BROWNFIELD SOLUTIONS LTD

GEO-ENVIRONMENTAL ENGINEERING EXCELLENCE

INTRO DEVELOPMENTS LTD

Gould Street, Manchester

Ground Investigation Scoping Report

AJS/C5692/13232

June 2024

PROJECT QUALITY CONTROL DATA SHEET

Site Name:	Gould Street, Manchester		
Document Name:	Ground Investigation Scoping Report		
Reference:	AJS/C5692/13232		
Status:	-	20/06/2024	Original.

Issued By:	**Client:**	**Civil/Structural Engineer:**
[redacted]		

CONTENTS

1.0 INTRODUCTION 1

1.1 Context 1
1.2 Proposed Development 1
1.3 Current Site Description 2
1.4 Limitations 2

2.0 PREVIOUS REPORTING AND SUMMARY OF AVAILABLE INFROMATION 4

2.1 Parkman - Site Investigation Report (1992/1993) 4
2.2 Entec UK Limited - Site Investigation Report Factual (February 2003) 4
2.3 Entec UK Limited - Factual Supplementary Site Investigation Report (October 2009) 6
2.4 Entec UK Limited - Hydrogeological Risk Assessment (March 2010) 8
2.5 Entec UK Limited - Stage 5 Remediation Strategy Report (September 2010) 13
2.6 AMEC Environment & Infrastructure UK - Human Health Risk Assessment (October 2011)13
2.7 Amec Environment and Infrastructure UK Ltd - Final Verification Report (October 2011) 14
2.8 WYG - Area A Supplementary Ground Investigation Factual Report (June 2015) 15
2.9 ECUS Environmental Consultants - Summary of Remediation Works (November 2015)..... 16
2.10 WSP - The Gasworks, New Town, Environmental Statement (November 2020)..... 16
2.11 WSP - Asset Survey and Proposed Groundwater Monitoring Technical Note (March 2021)16
2.12 Hydrock - Report Review and Gap Analysis (November 2021) 17
2.13 Hydrock - Ground Investigation Report (February 2022)..... 18
2.14 Hydrock - Preliminary Risk Assessment and Outline Remediation Strategy (January 2022) . 20
2.15 Environment Agency Comments on Proposals to Date..... 21
2.16 UXO Risk – EOD Detailed Explosive Ordnance Desktop Study 21

3.0 PROPOSED PHASE II GROUND INVESTIGATION 22

3.1 Context and Objectives 22
3.2 Coverage and Method of Site Investigation 23
3.3 Supervision..... 25
3.4 Testing 26
3.5 Monitoring 27
3.6 Reporting 28

DRAWINGS

Drawing Number	Rev	Title
128248_FO_2020-HARDWORKS-1674521	P09	Hard works
128248_FO_2020-LANDSCAPE_GA-1674519	P10	Landscape
128248_FO_2020-PHASING_PLAN-PHASE_1-1690693	-	Phase 1 Layout Plan
128248_FO_2020-PHASING_PLAN-PHASE_2-1690694	-	Phase 2 Layout Plan
128248_FO_2020-PHASING_PLAN-PHASE_3-1690695	-	Phase 3 Layout Plan
128248_FO_2020-PHASING_PLAN-PHASE_4-1690698	-	Phase 4 Layout Plan
C5692/01	-	Site Location Plan
C5692/02	-	Proposed Exploratory Hole Location Plan
C5692/03	-	Combined Exploratory Hole Plan

APPENDICIES

Appendix	Title
Appendix A	BSL Methodology and Guidance

1.0 INTRODUCTION

1.1 Context

This report describes a scoping exercise for a Ground Investigation to be carried out by Brownfield Solutions Limited (BSL) for a former gas works site off Gould Street, Manchester (nearest postcode M4 4DD) and details the requirements from a land quality perspective to satisfy the relevant planning conditions. The ground investigation and subsequent reporting with assessments to be undertaken will be 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.

By following the above guidance, it will ensure that any significant contaminated land related issues are picked up through the ground investigation, assessment and reporting process. Any proposed future ground investigation will be undertaken to obtain good coverage and adequate grid spacing as outlined within the above guidance and any significant sources of contamination identified through a thorough review of the available previous ground investigation data and a gap analysis.

1.2 Proposed Development

This scoping report has been prepared pursuant to Condition 4 of planning permission ref. 128248/FO/2020, granted by Manchester City Council on 16th November 2022 at the land bound by Gould Street, Williamson Street, Bromley Street and Binbrook Street, Manchester, M4 4DD (the Site).

Permission was granted for the erection of 9 No. buildings ranging from 8 to 34 storeys in height to form 1202 residential apartments (Use Class C3a) and ground floor commercial uses (Use Class E) (192 sqm) together with associated car parking, new vehicular and pedestrian access, public realm, landscaping and other associated works following demolition of existing structures and buildings.

Condition 4 relating details the following:

4) Notwithstanding the Environmental Statement. The Gasworks. New Town. Land off Gould Street Manchester. Prepared by WSP Ltd on behalf of South Valley Estates Ltd including:

- Volume 1 Main Text. Report Ref: REP-DH-13.11.20-GWNTESVOL1. V1. [November 2020]
- Volume 2 Technical Appendices. Report Ref: REP-DH-09.11.20-GWNT-ES. VOL2. V1. [November 2020]
- Volume 3 Figures. Report Ref: REP-DH-09.11.20-GWNT-ES. VOL3. V1. [November 2020]
- Volume 4 Non-Technical Summary. REP-DH-13.11.20-GWNT-ES. VOL4. [November 2020]
-Flood Risk Assessment and Outline Drainage Strategy. Gasworks. Manchester. Prepared by BDP. Report Ref: 2277-BDP-RPT-C-001. Rev A. [7th September 2020] 128248/FO/2020 Page 6 of 24
-Appendix 12.1. Remediation Statement. Gould Street Manchester. Prepared by Entec Ltd on behalf of National Grid Property Holdings Ltd. [15th March 2010]
-Appendix 12.2. Ecus Letter Report. Letter Ref: AG-6656-151125-ID-E. [25th November 2020]
-Appendix 12.3. Phase 1 Geo-Environmental Assessment. The Gasworks. New Town. Prepared by ECUS Ltd. Report Ref: 13863-P1. V2. [29th October 2020]

All stamped as received by the City Council, 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
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

- Submission of Site Investigation Proposals and Risk Assessment Report - 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 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).

1.3 Current Site Description

Based on a site walkover carried out on the 3rd April 2024 and a provisional review of previous reports, the site is predominantly occupied by hardstanding car parking at varying levels separated by retaining wall structures.

The site was a former gasworks with holders, tar tanks and associated historic process buildings present. The majority of these were demolished and remediated approximately 20 years ago. However, it is known that Tar Tank 1 was not remediated and that Centrica/Cadent still have some network infrastructure present on the site which is due to be diverted as part of the future development of the site (under a separate MCC planning permission ref 128431/FO/2020). In addition, a large telecommunications tower is present in the northeast of the site present within a small compound.

The site is to be developed in a phased approach; Phase 1 to 4 inclusive. Phase 1 and 2 in the southwest of the site were investigated as part of the proposed development, recently by Hydrock in 2022 and a remediation strategy was produced. Phases 3 and 4 of the development have not been investigated by the client as part of the proposed development works, although several phases of historic investigation, remedial design and remediation have been carried out across the site.

1.4 Limitations

This report 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.

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.

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 PREVIOUS REPORTING AND SUMMARY OF AVAILABLE INFROMATION

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. 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.

2.1 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.

2.2 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.

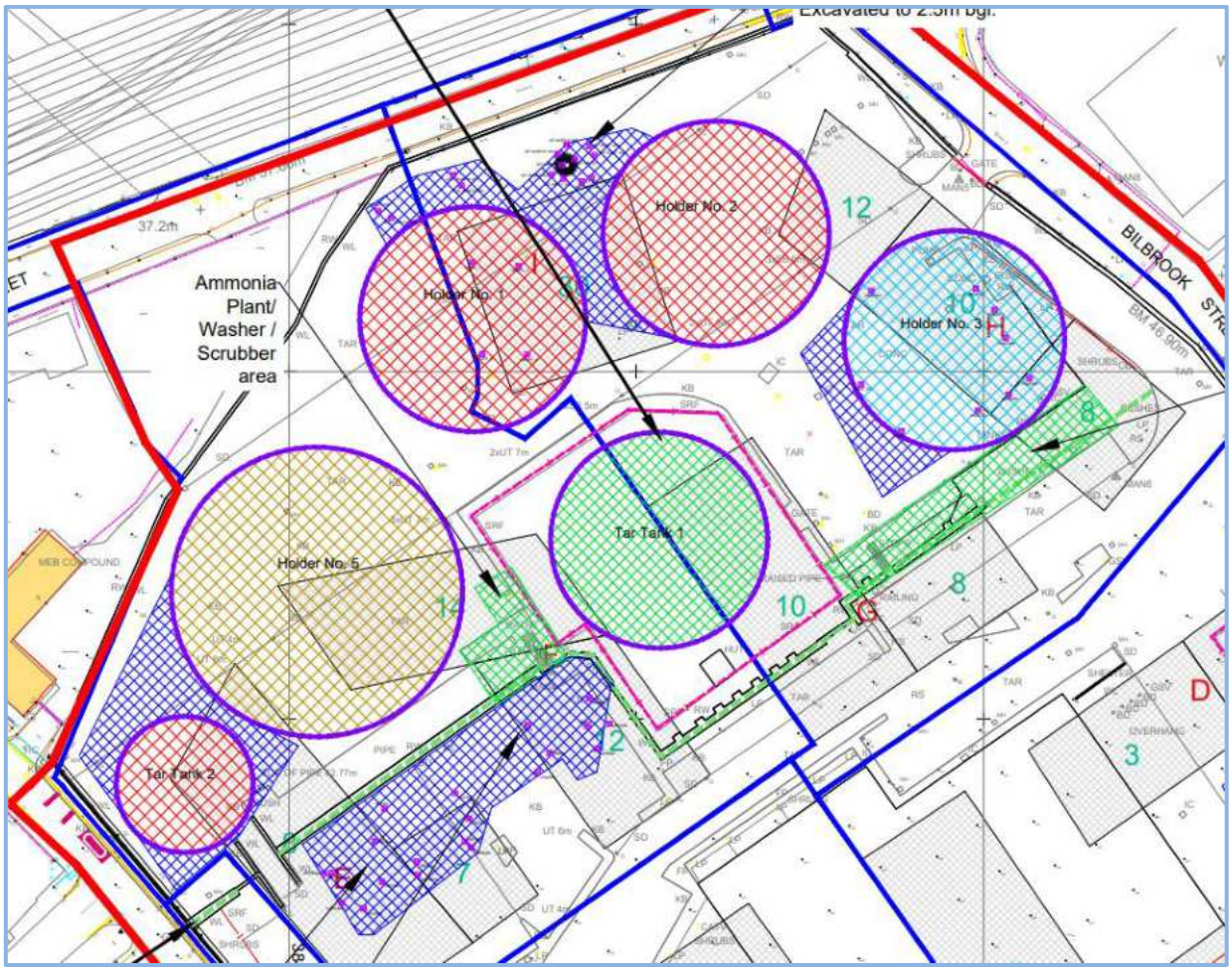
The site was previously used for the production and storage of gas, with an operational gas works present on site since 1824. The works started in the northwestern area of the site and then expanded south and east to cover the full site area. At its full extent, the retorts were present in the south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

2.3 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.

2.4 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.

2.5 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.

2.6 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.

2.7 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 19,041m³, of which a total of 15,518m³ was recovered for either on-site or off-site reuse. This comprised 3,600m³ of material which was stabilised ex-situ, 5,488m³ disposed as either non-hazardous, hazardous or WAC failing and a further 1,669m³ was recovered off-site by soil washing.

Additionally, 5,700m³ of material was treated by in-situ stabilisation. Clean import material amounted to 5,170m³. Approximately 78% of all materials were recovered either on or off-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.

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.

2.8 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.

2.9 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.

2.10 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.

2.11 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.

2.12 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.

2.13 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 and confirm the conclusions of this 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.

2.14 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.

2.15 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.

2.16 UXO Risk – EOD Detailed Explosive Ordnance Desktop Study

The site is known to lie within a moderate UXO risk zone. In order to support further investigation works, a detailed UXO risk assessment by a specialist was commissioned (EOD Contracts reference EOD/24/24210/DTS/REV1/Gould Street, Manchester, M4 4BH dated 12 June 2024). 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 below:



In addition, UXO awareness safety briefings should be provided to all site personnel.

3.0 PROPOSED PHASE II GROUND INVESTIGATION

3.1 Context and Objectives

Following review, BSL consider that the site investigation works done to date over the site as a whole 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, 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.
- 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 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 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 on going 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 informational 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 coring boreholes, trial pitting, windowless sampling, infiltration testing, gas and groundwater monitoring, laboratory chemical and geotechnical testing, with reporting on the findings.

The Phase II Ground Investigation and Geo-Environmental Assessment Report will be undertaken pursuant to Condition 4.

3.2 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. Additional days may be required subject to ground conditions and drilling progress, but regular updates would be provided.
- 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. As above, additional days may be required subject to ground conditions and drilling progress, but regular updates would be provided.
- 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 (6 No. to 20.00m bgl and 4 No. to 25.00m bgl.)
- 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.
- We consider that putting dual boreholes in cable percussive holes and rotary holes as per Hydrock's original suggestion, to be a high-risk strategy on a former gasworks site and has been historically flagged as such a risk by the EA. Sealing off dual monitoring installations is typically difficult to achieve in practice and preferential pathways for contamination migration can result.
- Therefore, we propose to omit the originally suggested 6 No. shallow dual wells and use additional standpipes within the window sample holes, allowing for 12 No. down to max. 5.00-6.00m deep installations. 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	TBC	<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.
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

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
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	BH8010	Foundation Design for Block H and Deep Soil and Groundwater Data Data in area of Condensors/Purifiers
4	BH8011	Foundation Design for Block H and Deep Soil and Groundwater Data in area of Gas Holder 3
4	BH8012	Foundation Design for Block H and Deep Soil and Groundwater Data
4	BH8013	Foundation Design for Block I and Deep Soil and Groundwater Data in area of Gas Holder 2
4	BH8014	Foundation Design for Block I and Deep Soil and Groundwater Data in area of Gas Holder 1
4	BH8015	Foundation Design for Block I and Deep Soil and Groundwater Data Gas Holder 1

Where obstructions are encountered exploratory holes will be relocated, time pursuant.

Once completed, the positions and elevations of all exploratory hole locations will be precisely recorded to 1 centimetre accuracy using GPS to National Grid coordinates and mOD elevations.

3.3 Supervision

The site works would be carried out under the full-time supervision of a qualified geo-environmental engineer who will set out the locations, obtain samples and log the holes in 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.

Positions in UXO moderate risk areas will be supervised and scanned by a UXO specialist.

Works will be carried out under CDM 2015 requirements, alongside CAR 2012.

BSL will ensure that the engineers, technicians and operatives (contractors) are competent in site investigation and have passed the Construction Skills Certification Scheme (or equivalent).

All personnel will be required to supply a valid and in date CSCS/CPCS card prior to commencing work on site. BSL will reserve the right to refuse entry into works areas without a valid CSCS card.

All BSL personnel that are supervising the site works have the following minimum training:

- BSL Internal Site Awareness.
- COSHH training.
- Asbestos Awareness and Non-Licensed Work training.
- Cable Avoidance Tool (CAT) and Genny training.
- Manual Handling.
- Emergency First Aid at Work.
- Fire Marshal.
- Calm Networks Training (water standpipe use).
- Sharps awareness.

The most senior Supervising Engineer will have attended a CITB approved Site Supervisor Safety Training Scheme (SSSTS).

3.4 Testing

During the drilling and excavation of the exploratory holes, representative samples were taken at regular intervals to assist in the identification of the soils and to allow subsequent laboratory testing. They will be stored and transported in general accordance with BS 10175:2011+A2:2017.

The type of testing scheduled may change depending on our findings of the site work, for example, additional sampling, testing and detailed risk assessment will be needed should significant contamination be identified, or should asbestos be identified in soils then additional quantification testing will be required. The requirements will be constantly reviewed.

The following has been allowed for at this stage based on the contaminants of concern identified at the site during prior works:

Contamination Soil Testing

- Provision of a PID for the duration of site works to screen for volatiles on all environmental soil samples.
- 36 No. BSL Default Soil Suites (Arsenic, Cadmium, Chromium (total and hex), Copper, Nickel, Mercury, Lead, Zinc, Selenium, speciated polycyclic hydrocarbons (PAH 16), water soluble sulphate (2:1 Extract), soil organic matter and pH) to provide a robust data set.
- 20 No. suites of speciated TPH CWG.
- 30 No. suites of SVOCs (Ex TICs).
- 30 No. suites of VOCs (Ex TICs).
- 15 No. Fraction of Organic Carbon Analysis (considered sufficient to provide background data for the required DQRA modelling).
- 30 No. total, free and complex cyanides, ammoniacal nitrogen, thiocyanate, speciated phenols.

Contamination Groundwater Testing

Total over two monitoring rounds (15 No. samples per round):

- 30 No. water suites (Ag, Al, As, B, Ba, Ca, Cd, Co, Cr (III), Cr(VI), Cr (Total), Cu, Fe, Hg, Mn, Na, Ni, Pb, Sb, Se, Sn, Zn, V, cyanide (total), cyanide (free), cyanide (complex), thiocyanate, phenols (total and speciated), ammoniacal nitrogen, ammonia, ammonium, dissolved organic carbon, bromate, chloride, fluoride, nitrate, nitrite, sulphate, PAH (speciated), pH, EC and hardness).
- 30 No. suites for speciated TPH CWG.
- 30 No. suites of SVOCs and VOCs.
- 10 No. Enhanced Degradation Suites (comprising nitrate (as $N0_3$ and $N0_2$), iron species (Fe^{2+}/Fe^{3+}) manganese II and manganese IV, sulphate as SO_4, sulphide, redox potential, pH, alkalinity (as $CaCO_3$) and electrical conductivity).

Further soil sampling will be carried out across the site to enable further testing if deemed necessary.

Should any exceedances of the above contaminants be identified against a residential without plant uptake screening criteria, these will be adequately addressed using measures outlined within a subsequent Remediation Strategy that will be submitted pursuant to Condition 4. Further assessment will also be required in respect to permanent ground gases and may also be required in respect to vapour intrusion.

The above data will also be utilised within an updated Detailed Quantitative Risk Assessment for controlled waters.

Geotechnical laboratory analysis to aid foundation design and construction includes chemical aggressivity, classification, strength, and stiffness testing. In situ geotechnical testing will comprise Standard Penetration Tests (SPTs) to assist with preliminary foundation design.

3.5 Monitoring

A potential on-site gas source has been identified associated with the made ground associated with previous developments. The preliminary CSM considers the sources to be a Moderate / Low risk to site end users and property.

In accordance with BS8485 and BS8576, the gas generation potential is considered to be low to very low. The sensitivity of the development is moderate on account of the proposed mixed multi-storey residential and commercial end-use.

In line with current guidance, we have allowed for ground gas monitoring comprising six visits over a two-month period.

Ground gas and ground water monitoring standpipes are proposed in 30 No. boreholes, with installation targeting a variety of strata, both laterally and vertically across the site, including shallow installations in the made ground, superficial strata and deeper installs targeting the bedrock geology., in order to inform and produce a robust CSM All gas monitoring will be undertaken using either a GA5000 or GFM436 infrared gas meter with integral electronic flow analyser.

Flow measurements on each standpipe (l/hr) will be taken. Measurements of the percentage volume in air (%v/v) of oxygen (O_2), carbon dioxide (CO_2) and methane (CH_4) will be 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).

All positions will also be subject to PID monitoring as a line of evidence to inform an initial vapour intrusion risk assessment alongside the soil and groundwater VOC testing data. If a significant risk is identified, then further testing and assessment may be required (e.g. gas vapour phase sampling).

Standpipes will be constructed in general accordance with the relevant guidance.

The frequency and duration of the gas monitoring period may change subject to any ground gas sources identified during the site investigation.

3.6 Reporting

On receipt of all the information, a Preliminary Risk Assessment (PRA or Desk Study – LCRM Stage 1 Tier 1) will be produced at the front end of a Phase II Geo-Environmental Assessment Report (LCRM Stage 1 Tier 2) which will be compiled and would include a review of all the existing information summarised into a singular report, the factual information obtained during the site investigation, and interpretative reporting including qualitative risk assessment, outline remedial strategy, preliminary foundation, floor slab, drainage and highway recommendations.

In addition, we will assess the chemical test results through a waste classification database which will allow soils waste to be classified as defined in the latest Environment Agency guidance (WM3 “Guidance on the classification and assessment of waste -Technical Guidance”).

Once the above is complete, the information obtained as part of the Phase II will inform an updated Detailed Quantitative Risk Assessment (DQRA) for controlled waters (LCRM Stage 1 Tier 3) to generate remedial targets.

The above will then be followed by the production of a formal Remedial Strategy (LCRM Stage 3), which will be detailed remedial requirements and also a Piling Risk Assessment.

DRAWINGS