monitoring Point within footprint	Target Stratum	Comments
Tar Tank No. 2	BH801 & BH807[1]	Bedrock	No significant reduction in contaminant concentrations between perched groundwater within the made ground and underlying Principal Aquifer. Highest concentrations of ammonia, BTEX, petroleum hydrocarbons and phenols have been recorded in BH807.
	WS818	Made ground	
Gas Holder No. 5	BH804	Bedrock	Concentrations of some metals, cyanide, phenols, PAHs and petroleum hydrocarbons a significantly lower in BH804 vs shallow installs. Notably, the exception to this trend is manganese which is present at concentrations circa 1-2 orders of magnitude higher in BH804 when compared to shallow installations.
	WS810 & WS815	Made ground	
Gas Holder No. 1	BH814A	Bedrock	Significant reduction in concentrations of vast majority of metals (including manganese) and PAH species within BH814A compared to BH815. Concentrations of cyanide, sulphate, nitrates and chloride are lower in BH814A, but ammonia compounds are higher in BH814A. Concentrations of aromatic petroleum hydrocarbons are generally lower in BH814A although concentrations of benzene and toluene are marginally higher in BH814A.
	BH815	Made ground	
Gas Holder No. 2	BH812[1]	Bedrock	Relatively few exceedances of the adopted Tier 1 screening values. It is noted that BH812 is arguably up-gradient of the source, although groundwater level analysis indicates the gradient is actually relatively flat in this area of the site. Exceedances recorded for cyanide, ammonia, selenium and some PAH species. Overall some of the lowest contaminant concentrations recoded on site.
Gas Holder No. 3	BH811B	Bedrock	Relatively few exceedances of the adopted Tier 1 screening values. Exceedances recorded for some metals, inorganics and PAH species. Overall some of the lowest contaminant concentrations recoded on site.

Feature	Monitoring Point within footprint	Target Stratum	Comments
Tar Tank No. 1	BH805	Made ground	No groundwater testing has been possible within the Principal Aquifer directly beneath this feature due to access and working methodology restrictions, groundwater quality in deeper aquifer monitored by proxy (i.e. surrounding positions). A sample of shallow perched groundwater was retrieved from BH805 during excavation of the service inspection pit, which indicates the presence of elevated inorganics, PAHs, metals and petroleum hydrocarbons.
Former Ammonia Plant / Tar Tank Area	BH802A[1]	Bedrock	Concentrations of hydrocarbons generally low. Relatively high and elevated concentrations of inorganic compounds including ammonia as well as manganese.

[1] Borehole located just outside feature footprint, but still sufficiently positioned for assessment.

The groundwater flow direction modelled as part of the current period of intrusive investigation across phases 3 and 4 appears to be towards the west, as shown on drawing ref C5692/16. This is consistent with the previous phase of work on phases 1 and 2 completed by Hydrock (2022) which also concluded that the groundwater gradient within the Principal Aquifer underlying the site reduces towards the west indicating the apparent hydrogeological flow direction. The westerly groundwater flow direction appears to be slightly conflicting with the location of the River Irk, which is located north and west of the site, although the River Irwell is also located circa 800m west of the site, and may be responsible for governing regional groundwater trends more than the Irk.

The observations in the table above provide evidence indicating that groundwater quality of the underlying Principal Aquifer in the majority of areas suggests an improvement when compared to shallower samples. However, the evidence also suggests that the Principal Aquifer has been impacted with various contaminants and therefore pathways do appear to exist between the made ground and the Principal Aquifer, albeit the current ground conditions comprising hard standing at surface, brick/concrete bases to the gasholders and superficial clay deposits are likely to be restricting contaminant migration to a degree across the site as a whole. The concentrations of contaminants also appear to be greater in general within installations located within the western part of the site, at this stage suggesting that groundwater quality is of lower quality down-gradient of the site compared to up-gradient.

There is a network of deep drainage on site as evidenced by a series of manholes in the western area, as shown on the Deep Drainage Survey Extract drawing, ref. C5962/18. A drainage survey was undertaken by General Utilities Northwest Ltd in May 2020, ref. 2020_05_18 GOULD STREET MANCHESTER BDP, which investigated the condition of manholes and drainage infrastructure on site and in the immediate surrounds. Manhole refs MH14, MH15 and MH16 were located by both General Utilities Northwest Ltd and appear to correlate to those located by BSL, and according to the drainage survey these manholes have invert levels between 10.25m and 12.00m bgl. Images of the manholes and deep drainage infrastructure indicate the structures appear to be constructed from masonry, and records from BH14 and MH16 indicate the deep drains may have partially collapsed and are assumed to be redundant. BH15 was able to be surveyed but no pipes were visible beyond circa 1m away from the base of the manhole. Given the otherwise largely impermeable superficial deposits, the deep drainage represents an area where contamination leaching from the made ground and gasholders could potentially collect and migrate within the site and possibly off-site, although the extent of leaching and contamination migration is unknown and may be limited given the evidence of collapse and blockages of the surveyed sections of the drainage. At this stage the drainage is considered to represent a potential pathway for mobile gross and dissolved

phase contamination, which may result in impaction of nearby surface water receptors and the Principal Aquifer underlying the site, depending on the extent and condition of the drainage networks as a whole.

Based on the investigation completed to date there is considered to be a viable source-pathway-receptor linkage and further assessment will be required in the form of a detailed quantitative risk assessment (DQRA), which will also enable establishment of site-specific controlled waters and soils remediation criteria. There is also a potential liability issue associated with the migration of contamination off site and it is recommended that discussion with the Environment Agency is entered into at the earliest opportunity to agree a scope of remedial works including establishing and agreeing realistic and achievable remedial target values (via DQRA), as remediating contaminant concentrations down to the DWS and/or EQS on site is unlikely to be achievable given the site's location and numerous off-site sources of potential contamination also likely impacting groundwater quality in the wider area.

Comparison of Recent Groundwater Results to Pre-remediation Testing

BSL has carried out a comparison of the results of groundwater testing completed by Entec in 2002 (pre-remediation) and results of groundwater testing recently completed during the current commission.

Entec monitoring wells BH2A, BH3A and BH5A are of particular importance, given they were installed with response zones within the sandstone bedrock and are located down-gradient of the majority of the known point sources on site. The Entec wells were unable to be located for samples to be obtained from the same location, however BSL installed monitoring wells BH801, BH804, BH807 and BH814A in relatively close proximity and along the north-western / western boundary (i.e. down gradient), and are the closest possible comparative datapoints.

Similarly, to allow a comparison of groundwater quality within the shallow perched groundwater body on site, predominantly within the made ground, Entec locations BH2, BH3, TP27 and TP31 are of particular interest given their location to the west of known point sources (pre-remediation). These have been compared to the closest BSL locations considered representative of the perched groundwater body.

The highest pre-remediation concentrations of ammonia, benzo(a)pyrene, naphthalene and benzene were recorded within BH2 in the north-west of the site. Nearby BSL locations WS806, WS810 and WS818 typically indicate a reduction in concentrations of these contaminants. Concentrations of cyanide do not appear to follow this trend, with higher concentrations consistently recorded within BSL monitoring locations. However, the highest concentration recorded by Entec (BHC6, 1,100 ug/l) is greater than the closest BSL representative monitoring point (WS801, 450 ug/l).

Whilst direct comparison of results from individual wells has not been possible, there is a consistent trend of a reduction in contaminant concentrations within the shallow perched groundwater body, which is suggestive of the previous remediation completed having been successful in providing an overall betterment of shallow groundwater quality on site.

In contrast, comparison of testing results from deep groundwater samples appears to show an opposite trend, with higher concentrations of cyanide, ammonium, PAHs and benzene recorded within BSL monitoring wells BH807 and BH814A in the west of the site, when compared to Entec BH2A, BH3A. The greatest concentrations of these key contaminants in the Principal Aquifer have been recorded in BH807, notably directly down-gradient of Tar Tank No. 1 which remains the most significant point source to have not yet been remediated. Based on the comparative assessment completed, it is likely that Tar Tank No. 1 is the primary source of contamination contributing to increased contaminant concentrations within the Principal Aquifer on site, possibly via diffuse leakages from the sides and base structures, whereas the evidence available suggests that the previous remediation has likely resulted in betterment, but results appear to be skewed by the likely ongoing impaction of the aquifer as a result of Tar Tank No. 1 remaining in situ.

11.7 Permanent Ground Gas and Vapours Results

A total of 6 ground gas monitoring visits have been carried out between the dates of 23rd July and 9th October 2024. Results are summarised in the table below:

	CH_4 (%)		CO_2 (%)		O_2 (%)		CO (ppm)		H_2S (ppm)		TVOC (ppm)		Steady Flow (l/hr)	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Peak	0.0	0.7	0.0	91.7	0.0	21.1	0.0	33.0	0.0	22.5	0.0	1.0	-24.2	78.0
Steady	-0.1	0.2	0.0	81.5	0.0	21.2							-1.5	4.1

Notes: CH_4 = Methane; CO_2= Carbon dioxide; O_2= Oxygen; CO= Carbon Monoxide; H_2S= Hydrogen Sulphide; TVOC (PID)= Total Volatile Organic Compounds (as measured with Photo Ionisation Detector); ppm= Parts Per Million.

The highest concentrations of carbon dioxide have been consistently recorded within WS806, BH814 and BH815, with peak carbon dioxide concentrations typically exceeding 50% v/v and regularly reaching circa 90% v/v in WS806 and BH815. Concentrations of carbon dioxide within the other monitoring wells on site have in general been recorded consistently below 5% v/w and have rarely exceeded 10% v/v.

The response zone of WS806 is between 2.50m and 4.50m bgl, the ground conditions comprising cohesive made ground described as reworked clay, and is not typical of the made ground present across the majority of the site, which is generally granular. There are no obvious sources of significantly high carbon dioxide generation within the made ground, and both methane concentrations and gas flow rates have remained consistently low within this monitoring well. WS806 is notably located in closest proximity to a deep sewer, although the cohesive nature of the made ground and absence of methane detected at this location suggest the sewer may not be the source of carbon dioxide.

The response zone of BH815 is between 4.00m and 7.00m bgl, the ground conditions comprising granular made ground containing visual and olfactory evidence of contamination in the form of a hydrocarbon odour, oily sheen, coal, clinker and slag. BH815 is also located within Gas Holder No. 1 and in close proximity to WS806. Despite this, there are no obvious sources of significantly high carbon dioxide generation within the made ground, and both methane concentrations and gas flow rates have generally remained consistently low within this monitoring well. The exceptions were the fifth and sixth visits where very high initial flow rates of 78.0l/hr and 26.2 l/hr were observed respectively, quickly reducing to a steady of 0.7 l/hr and 0.5l/hr respectively. Groundwater levels were noted to increase between the fourth and fifth visits at this location, potentially resulting in the creating of a localised large differential pressure as a result of the piston effect.

Based on the above, both WS806 and BH815 are considered to be outliers and unrepresentative of the gas regime in the made ground as a whole.

The concentrations of methane recorded to date have also been consistently low, with concentrations usually recorded below the detection limit of the monitoring equipment. The maximum concentration of 0.7% was recorded within BH815 on the fifth visit.

Ground gas flow rates have been consistently negligible (at or below detection limit of 0.1 l/hr) in the vast majority of monitoring locations. In a small number of locations installed within the shallow made ground, high initial flow rates have been recorded upon opening the valve, but in all instances these flow rates quickly reduced to significantly lower steady state flow rate. On the first visit, a 'hissing' sound was reported in BH814A (installed within the bedrock) alongside an initial flow rate of 25.7 l/hr, but this quickly reduced to a steady flow of 1.9 l/hr. Monitoring of the same well on subsequent visits has recorded a maximum initial flow of 0.9 l/hr and a maximum steady flow of 1.4 l/hr with no reports of hissing, therefore it is considered most likely that the very high initial flow rates observed were a result of artificial drilling

induced pressure accumulation within the monitoring standpipe, which was monitored shortly after drilling, creating a differential pressure gradient. Very high initial flows were not recorded in any wells across the site on visits 3 and 4.

Hydrocarbon odours were noted during monitoring within BH14A on three occasions, WS805 on two occasions and in BH301 on one occasion.

Low concentrations of carbon monoxide, typically between 10ppm and 30ppm, have been recorded in numerous monitoring wells, most of which are installed within the made ground. Hydrogen sulphide has generally not been detected throughout the recent monitoring undertaken by BSL, with the only exception of BH802A on the third, fifth and sixth visits when concentrations of between 16.8ppm and 23.0ppm were recorded; the response zone of this well is within the sandstone bedrock.

PID monitoring of the installations was also undertaken during monitoring, but the maximum concentration was 1.0ppm indicating no significant volatiles concentrations. In addition, PID head space monitoring was undertaken on all environmental soil samples taken during the ground investigation at the site, and the vast majority of the samples recorded PID results of less than 10ppm, indicating that no significant volatile vapour contamination was present. Samples from BH804, BH807 and WS817 taken during the intrusive investigation recorded PID readings of greater than 10ppm; the highest by far was BH807 at 7.20m bgl where PID monitoring recorded TVOCs of 386ppm. A suspected solvent odour was also noted during drilling in this location. Whilst no chlorinated solvents were detected during laboratory testing, various SVOCs were detected and at relatively high concentrations compared to other locations on site.

The atmospheric pressure ranged between 989mb and 1014mb over the monitoring period, of which visits were conducted over a range of falling, steady and rising pressure trends.

Groundwater levels were recorded above the response zones in a small number of monitoring wells, but the vast majority were either dry or groundwater levels were below the response zones.

11.8 Ground Gas Risk Assessment

Basis of Assessment
In order to assess the ground gas situation and the requirement for ground gas precautionary measures at the site, guidance was taken from BS8485:2015+A1:2019 'Code of Practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings' and CL:AIRE Technical Bulletin TB17 'Ground Gas Monitoring and 'Worst-Case' Conditions'.

Rationale and Suitability of Dataset
As per the Phase 1 Desk Study, in accordance with BS8485 and as set out in Appendix A of this report, the permanent ground gas generation potential is considered to be **very low to low** (sources as made ground). The sensitivity of the development is **low to moderate** on account of the proposed apartment buildings but with ground floor commercial units.

In line with current guidance, it is recommended gas monitoring should comprise 6 visits over a 3-month period. The recommended frequency and duration of monitoring has been met, with visits undertaken over a range of atmospheric pressure conditions, and it is therefore considered that the monitoring period has captured reasonable 'worst-case' atmospheric conditions.

Assessment of Data
Derivation of a Gas Screening Values (GSV) has been undertaken based on the guidance with BS8485 using the following equation: (max gas concentration / 100) x maximum steady flow.

A maximum representative steady flow of 1.9 l/hr has been used to derive the worst credible GSVs, which is considered to be a very conservative value for the site as a whole, given the very low to negligible flow rates recorded within the vast majority of monitoring wells. Separate GSVs have been presented for carbon dioxide including and excluding WS806 and BH815 from the dataset due possibly being an outlier. The GSV's for the site are presented below:

Ground Gas	Adopted Typical Steady Flow Rate (l/hr)	Max Concentration (% v/v)	Worst Credible GSV (l/h)	Classification based on GSV	Typical Threshold Concentration Exceeded
Methane	1.9	0.3	0.0057	CS1	No
Carbon Dioxide	1.9	91.7	1.74	CS3	Yes
Carbon Dioxide	1.9	22.2[1]	0.42	CS2	Yes

[1] Excluding data from WS806 and BH815

As stated above, the data from WS806 is considered to be an outlier when compared to the dataset for the wider site, with no obvious source of ground gas identified. In addition, soils from the response zone will be largely removed during earthworks as the in the north-western part of the site is scheduled for a significant cut. The maximum ground gas flow rate recorded at WS806 was also 0.1 l/hr, therefore using a characteristic site-wide gas flow rate would be unrepresentative for deriving a GSV based on data from WS806 alone. Flow rates from BH815 on the fifth visit, when the highest carbon dioxide concentration was recorded, appear to have been influenced by the piston effect so are unlikely to be representative of the site as a whole. Data from these monitoring locations has therefore not been considered further during assessment of the dataset.

The GSVs place the site into Characteristic Situation 2 (CS2), which is in line with the recommendation of CS2 for Phases 1 and 2 previously made by Hydrock. At this stage it is recommended that allowance is made for installation of ground gas protection measures into proposed structures in line with CS2.

The site will require an extensive earthworks and remediation programme which will include extensive cut and fill works, removal of large volumes of excess made ground materials off-site, as well as the likely removal or treatment/stabilisation of any heavily contaminated soils. These works are likely to have an overall positive impact on the ground gas regime as a whole, particularly with respect to the potential for volatile vapour contamination arising from free phase hydrocarbons which will be remediated. Therefore, it is recommended that further ground gas / soil vapour monitoring is completed with the installation of new monitoring wells and obtaining vapour samples for laboratory analysis (TPH CWG and VOCs), following completion of the enabling works / earthworks programme.

11.9 Qualitative Risk Assessment

The CSM has been revised based on the findings of the site investigation and laboratory testing results and these are presented overleaf and are visually depicted within the Pre-development Conceptual Site Model drawing, ref. C5692/06. Unless stated otherwise, in respect to off-site sources, only risks that are assessed as moderate and above within the preliminary CSM have been carried forward to this section, or where a previously unidentified potential source, pathway and / or receptor has been identified from the recent site works.

Human Health						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
On site General Made Ground Metals, petroleum hydrocarbons, PAHs, asbestos, inorganics	Root uptake, ingestion, direct contact, inhalation of dusts/vapours	End-users	Likely	Medium	Moderate	The ground investigation has confirmed the presence of widespread PAH and metals contamination within the made ground, in addition to more localised areas of the site which are impacted with petroleum hydrocarbons, benzene, phenols, inorganics, SVOCs and asbestos fibres. The redevelopment of the site will involve a substantial earthworks programme which will likely involve the removal or treatment of gross contamination alongside re-use of suitable soils beneath buildings and hard standing where they will pose negligible risk to human health. However, a heightened risk will remain in any areas of soft landscaping and additional remedial works will be required.
On site Made Ground Metals and organic contamination	Migration into/chemical attack of water supply pipelines	Water Pipelines / End users	Highly likely	Medium	High	Contaminants within the soil/groundwater could potentially attack the clean potable water supply pipe, contaminants should be assessed to determine the correct pipe material and level of precautions required. However, based on the widespread distribution and concentrations of contaminants, it is highly likely that remediation will be required in the form of removal of any gross contamination, installation of barrier pipe alongside the over-excavation and installation of clean service corridors.
On site Former Gas Works underground structures including gasometers and tanks PAHs, petroleum hydrocarbons inc. BTEX and phenols, metals, ammoniacal liquor (chlorides,	Root uptake, ingestion, direct contact, inhalation of dusts/vapours	End-users	Likely	Medium	Moderate	As detailed above, the ground investigation has confirmed the presence of widespread PAH and metals contamination within the made ground, in addition to more localised areas of the site which are impacted with petroleum hydrocarbons, benzene, phenols, inorganics, SVOCs and asbestos fibres. The redevelopment of the site will involve a substantial earthworks programme which will likely involve the removal of gross contamination alongside re-use of suitable soils beneath buildings and hard standing where they will pose negligible risk to human health. However, a heightened risk will remain in any areas of soft landscaping and remediation will be required to make the site suitable for the proposed mixed residential and commercial end use.

Human Health						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
thiocyanate, ammonia), hydrogen sulphide, spent oxide (blue billy, cyanide, thiocyanates), asbestos						
On site Made ground Ground Gas (carbon dioxide, methane, hydrogen sulphide, carbon monoxide)	Migration into confined spaces, inhalation and asphyxiation/ explosion	End-users / property / structures	Low likelihood	Severe	Moderate	The site is underlain by significant thicknesses of made ground and this appears to be a source of carbon dioxide and carbon monoxide based on the monitoring undertaken. Made ground is generally considered to have a very low or low ground gas generation potential, as evidenced by the very low ground gas flow rates recorded on the site as a whole, which is considered to reduce the likelihood of accumulation of ground gases beneath the site. The ground gas monitoring data suggest the site should be classified as CS2 due to concentrations of carbon dioxide and carbon monoxide, and would also help address any potential residual risks from hydrocarbon or SVOC vapours remaining following remediation. Hydrock have also previously assessed the southern half of the site as falling within CS2 classification. The overall risk at this stage is therefore considered to be moderate. However, given the extensive earthworks and remediation which will be required, including removal of some made ground and removal or treatment of any free phase contamination, it would be prudent to carry out further monitoring and detailed assessment of the ground gas regime following completion of the earthworks, which may result in a re-evaluation of the risk.
On site Made Ground Vapours	Migration into confined spaces, inhalation and asphyxiation/ explosion	End-users /Property/Structures	Low Likelihood	Severe	Moderate	Given the previous uses of the site and evidence from previous investigations there are potential sources of VOCs. The 2022 Hydrock ground investigation on the southern portion of the site identified concentrations of VOCs above the GACs and vapour protection measures were recommended for the southern portion. During the recent site investigation focusing on the northern half of the site, PID monitoring during the site investigation did not encounter any significant widespread evidence of VOC contamination within soils, although evidence of SVOC contamination has been recorded within the far north-eastern area of the

Human Health						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
						site. Widespread elevated concentrations of naphthalene are present across the site which may also pose a risk to human health via vapour inhalation. The risk is considered to be moderate at this stage and remediation will be required, although given the extensive earthworks and remedial works which are required, further monitoring and assessment of the vapour risk may be considered post-earthworks to confirm the site conditions at that stage, including obtaining vapour phase samples, which may result in a re-evaluation of the risk.
On site Electrical Sub-station PCBs	Ingestion, direct contact, inhalation of vapours/dusts	End-users	Unlikely	Medium	Low	The mobility of this contaminant is low, and chemical testing of the made ground in close proximity to the substations has not detected the presence of PCBs on site. Previous investigations have also not encountered any evidence of PCB contamination. The overall risk is therefore assessed as low.
Off site Depot/Garages Heavy metals, petroleum hydrocarbons, PAHs, Asbestos, Ground Gas	Ingestion, direct contact, inhalation of vapours/dusts.	End-users	Likely	Medium	Moderate	WS04A (ENTEC, 2002) encountered shallow hydrocarbon contamination at the southeast edge of the site adjacent to the series of depots and garages extending from the southwest of the site. In 2022, adjacent Hydrock trial pit TP720 encountered perched groundwater containing a sheen and diesel odour at the base of the made ground. Based on the known potential sources identified within the preliminary CSM, BSL believe it is possible these observations relate to the off-site garages which are immediately adjacent to this area of the site and located atop a retaining wall. These off-site sources are still present and due to their proximity to the site, the risk from off-site garages has been assessed as moderate and remedial measures will be required.

Controlled Waters						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
General Made Ground Metals, petroleum hydrocarbons, PAHs	Overland flow, / migration through saturated zone	River Irk, 117m away (Surface waters)	Low likelihood	Medium	Moderate / Low	Areas of gross contamination are generally localised to the former gasometers and tanks in the northern areas, and significant gross contamination is largely absent across the southern portion of the site investigated by Hydrock in 2022. The redevelopment of the site will involve a significant period of earthworks, turnover of made ground alongside removal of any grossly contaminated soils, in addition to renewed hard surfacing and drainage systems. The potential for overland flow is significantly diminished given the site's setting, due to the presence of hard standing both on and off site and extensive drainage network, and the potential for lateral migration via either the unsaturated or saturated zone is reduced based on the distance between the site and the River Irk which would allow degradation of contaminants
	Leaching through unsaturated zone / Migration through saturated zone	Secondary (Undifferentiated) Aquifer (Groundwater)	Likely	Mild	Moderate / Low	As contamination has been observed within perched groundwater in the made ground, it is possible contaminants could leach through pockets of granular material into the secondary aquifer, although the glacial Till underlying the site is not considered to be a sensitive receptor due to its cohesive nature, inconsistent distribution and thickness on site, and absence of any groundwater abstractions from this stratum. The risk has been assessed as moderate/low.
	Migration through saturated zone	Principal Aquifer (Groundwater)	Low likelihood	Medium	Moderate / Low	Based on the Hydrock investigation in the southern portion of the site, the general made ground in this area is up to 4-5m in thickness and is underlain by glacial till comprising clays with only minor occurrences of granular soils. In the northern area of the site, the thickness of made ground outside of the former gasholders is relatively limited, and boreholes located outside of the gasholders have proven between 5.50m and 9.10m of superficial soils predominantly consisting of cohesive glacial Till. The significant thickness of glacial Till (outside of the gasholders) is likely to minimise migration of shallow groundwater and/or leachate from the general made ground towards the Principal Aquifer. The overall risk is considered to be moderate / low. A Piling Risk Assessment will be required should piles be used for the proposed development to assess the potential of creating pathways for contaminants.

Controlled Waters						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
Former Gas Works underground structures including gasometers and tanks PAHs, petroleum hydrocarbons, metals, chlorides, thiocyanate, ammonia), spent oxide	Overland flow, migration through saturated zone, migration via existing redundant drainage	River Irk, 117m away (Surface waters)	Low likelihood	Medium	Moderate / Low	The ground investigation has confirmed the presence of elevated concentrations of contaminants within the former gasholders and the bases of these structures vary between circa 6 and 10m bgl, with the majority between 8.0 and 8.5m bgl. There is evidence to indicate that contaminants are impacting the underlying Principal Aquifer, discussed further below, however visual and olfactory evidence of contamination made during the investigation indicates that gross contamination is generally present towards the base of the gasholders/tar tanks. Evidence suggests the sidewalls of the tanks remain intact in situ and are surrounded laterally by glacial Till comprising clays. These ground conditions are likely to promote vertical (downwards) migration rather than lateral, as evidenced by the absence of visual or olfactory evidence of contamination of the natural superficial soils, in particular those encountered outside of the footprints of the gasholders. The potential for overland flow is significantly diminished due to the site's setting given the presence of hard standing both on and off site and extensive drainage network, and the potential for lateral migration via either the unsaturated or saturated zone is reduced based on the distance between the site and the River Irk which would allow degradation of contaminants. The full extent and condition of the existing deep drainage is unknown within the site boundary and beyond, although it is likely the drainage network has largely collapsed based on the available survey information, which would@ limit potential for contaminant migration to an extent. A DQRA will be required in order to confirm the risk to the river.
	Leaching through unsaturated zone / Migration through saturated zone, migration via	Secondary (Undifferentiated) Aquifer (Groundwater)	Highly Likely	Mild	Moderate	Despite the previous partial remediation of the site which has been carried out to date, evidence of gross contamination and significantly elevated concentrations of contaminants have been identified associated with the former gasworks structures. However, the superficial deposits are predominantly cohesive and are not laterally continuous beneath the site, due to the presence of historical underground features. The net result is a very limited and non-sensitive groundwater body. Nevertheless, some localised sand bands are present which could represent migration pathways impacting other receptors, and there is

Controlled Waters						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
	redundant drainage					evidence that some sand layers may have been impacted by the former gasworks processes and further consideration is required. The overall risk is moderate.
	Migration through saturated zone, migration via redundant drainage	Principal Aquifer (Groundwater)	Highly Likely	Medium	High	The made ground within the gasholders has been demonstrated to contain in some cases significantly elevated concentrations of various organic and inorganic contaminants. Tar Tank No. 1 is known to contain circa 3-5m of free phase tar contamination present in the annulus at the base of the tank, which will require remediation. Whilst the gasholder/tar tank bases are mostly in situ, and the majority of gasholders/tar tanks are underlain by a limited thickness of clay, groundwater testing carried out across the site strongly suggests the Principal Aquifer has been impacted, based on the recorded concentrations of PAHs, metals, phenols, petroleum hydrocarbons, benzene, and inorganic compounds. Remediation will be required and it is recommended that a DQRA is completed in order to establishing site specific screening criteria which will form realistic and achievable remedial target values. Following the production of a DQRA, a Remedial Strategy will be required alongside a Piling Risk Assessment.

11.10 Outline Remedial Measures

As relevant contaminant linkages have been identified from the above assessment, they represent unacceptable risks to identified receptors. In order to determine the most suitable remediation techniques, a Remediation Options Appraisal should be undertaken, with due consideration to a sustainable approach to ensure the benefit of doing the remediation is greater than its impact utilsing SuRF-UK guidance.

In respect to controlled waters, a detailed quantitative risk assessment will be required in order to inform acceptable remedial target values and determine the scope of remediation required which will be presented within an options appraisal and detailed Remedial Strategy in due course. With respect to Tar Tank No. 1, when the Cadent PRS infrastructure has been removed, then further confirmatory investigation should be completed upon commencement of enabling works in order to confirm the nature of the ground conditions, presence depth and distribution of tar as expected, and profile of the structure, to confirm/refine the CSM, DQRA modelling parameters and detailed Remediation Strategy. Carrying such works out before the PRS infrastructure is removed and establishment of remediation plant/equipment on site would likely prove unpractical.

It is recommended that the approval of the Regulators (Local Authority / Environment Agency) and any warranty provider is obtained in regard to the above prior to any irrevocable action is taken at the site.

In addition to the options appraisal and remedial strategy, the writing and approval of a Materials Management Plan (MMP) or suitable exemptions/permits will be required to allow re-use of suitable material at the site.

Once remediation is complete, verification reports will need to be produced by a suitably qualified independent geo-environmental engineer, such as BSL, in order to achieve regulatory sign off.

11.11 Health and Safety Issues

During the reclamation and construction phases of the site development it will be necessary to protect the health and safety of site personnel. The risk to construction and ground workers is assessed in the table below:

Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk
Made Ground (heavy metals, PAHs, petroleum hydrocarbons, cyanide, ammonia)	Ingestion, direct contact, inhalation of dusts.	Construction Workers	Likely	Medium	Moderate
Asbestos	Ingestion, direct contact, inhalation of dusts.	Construction Workers	Likely	Medium	Moderate
Ground gas and vapours	Inhalation in confined spaces/trenches	Construction Workers	Low likelihood	Severe	Moderate

In addition to the above, the risks to nearby off site residents should also be considered from dusts and vapours generated during groundworks; perimeter monitoring and dust/odour suppression may be required.

The risk from asbestos should be highlighted in the method statements and site induction. If further evidence of asbestos is encountered in the soils, work should cease until asbestos control measures have been agreed and put in place. Asbestos is further discussed in Section 8.12 below.

The risk from made ground will be mitigated by standard PPE including gloves. Welfare facilities should be made available to wash before hand to mouth activities.

It is noted that concentrations of carbon dioxide (an asphyxiant) in the soil exceed HSE Workplace Exposure Limits for personnel in the working environment of 1.5% for short term (15 minutes) exposure and/or 0.5% for long term exposure. The risk assessment above considers the fact that the vast majority of construction works will take place in open air which will significantly reduce the possibility of gases accumulating to harmful concentrations.

Soil gas concentrations are not necessarily reflected by those in the breathing zone, all contractors and maintenance workers should be made aware of the possible presence of carbon dioxide and should take all necessary health and safety precautions when working in trenches or confined spaces.

General guidance on these matters is given in the Health and Safety Executive (HSE) document "Protection of Workers and the General Public during the Redevelopment of Contaminated Land". In summary, the following measures are suggested to provide a minimum level of protection:

- All ground workers should be issued with the relevant protective clothing, footwear and gloves. These protective items should not be removed from the site and personnel should be instructed as to why and how they are to be used.
- Hand-washing and boot-washing facilities should be provided.
- Care should be taken to minimise the potential for off-site migration of contamination by the provision of dust suppression control and wheel cleaning equipment during the construction works.
- Good practices relating to personal hygiene should be adopted on the site.
- The contractor shall satisfy the Health and Safety Executive with regard to any other matters concerning the health, safety and welfare of persons on the site.

11.12 Asbestos

The investigation of asbestos issues within structures was beyond the scope of this report. However, guidance from UK Government indicates that asbestos should be assumed to be present in buildings unless proven otherwise.

Any asbestos within structures will require removal prior to re-development. This will need to be done by a suitably qualified experienced and licensed contractor, who ensures that adequate PPE is provided to operatives, and that all the relevant legislation is adhered to.

In addition, the presence of asbestos within the ground will require, a safe system of work to be set up on site to deal with the asbestos risk from the made ground. This may include but be not limited to:

- The use of qualified personnel where required.
- Careful segregation of stockpiles on site.
- Defining transport routes.
- Cleaning down of machinery in designated areas.
- Decontamination unit for ground workers.
- Damping down of soils to prevent dust migration.

Asbestos has been identified in a total of fifteen samples at the site over the various investigations to date, all located within phases 1-3. The asbestos has generally been encountered as free fibres or fibrous debris; where quantified the concentrations in most samples are at trace levels which should be assumed across phases 1-3. No asbestos has been identified to date in Phase 4.

Concentrations have exceeded trace levels in three locations within phases 1 and 3 and all in the current upper level; TP704 (0.013%), TP816 (0.003%) and TP818 (0.014%). Suspected asbestos cement fragments and insulating board debris has been encountered in two locations in the upper level; HP1008 (AIB debris) and MPBH703A (cement).

At trace concentrations the liberation of fibres is considered to be unlikely and no specific precautionary measures with regards to asbestos are likely to be required at the site. The level of precautions required are at the discretion of the principal contactor on site however good site practices including minimising the generation of dusts should be adhered to and sufficient to mitigate against the risk from asbestos. In addition site personnel should have the risk communicated at the induction stage. For areas where asbestos is present at greater than trace concentrations, and/or where visible asbestos fragments are known or suspected, additional control measures will be required for any works within such areas, and should be detailed within an asbestos plan of works specific to the works area. It is recommended that the asbestos in construction materials assessment tool is used at the site to inform asbestos licensing and control measures.

Excavations in soils containing asbestos should comply with the CL:AIRE publication 'Interpretation for Managing and working with Asbestos in Soil and Construction and Demolition Materials' (CARSOIL) and CAR 2012. All such works will need to be agreed with the regulatory bodies (HSE and/or LA).

Additional guidance is provided within the BSL methodology Guidance Note in Appendix A.

12.0 WASTE SOIL CLASSIFICATION & ASSESSMENT

12.1 Summary

BSL have undertaken a preliminary assessment of potential excavation waste to arise from the site during redevelopment to:

- Classify the excavation waste to arise as either hazardous or non-hazardous.
- Identify the most sustainable options for the wastes to arise in accordance with the waste hierarchy.
- Provide a written description of the waste required as part of the Duty of Care.
- Provide details of "hazardous properties" to complete hazardous waste consignment note (where applicable).
- Be able to provide a basic classification report to a landfill operator (where waste is destined for landfill disposal).

It should be noted that testing requirements for contaminated land risk assessment differ to those for waste classification purposes. Unless otherwise stated, the assessment in this section has been carried out to provide initial indications in respect to disposal of waste soils, however this may not be fully compliant with waste testing requirements or frequencies, with further testing potentially required.

12.2 Soils Waste Classification Procedure

As described in the 'Waste Duty of Care Code of Practice (2016)' any substance or object that the holder discards, intends to discard or is required to discard is a waste. It is the responsibility of the waste producer to classify this waste. The classification process is described in the 'Guidance on the classification and assessment of waste' WM3 and aims to determine whether the waste is Hazardous or Non-Hazardous to human health and the environment.

Waste classification should be based on soils analyses that are representative of the actual waste load. At the stage of ground investigation, the materials that will become waste have generally not been defined yet, however test data can provide a useful guide to the likely waste classification before it is generated.

Further guidance is provided in Appendix A.

The Landfill Directive (Directive 1999/31/EC on the landfilling of waste, Decision 2003/33/EC and Landfill Regulations 2005) led to the establishment of a methodology for classifying wastes. Wastes first need to be classified based on their total concentrations and classified as either hazardous or non-hazardous waste. WAC testing is only required if the end disposal route is a landfill and WAC analysis must not be used for waste classification.

Wastes can only be accepted at a landfill if they meet the relevant Waste Acceptance Criteria (WAC) for that type of landfill. A waste must comply with the WAC limits for the relevant landfill, otherwise the soil will need to be pre-treated. There are three different WAC criteria, these are:

- Inert waste.
- Stable Non-Reactive Hazardous Waste (SNRHW).
- Hazardous waste.

Details of how material should be classified for waste disposal are presented in the BSL Methodology and Guidance in Appendix A and are summarised in the table below:

	PRIOR TO LEAVING SITE			
Classification based on Total Concentrations[1]	**Non-Hazardous Waste**		**Hazardous Waste**	
	IF SOILS CANNOT BE RE-USED ELSEWHERE AND MUST GO TO LANDFILL			
WAC testing	Below inert WAC limit values	Above inert WAC limit values	Below hazardous WAC limit values[4]	> WAC limit values
Landfill requirements	INERT landfill	NON-HAZARDOUS landfill[2]	HAZARDOUS landfill	PRE-TREATMENT[3]

1 Total concentrations are defined as tests results on solids as opposed to leachate (i.e. a liquid).
2 Individual sites may have certain limit values pre-determined in their licence.
3 After pre-treatment the material characteristics may have changed to an extent that allow the soil to be re-classified.
4 Possibility that wastes could be classified as stable Nonreactive HAZARDOUS waste in non-hazardous Landfill (e.g. soils containing low concentrations of asbestos, gypsum or sulphate bearing soils).

Inert Waste
The possibility of automatic inert classification of the naturally occurring "clean" soils should be explored in accordance with Section 4.3 of the EA guidance document. See Appendix A for further guidance.

12.3 Waste Classification and Waste Acceptance Criteria (WAC)

We have reviewed the testing results and assessed them through a waste classification database (HazwasteOnline™) which allows users to code and classify waste as defined in the EWC (European Waste Catalogue) based on EC Regulation 1272/2008 on the Classification, Labelling and Packaging of Substances and Mixtures (CLP) and latest Environment Agency guidance (WM3 "Guidance on the classification and assessment of waste -Technical Guidance").

The samples tested were screened against assessment criteria within WM3 using the HazWasteOnline tool to assess whether they contained any contaminants in the hazardous range.

The Waste Classification Report is presented in Appendix J. Locations of hazardous soils are presented in the table below.

Contaminative Feature	Location	Depth (m)	Stratum	Waste Classification	Hazardous Property	Contaminant
Gas Holder 1	BH815	1.80 – 2.20	Made Ground	Hazardous	HP 3(i), HP 7, HP 11	Petroleum Hydrocarbons (C6-C40)
Gas Holder 2	BH813	7.00 – 7.60	Made Ground	Hazardous	HP 3(i), HP 7, HP 11	Petroleum Hydrocarbons (C6-C40) and BTEX
Between holders 2 and 3	TP803	0.60 – 1.00	Made Ground	Hazardous	HP 3(i), HP 7, HP 11	Petroleum Hydrocarbons (C6-C40)
Gas Holder 3	TP809	0.50 – 0.70	Made Ground	Hazardous	HP 3(i), HP 7, HP 11	Petroleum Hydrocarbons (C6-C40)
Gas Holder 5	TP804	1.40 – 1.80	Made Ground	Hazardous	HP 14	Zinc, cyanide
Gas Holder 5	WS815	1.30 – 1.50	Made Ground	Hazardous	HP 3(i), HP 7, HP 11	Petroleum Hydrocarbons (C6-C40) and BTEX
Ammonia Plant Area	BH806A	4.50 – 4.80	Made Ground	Hazardous	HP 3(i), HP 7, HP 10, HP 11, HP 14	PAHs, Petroleum Hydrocarbons (C6-C40) and BTEX
Ammonia Plant Area	BH803	4.50 – 5.00	Made Ground	Hazardous	HP 3(i), HP 7, HP 11	Petroleum Hydrocarbons (C6-C40)

Contaminative Feature	Location	Depth (m)	Stratum	Waste Classification	Hazardous Property	Contaminant
Between Tar Tank 2 and Gas Holder 5	WS817	1.60 – 1.90	Made Ground	Hazardous	HP 3(i), HP 7, HP 11	Petroleum Hydrocarbons (C6-C40) and BTEX

Based on the waste classification assessment, the made ground present within contaminative historical features (as identified on BSL drawing ref. C5692/05), and any grossly contaminated soils encountered during groundworks, should be considered **hazardous** for waste disposal purposes. Due to the limited testing undertaken within Tar Tank No. 1, soils from this location should be assumed as hazardous at this stage until confirmatory investigation, testing and waste classification can be completed on these soils.

In addition, Hydock have previously undertaken preliminary testing of PAH concentrations on buried bituminous hardstanding present within TP704 and TP722 on the southern part of the site. Laboratory chemical testing confirmed concentrations of benzo(a)pyrene above 50mg/kg, at 200mg/kg in TP704 and 600mg/kg in TP722, a key indicator of the presence of coal tar (as defined in the guidance note produced by the Association of Directors of Environment, Economy Planning and Transport (ADEPT) entitled "Managing Reclaimed Asphalt – Highways and Pavements", version 2016-1. Asphalt waste containing coal tar is considered to be hazardous waste where the level of coal tar is >0.1%.

Based on the waste classification database assessment, the general made ground soils outside of the gas holders have been classified as **non-hazardous**. The general made ground within Phases 1 and 2 were classified as non-hazardous during the previous reporting undertaken by Hydrock.

Note that further testing of the soils (WAC testing) may be required on the actual arisings in order to satisfactorily categorise the soil for its suitability for disposal to landfill; soils within the gas holders may require pre-treatment prior to disposal.

Waste Containing Asbestos

Should soils contain asbestos, the concentration and type of asbestos identified, in addition to the chemical composition (i.e. hazardous or non-hazardous detailed above), will determine which waste code is applicable to the soils and which landfill will accept it as summarised below:

Waste	Conc. by Weight (%)	EWC 2002 Catalogue Entry Code	Waste Disposal Route
Non-hazardous containing asbestos fibres	<0.001 - <0.1%	17 05 04 (soil and stones other than those mentioned in 17 05 03*)	Non-hazardous landfill subject to achieving Waste Acceptance Criteria (WAC) for a stable non-reactive hazardous landfill site.
Hazardous containing asbestos fibres	<0.001 - <0.1%	17 05 03* (soil and stones containing dangerous substances)	Hazardous landfill subject to achieving Waste Acceptance Criteria (WAC) for a hazardous landfill site.
Non-hazardous soils containing asbestos fibres	>0.1%	17 05 03* (soil and stones containing dangerous substances)	Hazardous landfill authorised to receive asbestos, or in a stable non-reactive hazardous waste cell at a non-hazardous landfill authorised to receive asbestos.
Non-hazardous Soils containing ACM (Mechanically separable)	>0.1%	17 06 05 (construction material containing asbestos) 17 05 04 (soil and stones other than those mentioned in 17 05 03*)	ACMs disposed of at a hazardous landfill authorised to receive asbestos, or in a stable non-reactive hazardous waste cell at a non-hazardous landfill authorised to receive asbestos. Soils should be disposed of at a non-hazardous landfill subject to achieving Waste Acceptance Criteria (WAC) for a stable non-reactive hazardous landfill site.

Waste	Conc. by Weight (%)	EWC 2002 Catalogue Entry Code	Waste Disposal Route
Hazardous soils containing ACM	>0.1%	17 05 03* (soil and stones containing dangerous substances)	Hazardous landfill subject to achieving Waste Acceptance Criteria (WAC) for a hazardous landfill site.

A summary of locations where asbestos was identified by BSL is presented in the table below:

Location	Depth (m)	ACM	Conc. by Weight (%)	Waste Disposal Route
WYG 2015				
HP1002	0.40	Free fibres (chrysotile)	Not Quantified	Unknown
HP1004	0.20	Free fibres (amosite)	Not Quantified	Unknown
HP1005	0.35	Free fibres (chrysotile)	Not Quantified	Unknown
HP1008	0.45	Asbestos Insulating Board Debris (amosite & chrysotile)	Not Quantified	Hazardous
Hydrock 2021				
MPBH703A	0.20-0.40	Suspected Asbestos Cement (60x80mm, 20x30mm and 10x15mm)	Not Quantified	Hazardous
MPBH703A	0.20-0.40	Chrysotile	<0.001	Non-hazardous
TP704	0.90-1.10	Loose fibrous debris (chrysotile)	0.013	Non-hazardous
TP711	0.65	Loose fibres (amosite)	<0.001	Non-hazardous
TP715	0.75	Loose fibres (chrysotile)	<0.001	Non-hazardous
WS701	0.50	Loose fibres (chrysotile)	<0.001	Non-hazardous
WS704	0.90	Loose fibres (amosite)	<0.001	Non-hazardous
BSL 2024				
TP818	0.10 – 0.50	Loose Fibres (amosite and chrysotile)	0.014	Non-hazardous
TP816	0.10 – 0.50	Loose Fibres (amosite and chrysotile)	0.003	Non-hazardous
WS815	1.30 – 1.50	Loose Fibres (amosite)	<0.001	Hazardous (due to other contaminants)
WS816	3.50 – 4.00	Loose Fibres (amosite)	<0.001	Non-hazardous

A watching brief should be maintained for evidence of Asbestos Containing Materials (ACMs), any ACMs observed should be handpicked and disposed of in accordance with current asbestos disposal regulations.

General
Following the classification of waste materials, the options available for the waste can be considered in the context of the waste hierarchy as below:

- Onsite re-use (with or without prior treatment) under suitable exceptions/permits.
- Offsite processing for recycling or recovery e.g. screening.
- Offsite disposal (with or without prior treatment) i.e. landfill.

Where feasible, efforts should be made to retain soils for onsite re-use to minimise costs and maximise the sustainability of projects.

If any gross hydrocarbon contaminated material is encountered during the construction phase, it is possible that this may be classified as hazardous and testing should be undertaken at that time.

Where it is necessary to dispose material off site it is recommended that materials are segregated and sufficient time is allowed to further classify the actual soil arisings that constitute the waste, including discussion with landfill sites and waste transfer stations to find the best disposal route. It is illegal to dilute and mix soils without a suitable permit.

Where possible, the option that the soils could be recycled at a suitable local waste treatment plant or transfer station rather than a landfill disposal route should be explored.

12.4 Re-use of Soils

By definition in law, any material excavated from the ground becomes waste at the moment of excavation. If that soil (now a "waste") is then placed on another part of the development site (or used on another development site) without an appropriate materials management plan, permit or exemption being in place, by law this material is defined as "illegally deposited waste".

In order to comply with UK legislation and avoid excessive costs, if the re-use of soils is proposed on site, this should be done in accordance with the relevant exemptions or permits in place.

Soils Re-use Under DoWCoP
One of the main industry mechanisms for allowing the re-use of soils in construction is the CL:AIRE "Development Industry Code of Practice for the Definition of Waste" (CL:AIRE DoWCoP) also known as a Materials Management Plan (MMP). Further guidance is provided in the BSL Methodology and Guidance in Appendix A.

In order to re-use soils under the DoWCoP, there are four key criteria that need to be met:

- The aims and objectives of the project meet the requirements of the Waste Framework Directive (does not harm human health or the environment).
- The soils can be demonstrated to be suitable for use (backed up by chemical/geotechnical testing and assessment).
- There is certainty of use (planning consents are in place alongside materials tracking, which should be in place as part of good site practice in any case).
- Quantity (the quantity of materials used should be known).

Information on existing site levels, proposed levels, volumes generated (e.g. foundation / drainage excavation arisings) would need to be known in order to complete the MMP.

If the DoWCoP is the chosen route, the MMP should be in place and declared by a Qualified Persons (QP) before works commence, otherwise excavated soils could constitute an illegal deposit of waste and enforcement action could be taken by the EA and HMRC.

Once the project is complete, a verification report detailing soils re-use/import will need to be produced and submitted to CL:AIRE, which may be subject to a random audit process. Sites found to be non-complaint with the CoP can be referred to the EA for further investigation.

Note that for re-use of landfilled materials or mining wastes, the DoWCoP may not apply and a Waste Recovery Permit (or others) may be required. Liaison with the Environment Agency would be needed on a case by case basis to determine the best option.

Re-use of soils containing asbestos should comply with the CL:AIRE publication 'Interpretation for Managing and working with Asbestos in Soil and Construction and Demolition Materials' (CAR-SOIL™) and CAR 2012.

In terms of the re-use of brick/concrete crush materials, the DoWCoP does cover aggregates, but only on the site of origin, and the EA WRAP aggregate Quality Protocol might best apply to ensure quality standards, which are discussed further below.

Soils Re-use under Exemptions and Permits

Other potentially suitable re-use mechanisms may include U1 Exemptions, WRAP quality protocols (for aggregates) or Waste Framework Directive (WFD) Exclusions, amongst other mechanisms. Further details are provided in Appendix A.

13.0 CONCLUSIONS

13.1 Geo-Environmental

Geo-Environmental – Human Health – Soils
Based on the testing and assessment undertaken there is pervasive contamination within the made ground across the site, predominantly in the form of metals and PAHs attributed to ash within the made ground strata. In addition, petroleum hydrocarbons, benzene, SVOCs, cyanide and phenols are present more locally within the made ground, although areas of gross contamination have been encountered, predominantly associated with the former gas holders and tar tanks which remain as infilled historical below ground structures.

Asbestos fibres have been detected at trace levels in numerous samples across phases 1-3 and trace concentrations should be assumed across these areas of the site. Concentrations of asbestos has been found to exceed trace concentrations in three locations within Development Phases 1 and 3. Suspected visible ACMs have been encountered during the previous investigations at two locations to date.

The above are considered to pose a risk to human health and remedial measures are required. A substantial period of enabling works and earthworks will be required in order to achieve the desired finished site levels. Detailed requirements to be determined following completion of a DQRA, remedial options appraisal and design of a detailed remedial strategy.

Geo-Environmental – Ground Gases and Vapours
Ground gas monitoring results indicate the made ground is a source of carbon dioxide and carbon monoxide and is considered to pose a risk to human health. With respect to vapours, PID monitoring during the site investigation and monitoring did not encounter any significant widespread evidence of VOC contamination within soils, although evidence of SVOC contamination has been recorded within the far north-eastern area of the site. Widespread elevated concentrations of naphthalene are present across the site which may also pose a risk to human health via vapour inhalation.

Based on the completed gas monitoring the site is classified as Characteristic Situation 2 and ground gas protection measures are required and should also incorporate a membrane impervious to VOCs, subject to post earthworks monitoring and assessments to confirm design requirements.

Geo-Environmental – Controlled Waters
The results of groundwater testing indicate the Principal Aquifer underlying the site is impacted by various contaminants including metals, cyanide and other inorganic compounds, PAHs, phenols, petroleum hydrocarbons, benzene and xylene. The concentrations of contaminants also appear to be greater in general within installations located in the western part of the site, at this stage suggesting that groundwater quality is of lower quality down-gradient of the site compared to up-gradient.

Whilst the deeper groundwater representative of the Principal Aquifer has been impacted, the testing and assessment completed suggest that groundwater quality in the Principal Aquifer generally shows improvement when compared against contaminant concentrations in the samples of shallow perched groundwater within the made ground. This is likely due to the current ground conditions comprising hard standing at surface, brick/concrete bases to the gasholders and underlying superficial clay deposits, which are considered likely to be restricting contaminant migration to a degree across the site as a whole.

However, in summary, based on the initial semi-quantitative assessments completed, there is considered to be a viable source-pathway-receptor linkage between the deep made ground and the Principal Aquifer, and the overall risk to controlled waters is considered to be moderate to high at this stage. Further detailed assessment will be required in the form of a detailed quantitative risk assessment (DQRA).

Waste
Based on the waste classification assessment, the made ground present within contaminative historical features (as identified on BSL drawing ref. C5692/05), and any grossly contaminated soils encountered during groundworks, should be considered **hazardous** for waste disposal purposes. Due to the limited testing undertaken within Tar Tank No. 1, soils from this location should be assumed as hazardous at this stage until confirmatory investigation, testing and waste classification can be completed on these soils.

Based on the waste classification database assessment, the general made ground soils outside of the gas holders have been classified as **non-hazardous**. The general made ground within Phases 1 and 2 were classified as non-hazardous during the previous reporting undertaken by Hydrock.

13.2 Geotechnical

Foundations
Based on the proposed development and encountered ground conditions, piled foundations are considered the most suitable foundation option socketed into the competent sandstone bedrock.

As a preliminary guide, allowable axial loads for a circular pile range between 1.3MN for a 600mm diameter pile with 1.0m embedment up to 8.8MN for a 900mm diameter pile with 9.0m embedment.

Floor slabs
Basement floor slabs and suspended floor slabs should be supported by piles.

Concrete classification
The results of laboratory pH and sulphate content, alongside the BRE full suite tests, indicate that sulphate class DS-4 and ACED Class AC-4 conditions prevail in the made ground strata in accordance with BRE Special Digest 1 “Concrete in aggressive ground” 2005, and DS-1 and ACEC Class AC-1 prevail in both the natural superficial strata and the solid geology of the Chester Formation.

Highways
A site wide programme of earthworks will alter the properties of the existing made ground and providing these soils are placed to a suitable specification, CBR values in the range of 3- 5% would likely be achieved in granular fill and 2% for cohesive fill.

To aid design proposals during construction of haul roads etc, based on Table 5.1 from DMRB IAN 73/06 Rev 1 equilibrium CBR values of 5% are likely to be achieved in undisturbed natural granular soils where they are encountered and 2% for made ground and natural clays soils for pavement design purposes, unless proven otherwise by in-situ testing at formation level by a specialist geotechnical engineer.

Drainage (SuDS)
Falling head tests were carried out in five locations with the made ground, superficial cohesive strata and sandstone bedrock, with Hydraulic Conductivity results in the range of 10^{-3} m/s to 10^{-6} m/s being calculated.

However, the use of sustainable drainage systems, such as traditional soakaways within the natural ground, is not likely to be feasible over large areas of the site due to the presence of low permeability cohesive strata underlying the site, alongside the presence of variable and potentially contaminated made ground near the surface and extending to depths in excess of 10.00m bgl.

Slopes & Retaining Structures
A large retaining wall approximately 6m high of concrete and brick construction is present onsite bisecting approximately the centre, running west to east across the entire width of the site, with two ramp features to provide access between the upper and lower levels. It was outside the scope of this investigation to

undertake a detailed inspection of the construction or a structural inspection of the walls. BSL recommends inspection of the walls by a structural engineer to assess their condition and determine what, if any, specialist requirements there are in respect to demolition and removal. Inadequate demolition may result in the instability of soils behind the wall, potentially resulting in dangerous collapse.

Earthworks
Given the variability of existing site levels and development layout requirements, earthworks will be required in order to achieve the desired development platform levels.

Design of the earthworks, particularly in the north and north-western part of the site, should consider the stability of any cut or fill slopes. Any fill should be placed in accordance with an appropriate specification, discussed further below. Designs should allow for incorporation of suitable drainage to prevent the build-up of pore water pressure which could lead to slope instability.

An initial assessment reveals spoil resulting from excavations within the superficial deposits should generally be suitable for re-use as general fill subject to further testing and specification or may be disposed off site.

13.3 Further Work

The following further work is considered necessary to progress the site to construction phase:

- Undertake Detailed Quantitative Risk Assessment for controlled waters.
- Remediation Options Appraisal, Design of Remedial Strategy and confirmation with the Local Authority /EA / warranty provider.
- Production of Earthworks Specification.
- Production of Materials Management Plan (MMP) under the CL:AIRE DoWCoP, if required.
- Confirmatory testing and supervision of excavations in Tar Tank No. 1 on commencement of enabling works.
- Undertake confirmatory ground gas / vapour monitoring post-earthworks, if required.
- Production of Ground Gas Protection Measures Verification Plan, if required.
- Implementation of the Remedial Strategy and verification of the remedial works.

14.0 ABBREVIATIONS AND DEFINITIONS

GLOSSARY	
Term / Abbreviation	**Definition**
AST	Above Ground Storage Tank.
B(a)P	Benzo (a) Pyrene.
BGS	British Geological Survey.
BRE	Building Research Establishment.
BS	British Standard.
BSL	Brownfield Solutions Ltd.
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes.
CBR	California Bearing Ratio (used in pavement/highways design).
CAR 2012	Control of Asbestos Regulations (2012).
CBCB	Cheshire Brine Compensation Board.
CBCD	Cheshire Brine Compensation District.
CBR	California Bearing Ratio.
CIEH	Chartered Institute of Environmental Health.
CIRIA	Construction Industry Research Association.
CL:AIRE	Contaminated Land: Applications in Real Environments.
CLEA	Contaminated Land Exposure Assessment.
CLO	Contaminated Land Officer.
COMAH	Control of Major Accident Hazards.
Contamination	Presence of a substance which is in, on or under land, and which has the potential to cause significant harm or to cause significant pollution of controlled water. There is no assumption in this definition that harm results from the presence of the contamination. Naturally enhanced concentrations of harmful substances can fall within this definition of contamination. Contamination may relate to soils, surface water, groundwater or ground gas.
Controlled Waters	Inland freshwater (any lake, pond or watercourse above the freshwater limit), water contained in underground strata and any coastal water between the limit of highest tide or the freshwater line to the three-mile limit of territorial waters.
CPT	Cone Penetration Test.
CSM	Conceptual Site Model. A schematic hypothesis of the nature and sources of contamination, potential migration pathways (including description of the ground and groundwater) and potential receptors, developed on the basis of the information from the preliminary investigation and refined during subsequent phases of investigation and which is an essential part of the risk assessment process. The conceptual site model is initially derived from the information obtained by the preliminary investigation (i.e. the Phase I Desk Study). This conceptual model is used to focus subsequent investigations, where these are considered to be necessary, in order to meet the objectives of the investigations and the risk assessment. The results of intrusive investigations can provide additional data that can be used to further refine the conceptual site model.
DCP	Dynamic Cone Penetrometer.
DNAPL	Dense Non-Aqueous Phase Liquid.
DoWCoP	Definition of Waste Code of Practice.
DWS	Drinking Water Standard.
EA	Environment Agency.
EHO	Environmental health Officer.
EQS	Environmental Quality Standard.

GLOSSARY	
Term / Abbreviation	**Definition**
GAC	Generic Assessment Criteria.
GDR	Geotechnical Design Report.
GFR	Geotechnical Feedback Report.
GIR	Ground Investigation Report.
GSV	Gas Screening Value.
Harm	Adverse effect on the health of living organisms, or other interference with ecological systems of which they form part, and, in the case of human health, including property/structures and water supply pipelines.
Hazard	Inherently dangerous quality of a substance, procedure or event.
HDPE	High Density Polyethylene.
HSV	Hand Shear Vane.
K	Modulus of Subgrade Reaction.
LCRM	Land Contamination: Risk Management (EA guidance).
LNAPL	Light Non-Aqueous Phase Liquid (petrol, diesel, kerosene).
LOD	Limit of Detection (for particular method adopted).
MMP	Materials Management Plan.
Mv	Modulus of Volume of Compressibility.
ND	Not Detected.
NHBC	National House Building Council.
NR	Not Recorded.
OS	Ordnance Survey.
PAH	Polycyclic Aromatic Hydrocarbon.
Pathway	Mechanism or route by which a contaminant comes into contact with, or otherwise affects, a receptor.
PCB	Poly-Chlorinated Biphenyl.
PCSM	Preliminary Conceptual Site Model.
pH	Scale used to specify how acidic or basic a water-based solution is.
PHC	Petroleum Hydrocarbons.
PID	Photo Ionisation Detector.
PNEC	Predicted No-Effect Concentration.
Precision	Level of agreement within a series of measurements of a parameter.
PSD	Particle Size Distribution.
PVC	Polyvinyl Chloride.
Receptor	Human health, living organisms, ecological systems, controlled waters (surface waters and groundwater within aquifers), atmosphere, structures and utilities that could potentially be adversely affected by contaminant(s).
Risk	Probability of the occurrence, magnitude and consequences of an unwanted adverse effect on a receptor.
Risk Assessment	Process of establishing, to the extent possible, the existence, nature and significance of risk.
Sampling	Methods and techniques used to obtain a representative sample of the material under investigation.
SOM	Soil Organic Matter.
Source	Location from which contamination is, or was, derived. This could possibly be the location of the highest soil, groundwater or gas concentration of the contaminant(s).
SPT	Standard Penetration Test.
SVOCs	Semi Volatile Organic Compounds.
TOC	Total Organic Carbon.

GLOSSARY	
Term / Abbreviation	**Definition**
TPH CWG	Total Petroleum Hydrocarbon (Criteria Working Group).
TVOCs	Total volatile organic compounds.
UCS	Unconfined Compressive Strength.
Uncertainty	Parameter, associated with the result of a measurement that characterises the dispersion of the values that could reasonably be attributed to the measurement.
UST	Underground Storage Tank.
UXO	Unexploded Ordnance.
VCCs	Vibro Concrete Columns.
VSCs	Vibro Stone Columns
VOCs	Volatile Organic Compounds.
WAC	Waste Assessment Criteria.
WFD (in waste context)	Waste Framework Directive.
WFD (in water context)	Water Framework Directive.
Units	**Definition**
°	Degrees
Φ	Phi angle (in degrees)
g/l	Grams per Litre
Km	Kilometres
kPa	Kilo Pascal (Equivalent to kN/m^2)
$KN/m^2/mm$	Kilo Newton per metered squared per millimeter
kN/m^2	Kilo Newtons per metre squared
kPa	Kilo Pascal (Equivalent to kN/m^2)
l/hr	Litres per hour
MJ/kg	Mega joule per kilogram
MN	Mega Newton
M^2/MN	Mega Newton per metre squared
M	Metres
m bgl	Metres Below Ground Level
m OD	Metres Ordnance Datum (sea level)
µg/l	Micrograms per Litre (parts per billion)
µm	Micrometre
mb	Millibars (atmospheric pressure)
mg/kg	Milligrams per kilogram (parts per million)
mg/m^3	Milligram per metre cubed
mm	Millimetre
ppb	Parts Per Billion
Ppm	Parts Per Million

15.0 REFERENCES

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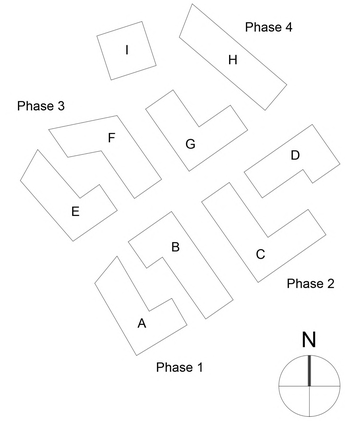
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DRAWINGS





Key To Spaces
1 - The Lanes and Square
2 - The Park
3 - The Slinky
4 - Southside
5 - Gould Street
6 - Bilbrook Street
7 - Resident's Courtyard
8 - Semi Public resident's courtyard
9 - National Grid Area

Rev	Description	Date	Dr by	App by
2	Planning issue	31.08.20	AW	DB
1	Pre-Planning Issue	07.08.20	AW	DB

original by	date created	approved by
AW	06/22/20	DB

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client name
Southvalley Estates Ltd

project
The Gasworks New Town - Site

drawing
Level 0 - Site plan

computer file
C:\Revit Projects\Gould Street Amended Site Plan_feshlim.white.rvt

plot date

project number	scale	
2015.00541.000	1 : 500	@A1
drawing number	rev	issue status
GDS-AHR-SO-00-DR-A-PL-003	2	S0

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original by		date created		approved by
FW		25.05.21		DB

Choose Office

Address

client
Southvalley Estates Ltd

project
The Gasworks New Town - Site

drawing
Phasing Plan
Phase 1

project number		scale
2015.00541.000		N.T.S @A3
drawing number	rev	issue status
GDS-AHR-SO-XX-DR-A-PL-101	-	S0

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The Gasworks New Town - Site

drawing
Phasing Plan
Phase 2

project number	scale	
2015.00541.000	N.T.S @A3	
drawing number	rev	issue status
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The Gasworks New Town - Site

drawing
Phasing Plan
Phase 3

project number	scale	
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drawing number	rev	issue status
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original by		date created		approved by
FW		25.05.21		DB

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project
The Gasworks New Town - Site

drawing
Phasing Plan
Phase 4

project number	scale	
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drawing number	rev	issue status
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5. The dimensions of all materials must be checked on site before being laid out.
6. This drawing must be read with the relevant specification clauses and detail drawings.
7. Order of construction and setting out to be agreed on site.

BOUNDARY KEY

- **Site Boundary**

PAVING KEY

- P1 **Yorkstone Flag Paving** — To footpaths and adopted areas. Size/colour/finish: To MCC standard detail.
- P2 **Large Format Granite Paving** — To the Lane and Williamson Street / Park edge. Colour: Grey / mix to complement architectural material palette (subject to further detailed design)
- P3 **Clay Paving** — To pedestrian areas throughout the site. Size: small format units. Colour: Various to complement architectural material palette
- P4 **Resin Bound Gravel** — To courtyard spaces. Size/colour: Buff colour
- P5 **50/50 Permeable Paving** — To the Lane. Size/colour: Paving infill units to match adjacent Clay Paving
- P6 **Self bound Gravel** — To play areas along central street. Size/colour: Buff colour
- P7 **Timber Deck Surfacing** — To private curtilages
- P8 **Natural stone stepping stones** — To paths through planting. Size/colour: TBC
- P9 **Natural stone steps** — To have hazard warning paving to top and bottom of steps. Colour: Grey
- P10 **Exposed Aggregate Concrete Surfacing** — To vehicle access routes off Gould St / Bilbrook St
- P10 **Tarmacadam Surfacing** — To vehicle access routes adjacent to gas compounds

FURNITURE AND STRUCTURES KEY

- F1 **Bicycle Stands** — Rivet-fixed, 1m spacings
- F2 **Telescopic Bollards** — Automated system with CCTV
- F3 **Feature Seating Elements** — To the Lane and Viaduct Green. Timber tops with Corten Steel frame
- F4 **Feature Seating Elements** — To Courtyards. Timber tops with Corten Steel frame
- F5 **Seating Edge** — To Courtyards. Timber tops to edge of planting areas
- F6 **Seating Edge** — To Public Realm generally. Natural Stone with timber tops
- F7 **Informal Play Features** — To the Lane, Slinky and Courtyards. Play boulders and other informal play features
- F8 **Green Structure** — To the Lane. Steel frame referencing gasometers with planting
- F9 **Original Pediment from Gas Works Office** — To corner of Green at Gould St. Reclaimed from site, use subject to assessment of condition
- F10 **Perforated Corten Balustrade** — To the Lane at Bilbrook St. Opportunity for graphic artwork incorporation
- F11 **Metal Gate to access ramp** — To the Phase 3 car park access. To have access control for residents and National Grid

Revision	Date	Description	Drawn	Apprvd.
S2-P09	06-05-21	Material update, gate added to P2 ramp	TF	MS
S2-P08	29-10-20	Planning Issue	TF	MS
S2-P07	24-09-20	Planning Issue	TF	MS
S2-P06	18-09-20	Planning Issue	TF	MS
S2-P05	11-09-20	Planning Issue	TF	MS
S3-P04	04-09-20	Draft Planning Issue	TF	MS
S3-P03	08-07-20	Design Development	TF	MS
S3-P02	09-06-20	Design Development	TF	MS

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Client MCR Property Group

Project The Gasworks, New Town

Drg Title Hardworks

Created on	Created by	Approved by
04.05.20	MS	KR

Scale	Size	Workstage
1:500	A1	Stage 2

Drg No. 2277-PLA-XX-XX-DR-L-1000

Suitability S2

Revision P09

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BROMLEY STREET
PARLANE STREET
WILLIAMSON STREET
399300N
399200N
384600
384700
384800
SL
SL
SL
BM 37.66m
37.2m
39.6m
33.9m
45.4m
24b
79
El Sub Sta
MEB COMPOUND
TIC
KB
RW
GSV
Works
BILBROOK STREET
BURSTOCK STREET
PEARY STREET
Works
MANH
MANH
MANH



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1. Do not scale from this drawing.
2. Always work to noted dimensions.
3. All dimensions are in millimetres unless otherwise stated.
4. All setting out, levels and dimensions to be agreed on site.
5. The dimensions of all materials must be checked on site before being laid out.
6. This drawing must be read with the relevant specification clauses and detail drawings.
7. Order of construction and setting out to be agreed on site.

Revision	Date	Description	Drawn	Apprvd.
S2-P08	18-09-20	Planning Issue	TF	MS
S2-P07	11-09-20	Planning Issue	TF	MS
S3-P06	04-09-20	Draft Planning Issue	TF	MS
S3-P05	18-08-20	Minor amendments to Bilbrook St interface with the Lane	MS	KR
S3-P04	22-06-20	Minor amendments to accommodate tracking to Gas PRS and compound	MS	KR
S3-P03	15-06-20	Alternative levels to park and interface with Williamson St	MS	KR
S3-P02	12-06-20	Levels amended in line with updated building FFLs / internal layouts	MS	KR
S3-P01	09-06-20	Levels amended in line with updated building FFLs	TF	MS

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Client MCR Property Group

Project The Gasworks, New Town

Drg Title Proposed Levels (Strategic)

Created on	Created by	Approved by
04.05.20	MS	KR

Scale	Size	Workstage
1:500	A1	Stage 2

Drg No. 2277-PLA-XX-XX-DR-L-3000

Suitability S2

Revision P08

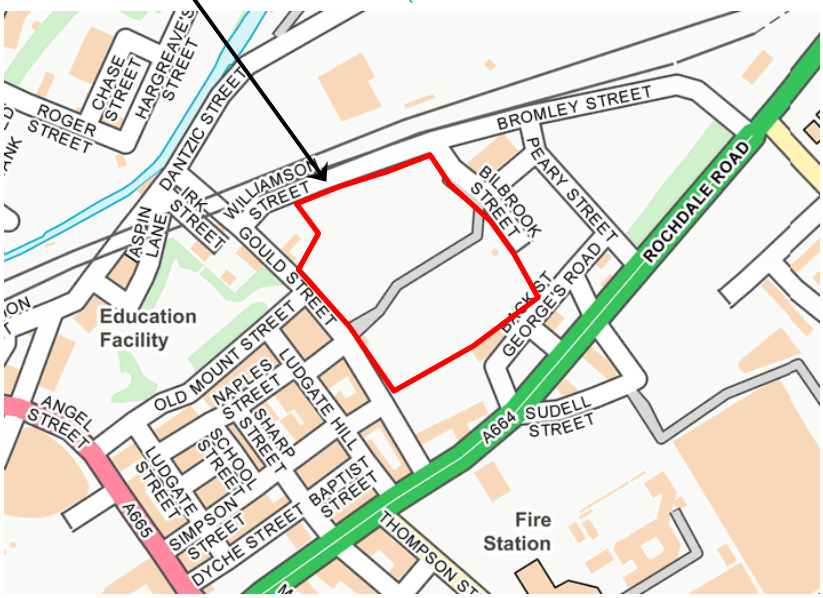
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SITE LOCATION

NEAREST POSTCODE: M4 4HY

SITE ENTRANCE WHAT3WORDS: ///CARE.BANANA.PILE



REV	DATE	DESCRIPTION	BY	CKD

BROWNFIELD SOLUTIONS LTD
GEO-ENVIRONMENTAL ENGINEERING EXCELLENCE

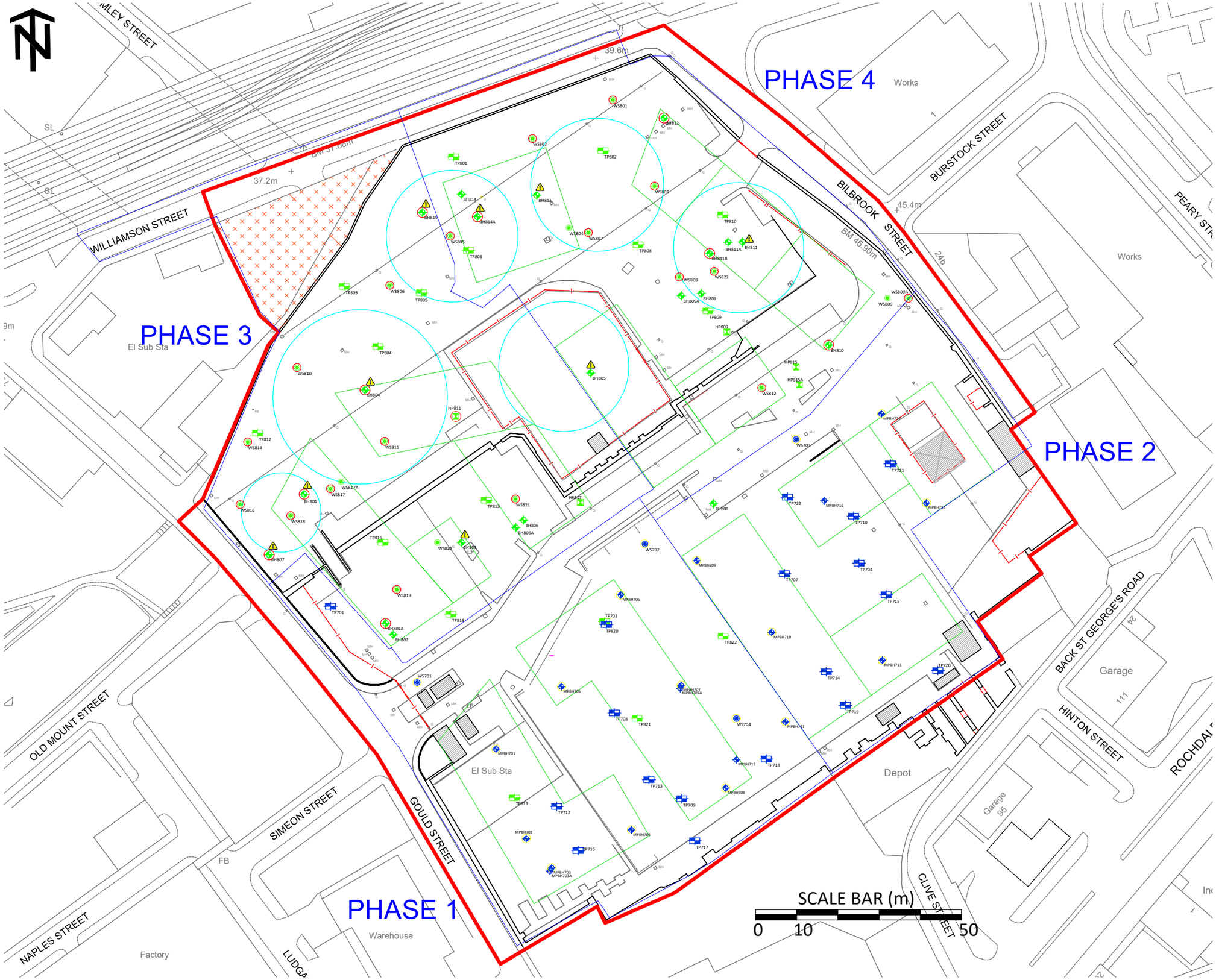
CLIENT
INTRO DEVELOPMENTS / MCR PROPERTY GROUP

PROJECT TITLE
GOULD STREET, MANCHESTER

DRAWING TITLE
SITE LOCATION PLAN

DRAWING No.	REVISION	SCALE	DATE
C5692/01	-	NTS	06/06/24

DRAWN BY	CHECKED BY
SD	AJS



KEY	
	APPROXIMATE SITE BOUNDARY
HP8XX / TP8XX	TRIAL PIT
WS8XX	WINDOW SAMPLE BOREHOLE
BH8XX	CABLE PERCUSSIVE BOREHOLE W/ ROTARY CORE FOLLOW ON
	BOREHOLE INSTALLATION

FEATURES	
	PROPOSED PHASE BOUNDARY
	PROPOSED STRUCTURE
	FORMER GAS HOLDERS & TAR TANKS
	CLEAN DRILLING TECHNIQUES UNDERTAKEN
	LAND INACCESSIBLE DUE TO DENSE VEGETATION & DANGER OF DEATH - HIGH VOLTAGE SIGNAGE

HYDROCK (2021)	
TP7XX	TRIAL PIT
WS7XX	WINDOW SAMPLE BOREHOLE
MPBH7XX	ROTARY CORED BOREHOLE
	BOREHOLE INSTALLATION

NOTES

1. ALL DIMENSIONS TO BE CHECKED ON SITE BEFORE COMMENCING WORKS. ANY DISCREPANCIES ARE TO BE REPORTED TO THE ARCHITECT & ENGINEER FOR VERIFICATION. FIGURED DIMENSIONS ONLY ARE TO BE TAKEN FROM THIS DRAWING.
2. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ENGINEERS REPORTS. THIS DRAWING IS COPYRIGHT OF BSL.
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REV	DATE	DESCRIPTION	BY	CKD

BROWNFIELD SOLUTIONS LTD

CLIENT
INTRO DEVELOPMENTS / MCR PROPERTY GROUP

PROJECT TITLE
GOULD STREET, MANCHESTER

DRAWING TITLE
POST-REMEDIATION EXPLORATORY HOLE LOCATION PLAN

DRAWING No.	REVISION	SCALE	DATE
C5692/02	-	NTS	30/09/24

DRAWN BY	CHECKED BY
PH	NS



KEY

	APPROXIMATE SITE BOUNDARY
TPXX	TRIAL PIT
WSXX	WINDOW SAMPLE BOREHOLE
BHXX	CABLE PERCUSSIVE BOREHOLE W/ ROTARY CORE FOLLOW ON
	BOREHOLE INSTALLATION
	DEEP SEWER WITH 1.50m EASEMENT

ASBESTOS RISK

ASB	ASBESTOS IDENTIFICATION >0.001%
ASB	ASBESTOS IDENTIFICATION Not Quantified
ASB	ASBESTOS IDENIFICATION <0.001%

HYDROCK (2021)

TPXX	TRIAL PIT
WSXX	WINDOW SAMPLE BOREHOLE
MPBHXX	ROTARY CORED BOREHOLE
	BOREHOLE INSTALLATION

WYG (2014)

HP100X	HAND DUG FOUNDATION PIT

AMEC (2011)

TPXX AMP-TPXX	TRIAL PIT
WSXX	WINDOW SAMPLE BOREHOLE
BHXX BHSXX	CABLE PERCUSSIVE BOREHOLE

ENTEC (2009)

HDPXX	HAND EXCAVATED TRIAL PIT
TPXX	TRIAL PIT
TTXX	TRIAL TRENCH
ICXX	INSPECTION CHAMBER TRIAL PIT
WSXX	WINDOW SAMPLE BOREHOLE
BHXX	CABLE PERCUSSIVE BOREHOLE W/ ROTARY CORE FOLLOW ON
	BOREHOLE INSTALLATION

ENTEC (2002)

HDPXX	HAND EXCAVATED TRIAL PIT
TPXX	TRIAL PIT
TWSXX WSXX	WINDOW SAMPLE BOREHOLE
BHXX RHCXX	CABLE PERCUSSIVE BOREHOLE
	BOREHOLE INSTALLATION

PARKMAN (2002)

TPXX	TRIAL PIT

NOTES

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REV	DATE	DESCRIPTION

BROWNFIELD SOLUTIONS

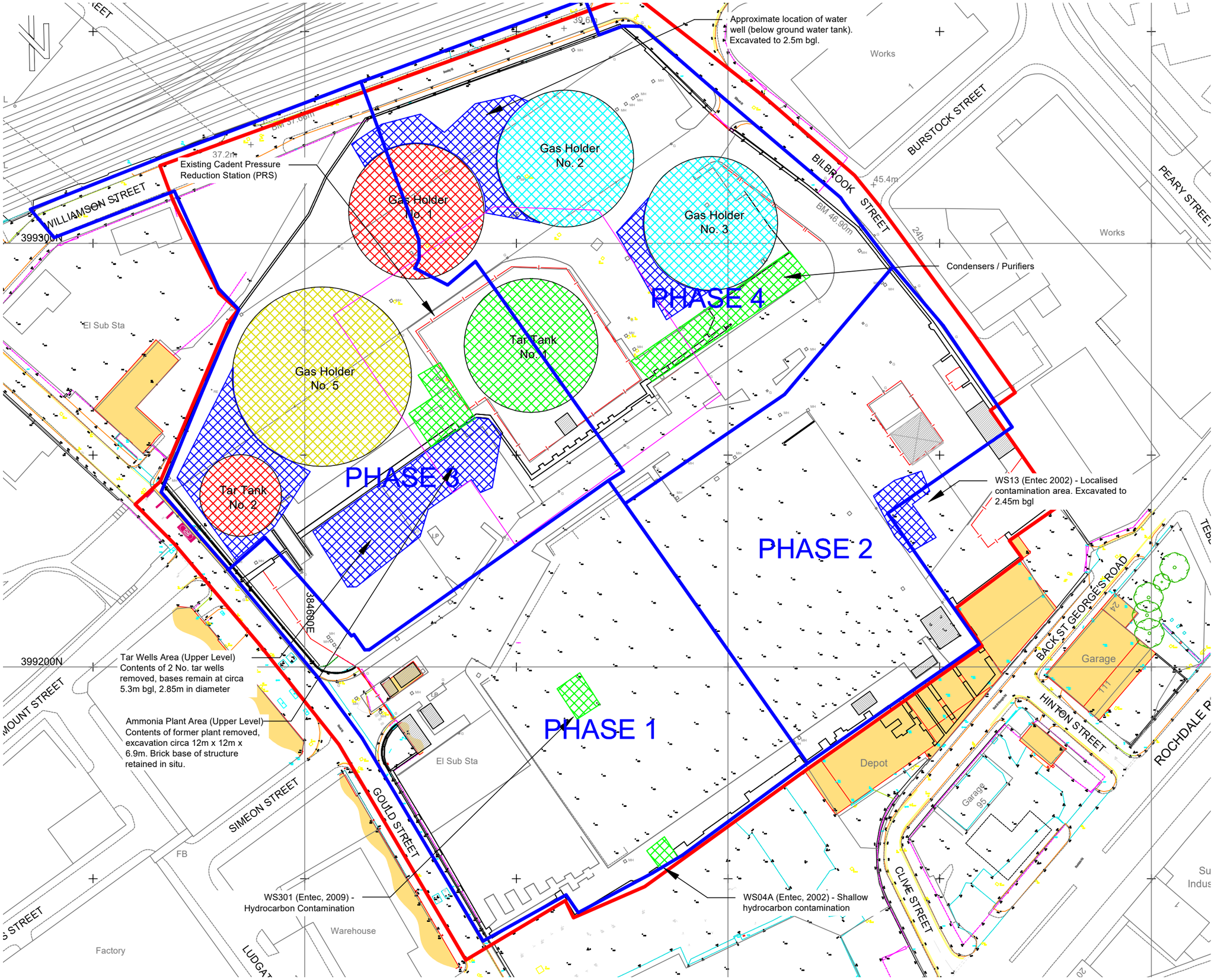
CLIENT
INTRO DEVELOPMENTS / M
PROPERTY GROUP

PROJECT TITLE
GOULD STREET, MANCHES

DRAWING TITLE
COMBINED EXPLORATORY LOCATION PLAN

DRAWING No.	REVISION	SCALE	DATE
C5692/03	D	NTS	30/

DRAWN BY	CHECKED BY
PH	NS



- APPROXIMATE SITE BOUNDARY
- DEVELOPMENT PHASE BOUNDARY
- PREVIOUS GAS HOLDERS AND TAR TANKS
- SHALLOW EXCAVATION OF CONTAMINATED SOILS
- REMAINING AREAS REQUIRING REMEDIATION
- CONTENTS REMOVED AND REPLACED BY FILL / PFA / ETC
- IN-SITU REMEDIATION (STABILISATION)
- CONTENTS RETAINED. SUMP EXCAVATION COMPLETED TO 8.7m BGL AND WATER PUMPED AWAY. LOW PERMEABILITY CAPPING LAYER EMPLACED

NOTES

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REV	DATE	DESCRIPTION	BY	CKD

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CLIENT
INTRO DEVELOPMENTS / MCR PROPERTY GROUP

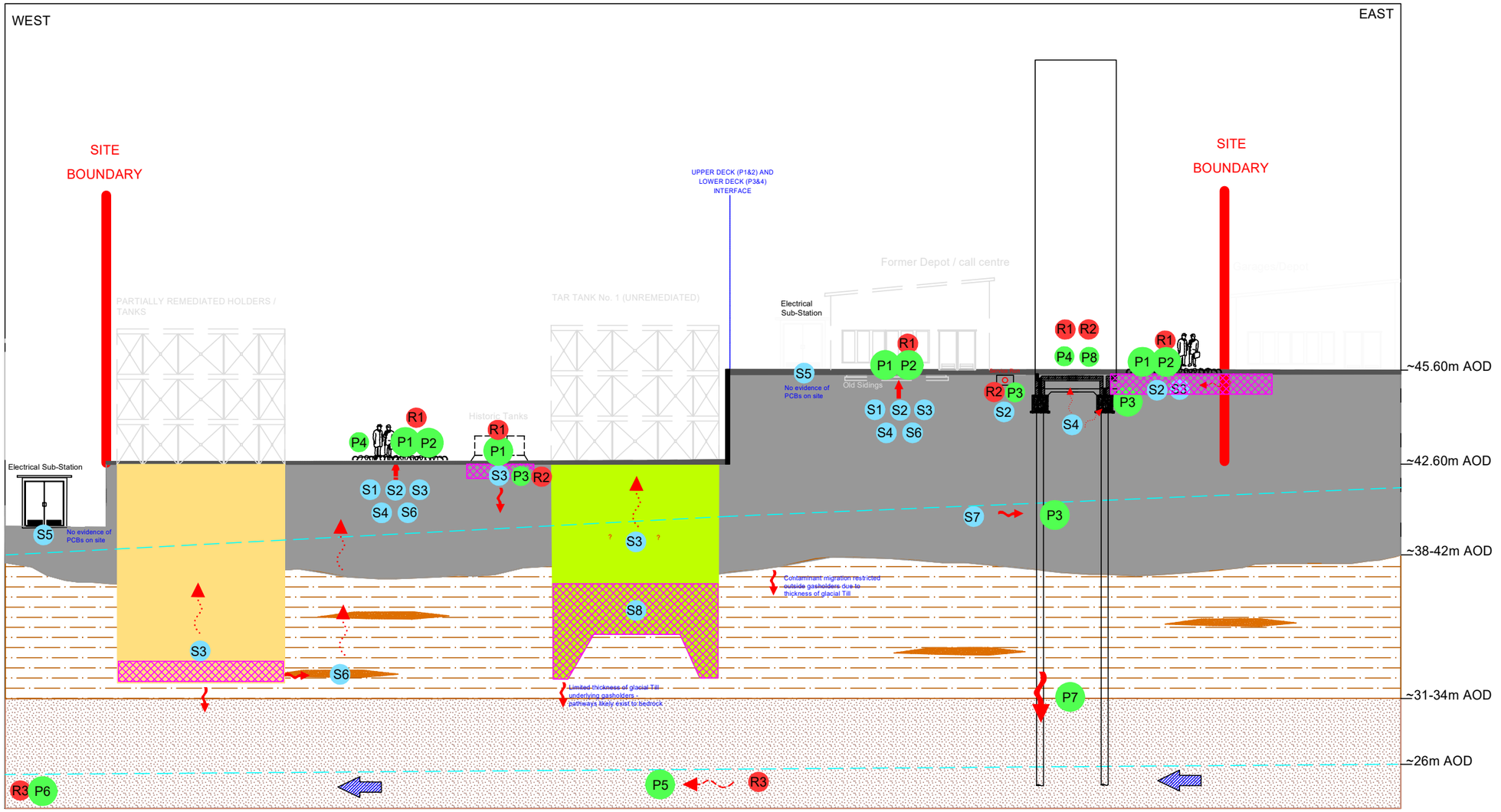
PROJECT TITLE
GOULD STREET, MANCHESTER

DRAWING TITLE
SUMMARY OF COMPLETED REMEDIATION TO DATE

DRAWING No.	REVISION	SCALE	DATE
C5692/05	-	NTS	19/09/24

DRAWN BY	CHECKED BY
TM	AJS

Gould Street, Manchester, Site of Former Gasworks



POTENTIAL PATHWAYS

Dermal Contact, Ingestion, Inhalation — Leaching, Dissolution — Wind Blown Dusts/Fibres — Dissolved Phase — Vapour — Groundwater Flow Direction

SOURCES OF CONTAMINATION

- S1 Asbestos fibres in soil or asbestos-containing materials in the Made Ground
- S2 Elevated metals, petroleum hyrdocarbon aliphatic and aromatic EC >C8-C12, BTEX at depths of pipework
- S3 Elevated PAHs, metals, petroleum hydrocarbons, ohenols, benzene, and inorganic compounds within Made Ground
- S4 Ground Gas (carbon dioxide, methane, carbon monoxide, hydrogen sulphide)
- S5 Poly-chlorinated bi-phenyls (PCBs)
- S6 Semi-Volatile Organic Compounds (SVOCs) within made ground soils and shallow groundwater
- S7 Elevated PAHs, metals, petroleum hydrocarbons, phenols, benzene, and inorganic compounds within groundwater
- S8 Free-Phase Contamination - Viscous Tar

POTENTIAL RECEPTORS

- R1 End users
- R2 Development end-use. (buildings, utlilites and landscaping
- R3 Principal Aquifer

POTENTIAL PATHWAYS

- P1 Ingestion
- P2 Inhalation
- P3 Direct Contact (Building and Utilities)
- P4 Inhalation of VOC
- P5 Migration of contamination via baseflow within the deep groundwater
- P6 Future abstraction
- P7 Migration through pathways formed in the soils from piling
- P8 End-users of new buildings (asphyxiation)

CURRENT STRUCTURES

HISTORICAL STRUCTURE

HISTORICAL BELOW GROUND TANK (UNREMEDIATED)

HISTORICAL BELOW GROUND TANK (PARTIALLY REMEDIATED)

SHALLOW MADE GROUND HOTSPOT

MADE GROUND

GLACIAL TILL (CLAY, SILT, SAND AND GRAVEL)

ISOLATED SAND BAND

BEDROCK CHESTER FORMATION (PRINCIPAL AQUIFER)

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REV	DATE	DESCRIPTION	BY	CKD
A	25/10/24	UPDATED FOLLOWING RECEIPT OF PREVIOUSLY REDACTED AMEC LOGS IN TAR TANK NO. 1 (BH601-603)	TM	AJS

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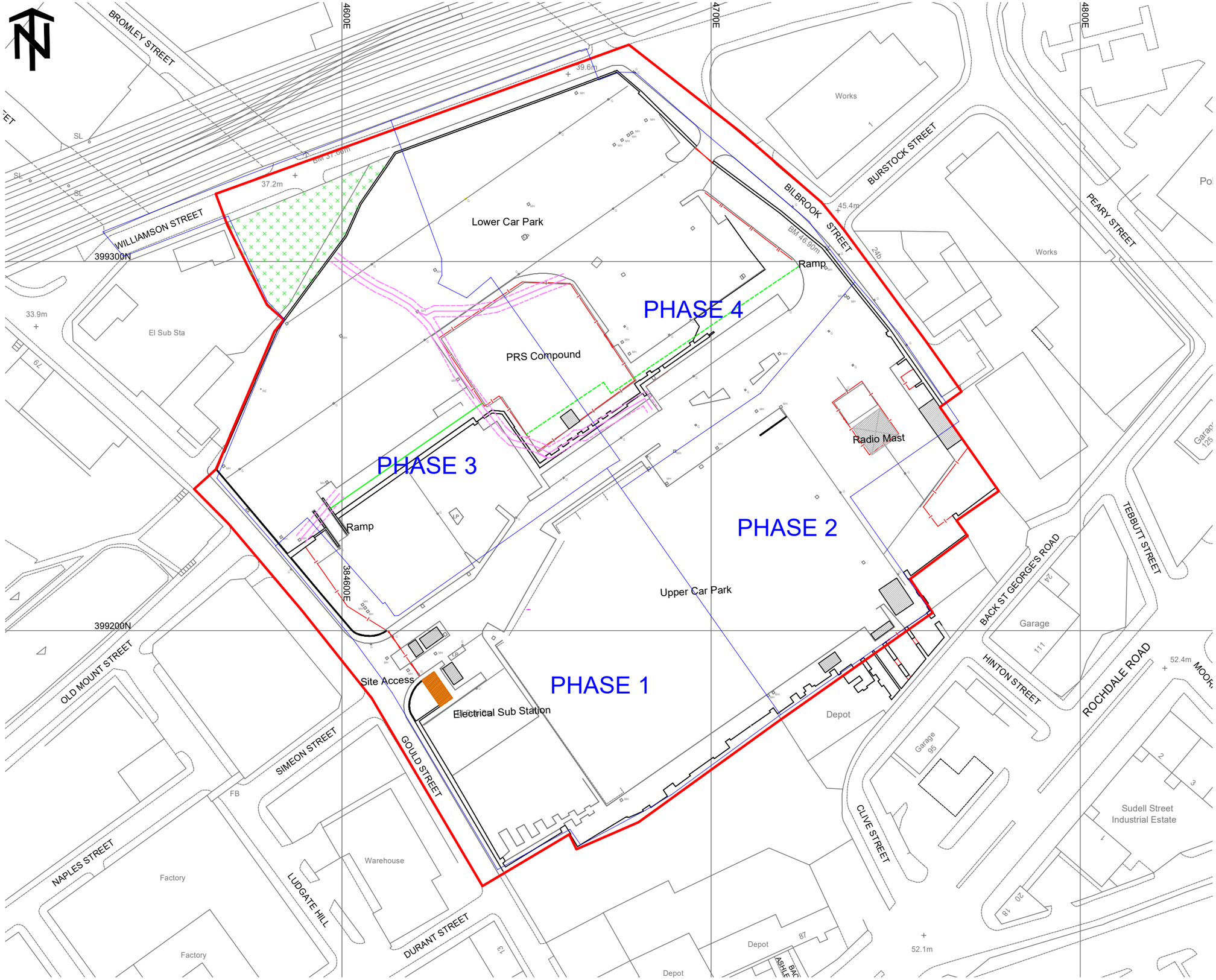
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INTRO DEVELOPMENTS / MCR PROPERTY GROUP

PROJECT TITLE
GOULD STREET, MANCHESTER

DRAWING TITLE
PRE DEVELOPMENT CSM

DRAWING No.	REVISION	SCALE	DATE
C5692/06	A	NTS	25/10/2024

DRAWN BY	CHECKED BY
KB	AJS



KEY	
	APPROXIMATE SITE BOUNDARY
	PHASE BOUNDARY
	LAND INACCESSIBLE DUE TO DENSE VEGETATION & DANGER OF DEATH - HIGH VOLTAGE SIGNAGE
	DEEP SEWER WITH 1.50m EASEMENT
	ELECTRICAL SUBSTATION
	ABOVE GROUND GAS PIPE - LOW PRESSURE
	ABOVE GROUND GAS PIPE - INTERMEDIATE PRESSURE

NOTES

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REV	DATE	DESCRIPTION	BY	CKD

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PROJECT TITLE
GOULD STREET, MANCHESTER

DRAWING TITLE
CURRENT SITE FEATURES PLAN

DRAWING No.	REVISION	SCALE	DATE
C5692/07		NTS	24/06/24

DRAWN BY	CHECKED BY
MB	JMJ