



NUVU DEVELOPMENTS LTD

**LAND BETWEEN TEN ACRES LANE AND MITCHELL STREET,
NEWTON HEATH, MANCHESTER**

**UPDATED COMBINED PHASE I PHASE II GROUND
INVESTIGATION REPORT**

OCTOBER 2022

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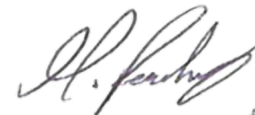
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1 EXECUTIVE SUMMARY

1.1.1 A summary of information contained within this report is provided within the table below.

Table 1.1: Executive Summary	
Item	Description
Site location	The Site is located at land between Ten Acres Lane and Mitchell Street, Newton Heath, Manchester at National Grid Reference 387599, 400309.
Current Use and History	Since the late 1890's it is understood that the Site historically operated as a brickworks with two large clay extraction pits, which culminated into two large excavations that occupied approximately 85% of the Site area. From the late 1940's onwards the clay extraction pits are indicated to have been infilled and during this period the Site was recorded as both a Historical and Registered Landfill. From the 1990's onwards, the Site has remained largely derelict to the present day. Tree felling and vegetation clearance has recently been undertaken at the site to facilitate site investigations.
Groundwater Vulnerability	Most of the Site is underlain by a superficial Secondary Undifferentiated Aquifer within Glacial Till and a bedrock Principal Aquifer within the Collyhurst Sandstone and Chester Formations. A superficial Secondary A Aquifer encroaches into the westernmost section of the site and a bedrock Secondary B Aquifer is also recorded within this area where the Manchester Marls Formation is recorded to subcrop. The site does not lie within a groundwater source protection zone and there are no potable groundwater abstractions within 2km of the site.
Surface Watercourses	The nearest viable graded surface watercourse is the River Medlock which is located c. 690m south of the site. The nearest surface water feature is the Rochdale Canal, which forms the northern boundary of the site.
Mining	The site was a former brickworks with associated clay extraction pits and lies within a Coal Authority Coal Mining Reporting Area. While historical deep (c. 1000m) coal mine workings are recorded within influencing distance of the site, all significant ground movement associated with these workings should now have ceased. There are no mine entries recorded on-site or within 20m of the site boundary. The presence of unrecorded mine entries, though very unlikely, affecting the site cannot be totally ruled out. Should such features be identified during further investigation work on site, or during site remediation or development, they should be reported for investigation, assessment and mitigation.
Unexploded Ordnance (UXO)	An updated UXO Risk Assessment will be required for any mass earthworks / development works that are to be undertaken at the site.

Table 1.1: Executive Summary	
Item	Description
Ground Conditions	Ground conditions are highly variable and comprise significant thicknesses of Made Ground to depths of between 0.3m and up to 14.8m bgl, underlain by between 35m to 45m of predominantly cohesive / low permeability Glacial Till (i.e. a geological barrier), which is in turn underlain by solid geology comprising weathered Sandstone of the Collyhurst Sandstone Formation and Chester Formation.
Groundwater	Shallow perched water strikes within Made Ground were encountered between 0.1m and 8.2m bgl with monitored elevations recorded between 85.18m and 75.49m AOD. Shallow perched groundwater strikes within the underlying natural superficial deposits were encountered between 1.0m and 15.0m bgl with monitored elevations recorded between 83.44m and 63.32m AOD. Monitored elevations of groundwater within bedrock were recorded between 75.76m and 54.39m AOD and are generally indicative of a hydraulic gradient to the west south west.
Contamination Human Health	A range of widespread to isolated exceedances of the initial conservative screening values were recorded for a range of determinands that included metals, PAH's, TPH's, total cyanide, PCB's, SVOC / VOC, PFAS and BTEX. Asbestos was identified in 26 No. samples at concentrations up to 5.11%. For most receptors, hardstanding and clean cover systems in soft landscaping areas will break source-pathway-receptor linkages. Increased risk to construction workers will be mitigated through the use of PPE, AMP etc. Risk from vapours will be assessed further at the DQRA stage.
Contamination Controlled Waters	A range of widespread to isolated exceedances of groundwater screening values within perched groundwaters have been recorded for metals, cyanide, sulphate, TPH, PAH, SVOC / VOC's, phenol, benzene and PFOS / PFOA with the most widespread and elevated exceedances within perched groundwaters within the Made Ground. There are multiple lines of evidence to demonstrate a lack of source-pathway-receptor linkages; most notably that the site is underlain by substantial thicknesses (between c. 35m and 45m) of predominantly cohesive Glacial Till (i.e. a geological barrier) and as such the site is not considered to represent an ongoing or potential future significant risk to controlled waters. As such, the requirement for a DQRA for controlled waters is not considered necessary; subject to agreement with the regulators.
Ground Gas	Ground gas risk assessments indicate Characteristic Situation 2 and that ground gas protection measures will be required. Protection measures are likely to comprise a gas / vapour / organic contaminant resistant membrane and passive subfloor dispersal layer.

Table 1.1: Executive Summary

Item	Description
Waste Materials	Care will need to be taken during earthworks that are undertaken at the site to avoid unnecessarily excavating materials that could be classified as waste. If the landfill materials are to be excavated and reused, they must meet a defined and pre-agreed end-of-waste criteria or be undertaken using a bespoke deposit for recovery permit. There are some areas of the site where it may be possible to reuse site won materials in accordance with the Definition of Waste Code of Practice (DoWCoP) or similar and an accompanying Materials Management Plan (MMP); early engagement and agreement with the regulatory authorities will be required to ascertain if this is an option.
Building Material Assessment	A worst-case Design Sulphate Class (DS) of "DS-2" and an Aggressive Chemical Environment for Concrete (ACEC) of "AC-3Z" has been determined for the Made Ground. For the suspected colliery spoil "DS-4" and "AC-5" is indicated. For the natural strata "DS-1" and "AC-1" is indicated.
Geotechnical Considerations	Several geotechnical abnormal constraints have been identified that include highly variable ground conditions, total settlements that could be ongoing or occur in the future, trafficability, bulking, excavatability, obstructions, buried highwalls, aggressive ground, faulting, unstable excavations, shrink / swell, shallow groundwater, collapse compression, combustion, slag expansion etc. Further details of these can be found in Sections 17 – 19.
Geotechnical Recommendations	Where natural ground is present at shallow depth or where Made Ground can be fully excavated and engineered without restriction, shallow reinforced foundations may be suitable. Where deeper Made Ground is present or where ground improvement is unlikely to be successful, deep trench reinforced foundations, raft foundations or piles are recommended. Suspended floor slabs to mitigate against settlement / differential settlement. Modification / stabilisation and / or ground improvement may be required for Made Ground to achieve good compaction. Possible solutions and mitigating measures for those and other geotechnical considerations are discussed in Sections 17 – 19.
Further Works	Numerous further works are required with the most notable being the requirement for a DQRA for human health, Options Appraisal and Detailed Remediation Strategy. An updated UXO risk assessment will also be required for remedial / construction works along with water supply pipe assessments, foundations works risk assessments, a non-native species management plan, further geotechnical and ground gas testing as part of and following earthworks, as well regulatory requirements (e.g. permits) etc. Other further works are discussed further in Section 19.

2 INTRODUCTION

2.1 Instructions

- 2.1.1 This report has been prepared in accordance with instructions issued by Nuvu Developments Ltd, c/o Your Housing Group (YHG), Youggle House, 130 Birchwood Boulevard, Birchwood, Warrington, WA3 7QH via email correspondence dated 24th February 2022 and the receipt of a Purchase Order (ref: PO102631,NV01) dated 28th February 2022. The work follows a proposal (JC/MP/LD10385/LET-001) dated 21st February 2022 put forward by Wardell Armstrong LLP (WA).

2.2 Site Location & Description

- 2.2.1 The site comprises a roughly rectangular area of derelict land between Ten Acres Lane and Mitchell Street, Newton Heath, located approximately 4km to the northeast of Manchester city centre at National Grid Reference 387599, 400309. The site location is presented on Drawing LD10385-001 (1:30,000 scale). A more detailed site location plan / aerial imagery is shown on Drawing LD10385-002 (1:5000 scale).
- 2.2.2 The site is bound by the Rochdale Canal to the north, Mitchell Street and residential properties to the east, residential properties and a school to the south and Ten Acres Lane and a sports centre to the west. Vegetation clearance has recently been undertaken at the site.

2.3 Proposed Site Use

- 2.3.1 A hybrid planning application (reference: 133700/FO/2022) has been submitted for the comprehensive redevelopment of the site to create up to 716 residential dwellings, a new secondary school and a community building; all with associated car parking, highways, landscaping and new public realm creation.
- 2.3.2 Full planning permission was granted on 29 October 2021 for remediation works to the site (reference: 129197/FO/2021) and the above hybrid planning application is pursuant to the completion of these remediation works.

2.4 Scope and Objectives

- 2.4.1 The purpose of this report is to provide an update to the previous WA Combined Phase I and Phase II Ground Investigation Report (ref: LD10162 RPT-001) dated May 2020 based on up-to-date desk-based information and additional WA intrusive ground

investigations that have since been carried out across the site to address planning conditions imposed by the regulators.

2.4.2 The scope of the additional ground investigation was submitted to the Environment Agency (EA) in a letter dated 13th January 2022 (ref: JC/LD10385/LET-001). The EA responded in a letter dated 16th February 2022 (ref: SO/2020/120757/05-L01) and agreed with the scope and methodologies proposed.

2.4.3 Results of the additional ground investigations have been used alongside the previous WA data to review and revise the Conceptual Site Model (CSM), establish whether the linkages identified previously are still plausible and establish the level of risk associated with the site.

2.4.4 Comparisons have also been drawn from third-party site investigation data, but it is the data from the more recent WA investigations and reports that have been relied upon to assess the current condition of the site and to inform the necessary risk assessments.

2.4.5 The scope of works are as follows:

- A review of past and current uses of the site and surrounding area including the nature of any hazards and physical constraints.
- To provide information in relation to the site's environmental setting including geology, geochemistry, mining, hydrogeology and hydrology based on up-to-date information.
- An up-to-date site walkover of the site identifying key environmental and geotechnical abnormal items.
- To identify any aspect of the current site that would require immediate attention (e.g. unstable buildings, insecure fences, hazardous substances accessible to trespassers or likely to be dispersed by wind or water).
- An updated review to confirm potential contamination sources, pathways, and receptors, including those that could be added in the future, so that an updated preliminary CSM and preliminary risk assessment can be produced. The review is based on all the information that was available at the point of the original WA Combined Phase I and Phase II Ground Investigation report dated May 2020, so that the assessment is consistent with previous reporting and to enable a

comparison to be drawn following the findings of the additional ground investigation.

- To collate the findings and results of the previous phases of WA ground investigation and update ground and groundwater conditions so that an updated generic quantitative risk assessment (GQRA) can be undertaken, using the most up to date and relevant guidance and screening data for identified receptors.
- Using the information from the most recent WA ground investigation produce an updated / revised CSM and undertake an assessment of the geotechnical and geoenvironmental risks in relation to the proposed future development of the site.
- Identify the requirements, or otherwise, for future works and give an early indication of possible remedial requirements.
- Identify, if necessary, the need to involve regulatory bodies in intrusive investigations.

2.4.6 This report has been prepared in accordance with British Standards BS 5930, BS 10175 and Land Contamination: Risk Management (LCRM) guidance.

2.5 Sources of Information

2.5.1 The following primary sources of information have been reviewed:

- An updated Envirocheck Report for the site area prepared by Landmark and dated 26th July 2022, included as Appendix B.
- Historical Ordnance Survey maps, included as Appendix B.
- Historical aerial photography viewed from the Britain from Above website.
- British Geological Survey (BGS) published geological mapping Sheet 85 Manchester (1:50,000 Scale) and the BGS interactive mapping database.
- BGS Geological Memoir 'Geology of the Manchester district: a brief explanation of the geological map Sheet 85'.
- Coal Authority online mapping products and databases.
- Flood maps for planning and long-term flood risk maps.
- EA Catchment Data Explorer.
- Site walkover notes and photographs.

- Other mining archives including the Mining Instability Study of Great Britain prepared by Ove Arup.
- Inhouse WA archives.
- Zetica unexploded ordnance risk map and reports, included as Appendix C.

2.5.2 The site has also been subject to previous investigations and reports that provide information on ground conditions, including a series of phased WA ground investigations, as well as historical third-party reports / investigations. The following reports have been considered:

- WS Atkins Consultants Ltd: “Former Jackson Brickworks, Manchester – Desk Study Report and Preliminary Environmental Liability Assessment” – dated December 2001. It should be noted that this report was not available for review by WA, but its findings were summarised in the Celtic report below.
- Celtic Technologies Ltd: “Desk Study, Ten Acres Lane, Newton Heath, Greater Manchester” (report ref: R1077/06/2958) – dated July 2006.
- Celtic Technologies Ltd: “Interpretative Report, Former Jacksons Brickworks, Ten Acres Lane, Newton Heath, Greater Manchester” (report ref: R1077/08/3328) – dated February 2008.
- WA: “Factual Site Investigation Report, Land Between Ten Acres Lane and Mitchell Street, Newton Heath, Manchester” (report ref: SH12254 RPT-001) – dated July 2019.
- Deloitte Real Estate: “Jacksons Brickworks Remediation Environmental Statement: Volume 1 (Chapter 8 – Ground Conditions)” – dated January 2021.
- WA: “Combined Phase I and Phase II Ground Investigation Report, Land Between Ten Acres Lane and Mitchell Street, Newton Heath, Manchester,” (report ref: LD10162 RPT-001) – dated May 2021.
- WA “Ground Investigation Report – Additional Works, Land Between Ten Acres Lane and Mitchell Street, Newton Heath, Manchester” – dated September 2021.
- Deloitte Real Estate: “Jacksons Brickworks Redevelopment: Volume 1 (Chapter 10 – Ground Conditions)” – dated May 2022.

2.6 Limitations of This Report

- 2.6.1 It is understood that the site is to be redeveloped for a residential end use that also includes a school and community building. Proposed development plans have been produced; however final site levels are not currently known. Following finalisation of any proposed development layouts, detailed design or structural loading assessments, earthworks designs or the findings of any subsequent investigations, this report may require review to ascertain if the assessment remains applicable or requires re-assessment and revision
- 2.6.2 It should be noted that the interpretation of the results of the ground investigation are based on a limited number of investigation points. The locations and numbers of the investigation points were governed by the physical state of the site and the location of known services at the time of the investigation. Although reasonable inferences have been made during the interpretation, it is possible that variances in the thickness, distribution and physical / chemical characteristics of the strata present will exist and hence the possibility of significant variation in ground conditions existing on site in comparison to those described within this report cannot be discounted.
- 2.6.3 The findings and recommendations given in the report are considered to be valid and appropriate at the time of preparation and for the specific purpose or purposes intended. WA will not be liable if any findings are used by third parties, without the written agreement of the company, or if an interpretation is made and action taken without further consultation.
- 2.6.4 The report is provided for the stated purpose and for the sole use of the client. It is confidential to the client and their professional advisors. WA accepts no responsibility whatsoever to any person other than the client.
- 2.6.5 Where data from third parties has been used, such as environmental baseline data from Landmark, exploratory hole logs and laboratory data, WA will not be liable for any errors or omissions within the original data. Additional information may become available in the future which may have a bearing on the conclusions of this report and for which WA LLP cannot be responsible.
- 2.6.6 The findings of this report will need to be agreed with the regulators (i.e. local council and Environment Agency) as part of the sign off of any planning conditions imposed on the development.

3 BACKGROUND

- 3.1.1 Numerous site investigation works have been carried out on the Ten Acres site as outlined in 2.5.2. This initially included a detailed site investigation by Celtic Technologies Ltd (report dated February 2008) and site investigation works undertaken by Wardell Armstrong (WA) for Vertase FLI (report dated July 2019).
- 3.1.2 Following a gap analysis carried out by WA in July 2020 (ref: JC/MP/SH12254/LET-003), further ground investigation was carried out by WA between September and November 2020. The original scope of that investigation was based on a proposal dated 07th August 2020 (ref: JC/SH12254/LET-004) that assumed that de-vegetation and tree felling would be completed ahead of mobilising to site. However, because of the presence of large stands of Japanese knotweed and tree felling licences not being in place, a significant portion of the site could not be cleared and investigated. Therefore, a reduced scope of ground investigation was completed on the understanding that additional site investigations would be carried out once the above access issues had been dealt with.
- 3.1.3 A Combined Phase 1 and Phase 2 Ground Investigation Report was produced and was used to support the planning application for the remediation of the site (ref: 129197/FO/2021). Planning consent was subsequently granted, but the planning permission contained a number of conditions imposed by the Environment Agency (EA) and Manchester City Council (MCC).
- 3.1.4 To address some of the planning conditions, WA provided a proposal in June 2021 (ref: JC/LD10246/LET-001) which included additional ground investigations, as well as outlining future requirements for a Detailed Qualitative Risk Assessment (DQRA), Options Appraisal and Detailed Remediation Strategy. WA were instructed to undertake some of the additional site investigation works, however vegetation clearance had still not been undertaken, so investigations in the areas that were previously inaccessible could still not be undertaken.
- 3.1.5 WA provided a proposal for the investigation of the inaccessible areas in February 2022 (ref: JC/MP/LD10385/LET-001) and were subsequently instructed on the 24th February 2022. The additional works commenced on the 14th March 2022 with the intrusive work being completed on the 27th April 2022 and the post fieldwork monitoring / sampling being completed 01st August 2022.

- 3.1.6 This report is a revision / update to the Combined Phase 1 and Phase 2 Ground Investigation Report (ref: LD10162 RPT-001) dated May 2020 and incorporates the findings of those subsequent additional ground investigation works that have been undertaken since its completion. This information has then been used to update the CSM and risk assessments.
- 3.1.7 While the historical third-party investigation data is useful for comparison, given the time that has elapsed and potential for changes to have occurred at the site since it was obtained, the results from the most recent WA investigations have been relied upon to assess the current condition of the site.

4 SITE HISTORY AND CURRENT LAND USE

4.1 Site History

4.1.1 Historical Ordnance Survey (OS) plans dating back to 1848 have been examined and are summarised in Table 4.1. OS historical mapping is contained within Appendix B.

Table 4.1: Summary of Previous Land Use		
Date	Site Land Use	Adjacent Land Use
1848	Open fields with field boundaries and possible ponds.	Ten Acres Lane borders the western boundary of the site. Rochdale Canal immediately north of site, with Newton Heath north west of site comprising residential dwellings. Cotton Mill south of the site.
1893	By 1893 brick works constructed in western part of site. A reservoir is located on the northern site boundary, likely associated with the bleach works/mills on adjacent side of Rochdale Canal. The remainder of site is undeveloped.	Expansion of Newton Heath, as well as development of numerous industrial units including Cotton Mills, Bleach Works, Dye Works, and Glass Works to the north of the site. Lancashire & Yorkshire Railway constructed to the north of Newton Heath. Tannery situated directly east of the site. Open fields to the east, south and west of site.
1908-1910	By 1908 additional brick work buildings noted in the eastern section of the site, with excavations nearby. Brick works in west of the site, also with excavation visible nearby.	Further expansion of Newton Heath. Park Engineering Works to the southwest of site.
1923	By 1923 expansion of excavations associated with both brick works towards the centre of the site, but also extending off-site to the south east. No indication of depth. Construction of additional buildings associated with brick works in the east.	Recreation ground bordering the southwestern boundary of the site. Expansion of Park Engineering Works to the southwest.
1931-1933	By 1932 the brick works in the west no longer recorded and a sports ground is now present with former excavations indicated to have been backfilled. Another sports ground is present within the south west. Expansion of excavations from the eastern brick works westwards with ponds indicated.	Residential properties and school now adjacent to southern boundary, partly constructed over off-site extent of clay pit.

Table 4.1: Summary of Previous Land Use		
Date	Site Land Use	Adjacent Land Use
1949-1951	By 1951 refuse heaps noted in the eastern section of the site with possible deep excavations as indicated by ponds within the excavations. Tramway associated with eastern brick works with reservoirs adjacent to brickworks buildings.	No significant changes.
1956	By 1956 the sports ground in south west of site is no longer recorded.	Further expansion of Engineering Works to the south west, and expansion of residential areas south and east.
1971-1978	By 1971 bowling green, tennis court and pavilion recorded in the west of the site. Reservoir in the north of site no longer present. By 1973 the eastern brick works, and remaining excavations are now listed as disused. Possible infilling of excavations as slopes and ponds no longer shown.	Numerous residential and industrial buildings immediately north of site now demolished.
1982-1983	By 1982 most of the excavations within the east of the site are no longer recorded. A disused pit is still recorded in the central part of the site. By 1983 brickworks buildings in the east are no longer recorded but a possible concrete slab still remains.	Residential housing developed immediately north of the site.
1991-1993	By 1991 excavations, sports ground, bowling green and tennis courts in west no longer recorded.	No significant changes.
1999	No significant changes.	Works to the southwest of site demolished, only one building remaining.
2006	No significant changes.	Makkah Close, and associated residential dwellings, constructed adjacent to site's southwestern boundary.
2020	Aerial photography shows the site as densely vegetated / overgrown with trees and shrubs. Possible concrete slab within the eastern section of the site.	No significant changes.

4.2 Site Use

4.2.1 The most recent site walkover was undertaken on the 18th July 2022 by a WA Engineer. The main observations from the site visit are described below:

- The site comprised derelict land that had recently undergone extensive vegetation clearance / tree felling works; although tree stumps and large stands of Japanese knotweed were noted to remain.
- Vehicular access to the site is via a locked / gated and fenced compound off Ten Acres Lane. Concrete blocks had been placed either side of the compound gates. The remainder of the site is secured by 2.5m high metal mesh security fencing along its boundaries. However, there were areas where fencing panels had been removed / cut allowing trespassers to enter the site.
- An area of concrete hardstanding was situated within the eastern section of the site adjacent to the site's eastern boundary.
- The Rochdale Canal and a series of locks forms the northern boundary of the site with a flow to the west. A footpath is adjacent to the Canal and was well used by members of the public at the time of the walkover. Residential properties are situated on the adjacent side of the canal.
- The eastern boundary of the site is adjacent to Mitchell Street, with residential properties beyond. A soil bund forms the boundary; beyond which is the recently erected security fencing noted above.
- The southern boundary is adjacent to the back gardens of residential properties of Briscoe Lane, as well as Briscoe Lane Academy School.
- The site has variable topography and generally falls from 87m AOD in the north to 78m AOD in the south west as shown in Drawing LD10385-005.
- Various derelict vehicles are located across the site, mostly in the centre. Various fly tipped materials were also noted in the areas adjacent to housing, notably at Mitchell Street and along the southern boundary of the site.
- Several large stands of suspected Japanese Knotweed were noted across the site with the most extensive areas being located within the central southern section of the site.

- Several mounds of soil with various constituents (mostly brick, timber and concrete) were observed in the western section of the site close to the fenced compound in this area and also within the central section of the site.
- No outfalls or discharges were noted from the site to the canal.
- A brick retaining wall forms the site's north westernmost boundary where there is a c. 2m drop from Ten Acres Lane down to the canal footpath. An orange seepage was noted coming from this wall and running onto the canal towpath.
- No services or infrastructure were observed at the site.

4.3 Asbestos

- 4.3.1 During the site walkover suspected asbestos containing materials (ACM's) were noted in the mounds of soil adjacent to the fenced compound withing the north western section of the site. ACM's and asbestos fibres were also identified during previous investigations at the site and given the sites former use as a landfill from the mid-20th Century onwards, it is likely that further ACMs and / or asbestos fibres may be present in soils on site.
- 4.3.2 It should be noted that the walkover survey does not constitute an asbestos survey and not all areas of the site may have been visited or made available for inspection.

4.4 Ecology

- 4.4.1 Although a site visit has been carried out, this was not specifically for ecological purposes and has not been undertaken by a qualified ecologist. Despite the recent vegetation clearance, areas of potential ecological value may still be present, and reference should be made to WA and third-party ecological reports that are available in the public domain under planning application reference: 133700/FO/2022.
- 4.4.2 A Nitrite Vulnerable Zone is recorded on-site, and an Area of Adopted Green Belt and a Local Nature Reserve are recorded approximately 583m and 603m to the south east of the site respectively. There are no other sensitive land uses indicated from the Envirocheck Report within 2km of the site.
- 4.4.3 It should be noted that the Rochdale Canal is designated as a Special Area for Conservation (SAC) some 1.2km upstream and to the north east of the site.

4.5 Invasive Plants

- 4.5.1 Extensive areas of Japanese knotweed were evident across all parts of the site. It should be noted that the survey was not specifically for ecological purposes and was not undertaken by a trained ecologist.
- 4.5.2 Appropriate mitigation is required to treat or remove invasive plant species and further specialist surveys and advice is recommended. It should be noted that it is an offence under the Wildlife and Countryside Act 1981 to knowingly permit the spread of Japanese knotweed.

4.6 Archaeology

- 4.6.1 The desk study and site walkover were not undertaken for archaeological purposes. Preliminary examination of historical maps of the site indicates that the site has been occupied by a brick works and clay pit from as early as 1893, however it is envisaged that most archaeological features would have been destroyed by the extensive excavations and subsequent landfilling that is recorded at the site.
- 4.6.2 Previous archaeological reporting indicates that industrial remains relating to the brickworks (e.g. kilns and processing areas) are of archaeological interest and a recent planning condition has stipulated that archaeological investigations are required at the site prior to remedial works / development.
- 4.6.3 No scheduled Monuments or Listed Buildings are recorded on site.

4.7 Environmental Management

- 4.7.1 On the basis of the desk study assessment and the site walkover survey, the overall condition of the site appears to be poor as there is evidence of extensive fly-tipping on the site.

5 GEOLOGICAL AND HYDROGEOLOGICAL INFORMATION

5.1 Geology

5.1.1 The assessment of the geology of the site is based on the published geological mapping (Sheet 85, Manchester, Bedrock and Superficial Edition, 1:50,000 scale), supplemented by various other geological mapping sheets, geological memoirs, topographical plans, a site visit and previous site investigations. Online data from the BGS has also been researched and borehole records are included at Appendix D.

5.1.2 A summary of the geological information is presented in Table 5.1. This has been supplemented by information contained within the Envirocheck Report contained within Appendix B.

Table 5.1: Summary of Geological Data	
Strata / Geohazard	Description
Made Ground	Previous site investigations and reports indicate extensive Made Ground deposits across the site to depths of up to 14.8m bgl that was generally found to be highly variable over small lateral distances and comprised a mixture of predominantly granular and to a lesser extent cohesive soils; all of which included various anthropogenic constituents of varying proportions and quantities (e.g. brick, concrete, timber, ash, clinker, fabrics, glass, metal, slag, plastics, ceramics and tile). Suspected combustion waste, suspected colliery spoil, suspected construction and demolition waste and suspected household wastes were also identified.
Superficial Deposits	Glacial Till is recorded to be present beneath the site. The site lies within a BGS recorded buried glacial valley where thick drift deposits are known to be present and has been proven in nearby BGS and third-party boreholes. Previous site investigations at the site have encountered a firm to stiff, fissured, brown, slightly sandy to sandy, gravelly Clay with occasional lenses of predominantly medium dense, brown / grey, gravelly, clayey Sand to depths of between 15.00m and c. 40m bgl.
Solid Geology	Chester Formation (sandstones with subordinate mudstone beds) and Manchester Marls Formation (calcareous mudstone and siltstone with thin beds of limestone) in the westernmost section of site. Collyhurst Series Sandstone (a soft red sandstone) underlies the remainder of the site. A dip to the south / south west is indicated.
Geological Structures	A fault trending northeast to southwest dissects the westernmost section of the site and downthrows the strata to the south west by an unknown distance.
Natural cavities	No hazard.

Table 5.1: Summary of Geological Data	
Strata / Geohazard	Description
Landslides	Very low risk indicated.
Collapsible deposits	Very low risk indicated.
Compressible deposits	Moderate risk indicated for most of the site. Very low risk indicated in the western section of site.
Ground dissolution	No hazard.
Running sands	Very low risk indicated.
Shrinkage/swelling clay	Very low risk indicated.

5.1.3 There are several freely available BGS boreholes and recent third-party boreholes in the vicinity of the site that indicate predominantly cohesive Glacial Till to depths of up to 40m bgl, where rockhead was encountered as follows:

- SD80SE76 located 440m north east of the site recorded rockhead at 35.05m bgl (53.34m AOD) overlain by mostly superficial strata comprising clay.
- TRC RC01A located 442m south west recorded rockhead at 39.50m bgl (29.50m AOD) overlain by mostly superficial strata comprising clay and to a lesser extent sand.
- SD80SE78 located 560m north west of the site recorded rockhead at 33.52m bgl (41.18m AOD) overlain by mostly superficial strata comprising clay and to a lesser extent sand.
- SD80SE94 located 720m north east of the site recorded rockhead at 34.13m bgl (53.87m AOD) overlain by mostly superficial strata comprising clay and to a lesser extent silt and sand with fine gravel.
- SJ89NE469 located 730m south west of the site recorded rockhead at 32m bgl (31.50m AOD) overlain by mostly superficial strata comprising clay and to a lesser extent sand.
- SJ89NE93 located 736m south east of the site recorded rockhead at 12.19m bgl (45.71m AOD) overlain by mostly superficial strata comprising clay.

5.1.4 There are also several other BGS boreholes that indicate significant thicknesses of Glacial Till to depths of between at least 22m bgl and 36m bgl (full thickness not proven).

5.1.5 Further information regarding ground and groundwater conditions from previous site investigations at the site are included in Section 8.

5.2 Hydrogeology

5.2.1 Hydrogeology information indicates that most of the site is underlain by natural superficial deposits, which are classified as a Secondary Undifferentiated Aquifer and bedrock, which is classified as a Principal Aquifer. However, a superficial Secondary A Aquifer encroaches into the westernmost section of the site and a bedrock Secondary B Aquifer is recorded within the westernmost section of the site.

5.2.2 The site lies within the Manchester and East Cheshire Permo-Triassic Sandstone Aquifers Water Body (EA Catchment Data reference – GB41201G101100) which was given an overall classification of Poor. The reason for not achieving “Good” status is under investigation and / or due to saline or other intrusions.

5.2.3 There are 22 No. groundwater abstraction licences within 2km of the site. The nearest is located 643m northwest of site and is used for cooling and manufacturing purposes.

5.2.4 There are no potable groundwater abstractions within 2km of the site and the site does not lie within a Source Protection Zone.

5.3 Soil Vulnerability Classification

5.3.1 The site’s groundwater vulnerability is recorded as Low. These are areas that provide the greatest protection to groundwater from pollution, likely characterised by low leaching soils and / or the presence of low permeability superficial deposits as supported by the previous investigations and nearby off-site BGS boreholes.

5.4 Hydrology

5.4.1 The site is located within the Irwell Management Catchment and falls within the Roch Irk Medlock operational catchment.

5.4.2 The River Medlock (a graded watercourse) is located 690m south of the site, downgradient, and flows to the west. Under the Water Framework Directive, the section of the River Medlock (Lumb Brook to Irwell, Water Body ID – GB112069061152) was assigned an overall classification of ‘Moderate’ in 2019 with a ‘Fail’ Chemical Rating, and ‘Moderate’ Ecological rating. The reasons for not achieving ‘Good’ status include sewage discharges, urbanisation, barriers and other.

- 5.4.3 The nearest surface water feature is the Rochdale Canal (Water Framework Directive Water Body ID – GB71210517) adjacent to the northern boundary of the site. The Canal flows from northeast to southwest and was assigned an overall classification of 'Moderate' in 2019 with a 'Fail' Chemical Rating, and 'Moderate' Ecological rating.
- 5.4.4 The nearest graded watercourse is Moston Brook located 675m to the north east of the site, but on the other side of the Rochdale Canal. The brook flows westwards and feeds into the River Irk and becomes culverted immediately west of the location noted above. The EA has not assigned a classification for Moston Brook but the River Irk was assigned an overall classification of 'Moderate' in 2019 with a 'Fail' Chemical Rating, and 'Moderate' Ecological rating in 2019. The reasons for not achieving 'Good' status include sewage discharges, contaminated land, landfill leaching, urbanisation etc.
- 5.4.5 There are fourteen surface water abstraction licences within 2km of the site. The nearest is located 322m southwest of the site at the Rochdale Canal where water is abstracted for boiler feed & manufacturing purposes. Most abstractions are for non-sensitive industrial purposes.

5.5 **Flooding**

- 5.5.1 To assess the potential flood risk at the site, reference has been made to the flood map for planning and the long-term flood risk information on the Gov.uk website. The site is located within a Flood Zone 1 and has a low probability of flooding (less than 1 in 1000 annual probability). According to the long-term flood risk map, the site is located within a very low risk flood area where the chance of flooding each year is less 0.1%.
- 5.5.2 The flood risk from surface water for the majority of site is considered to be very low, where the chance of flooding from surface water is less than 0.1%. However, there are small areas within the north eastern and western sections of the site classed as low to high risk where the chances of surface water flooding are between 0.1% and <3.3%.
- 5.5.3 The BGS Groundwater Flooding Susceptibility Map shows that most of the site is located in an area where there is limited potential for groundwater flooding to occur. However, the westernmost parts of the site are recorded as having the potential for groundwater flooding to occur to property situated below ground level. Previous investigations at the site have noted a localised groundwater seepage at the site's southern boundary between Hallam Road and Briscoe Lane Primary School.

- 5.5.4 As the site is greater than one hectare in size, a site-specific flood risk assessment will be required in accordance with Chapter 10 of the National Planning Policy Framework.

6 MINING AND QUARRYING

6.1.1 Research of the mining setting is based on examination of the published topographical, historical, and geological information as described in Section 4 and 5 of this report along with other mining archive information.

6.2 Coal Mining

6.2.1 Published information from the Coal Authority (CA) indicates that the site is located within a coal mining reporting area but is not located within a Development High Risk Area. No coal mine shafts, or adits were recorded on, or within 20m of, the site.

6.2.2 BGS geological mapping and boreholes from within the site indicate that the Coal Measures strata underlie the site at depths greater than 200m bgl. A historical CA mining report was obtained by WS Atkins (presumably dated December 2001) and they stated that the site is within the zone of influence from workings in one coal seam at a depth of 1,040m, which was last worked in 1954. This report states that ground movement from the workings should have ceased.

6.2.3 Consequently, the site is considered highly unlikely to be subjected to any future ground instability or any other impacts resulting from coal mining activities.

6.3 Other Mining

6.3.1 The site is not recorded to lie within a BGS Non-Coal Mining Area. However, there are two BGS Recorded Mineral Sites on site, both of which were opencast brick works which have now ceased operation. Mitchell Street Brickworks was situated in the east of the site and worked the Glacial Till. The Newton Brickworks in the west of the site worked the Manchester Marls Formation.

6.3.2 A further six BGS Recorded Mineral Sites are recorded within 2.0km of the site, all of which pertain to clay extraction and have now ceased operation.

7 ENVIRONMENTAL SETTING

7.1 Contaminated Land Register Entries and Notices

- 7.1.1 The site, or an area within 500m of the site has not been identified as potentially contaminated by the Manchester City Council under the Part IIA of the Environmental Protection Act 1990.

7.2 Landfills

- 7.2.1 A single historical landfill is recorded across much of the site (the exception being the north western section of the site) and was active from May 1973 to December 1984. Deposited waste types included inert, commercial and household waste.
- 7.2.2 A single registered landfill site is recorded on-site (extents similar to the historical landfill) which was active from July 1978. The last input date is not recorded, but the current status is recorded as licensed lapsed, cancelled, defunct, not applicable, surrendered / cancelled. Between 75,000 and 250,000 tonnes of construction and demolition waste, including industrial non-hazardous waste, slag and boiler flue cleanings, and foundry sand were deposited per year. Liquid and sludge wastes were prohibited.
- 7.2.3 There are a further eleven historical landfill sites, two registered landfill sites and a single BGS recorded landfill within 1km of the site. The nearest one is located 527m to the south east of the site at Clayton Vale. The first reported input date is 31st December 1901, and the last recorded input date is 31st December 1980. Deposited waste is reported to include inert and industrial waste.
- 7.2.4 There are also features on historical maps and areas of potentially infilled land, which may indicate the presence of unrecorded landfilling activities on-site and within influencing distance of the site. The on-site features appear to correlate with the clay pit extents recorded on historical mapping. Off-site examples include an area of infilled land immediately adjacent to the south eastern section of the site.

7.3 Waste Management

- 7.3.1 A single Licensed Waste Management Facility and Registered Waste Transfer Site is located 233m to the north east of the site. The types of waste processed include household, commercial and industrial waste.

7.3.2 A single Registered Waste Transfer Site is located 237m to the north east of the site that processes between 25,000 and 75,000 tonnes of various waste types (includes commercial, industrial, decomposable waste, scrap rubber, scrap machinery and asbestos mixed wastes).

7.3.3 There are no other Integrated Pollution and Control Waste Sites, Licensed Waste Management Facilities, Registered Waste Transfer Sites or Registered Waste Treatment or Disposal Sites within the immediately surrounding area that are likely to impact upon the site.

7.4 **Environmental Issues**

7.4.1 The environmental issues for the site and adjacent land have been reviewed from the Envirocheck Report, and those of potential significance to the site are highlighted below:

- There is a single Pollution Incident to Controlled Waters recorded 28m to the north east of the site pertaining to the Rochdale Canal that was classified as a Category 3 (minor incident). However, the source or type of pollutants were unknown.
- There are five Local Authority Pollution Prevention Controls (Part B) of relevance within 250m of the site. The nearest is located 94m to the south west of the site and pertains to iron, steel and non-ferrous metal foundry processes. A petrol filling station is located 131m to the east and further iron, steel and non-ferrous metal foundry processes are located 220m to the south west.
- There is a single fuel station entry located 115m east of the site that pertains to Briscoe Lane Service Station, which is currently operational.

7.4.2 Several industrial land uses are also recorded within 250m of the site and include garages, brewery supplies, damp and dry rot control, furniture manufacturers, chemists and pharmacist, domestic general servicing, carpet and upholstery cleaners, road haulage services, tyre dealers, tanks etc.

7.4.3 Examination of the available Envirocheck data for the site and surrounding areas has not shown any other Agency or Hydrological or Hazardous Substance Sites that are likely to impact upon the site.

7.4.4 The environmental issues identified above are not likely to have impacted the site in the past or significantly impact future development.

7.5 Radon

- 7.5.1 The Envirocheck report indicates that the site is in a Lower (less than 1% of homes estimated to be at or above the Action Level) to Intermediate (1 to 3% of homes estimated to be at or above the Action Level) probability radon area. No radon protective measures are indicated for the construction of new dwellings or extensions.

7.6 Unexploded Ordnance

- 7.6.1 A Zetica regional unexploded ordnance (UXO) risk map has been reviewed. The map indicates that the site is located within an area which is classed as Moderate risk. Several bomb strikes are also recorded within the surrounding area and the former Parks Engineering Works (located approximately 0.1km to the south west of the site and a strategic target) is indicated to have been manufacturing military aircraft and parts and also possibly producing munitions during both wars.
- 7.6.2 Consequently, a UXO Risk Assessment was carried out for the site in 2020 by Zetica. An overall low UXO hazard was indicated, and no additional measures were considered necessary to reduce the UXO risk on the site to As Low As is Reasonably Practicable (ALARP). However, this assessment was based on the proposed site investigation works and future bulk excavations of parts of the site. A reassessment will be required for the remedial works / bulk earthworks and any piled foundations that would need to be undertaken as part of the development of the site, to establish if any mitigation is required.

8 PREVIOUS THIRD-PARTY REPORTS

8.1.1 Numerous third-party investigations have been undertaken at the site and these are summarised below and have been used to inform the preliminary CSM for the site. The findings of the previous and most recent WA site investigation have been summarised in Section 11 and all the data has been combined so that an assessment of the full WA dataset can be undertaken.

8.2 WS Atkins Consultants Ltd: “Former Jackson Brickworks, Manchester – Desk Study Report and Preliminary Environmental Liability Assessment” – December 2001

8.2.1 This report was reviewed by Celtic (not seen by WA) in the report described at 8.3 below, and they stated that it included references to several other previous investigative reports produced for the site prior to 2001. However, it is understood that these earlier reports are no longer available for review.

8.2.2 Celtic stated that ground conditions included significant thicknesses of Made Ground (up to 14.8m in the central part of the site; although only 8.0m was proved in the Atkins investigation itself) comprising ash, clinker, brick, concrete rubble, timber, rags, glass, metal, plastic and limited amounts of bonded asbestos sheeting. ‘Domestic type putrescible’ waste was also recorded in some trial pits. 18m of ‘Boulder Clay’ was encountered beneath the Made Ground but it is not known if this was the recorded thickness or the depth that this material was proved to. Bedrock was not encountered.

8.2.3 Celtic stated that trial pits in the western part of the site recorded perched water at depths of between 2.0 and 3.0m below ground level (bgl).

8.2.4 Celtic stated that chemical analysis of the soil recorded elevated concentrations of contaminants including zinc, copper, phenol, and sulphate. Analysis of perched water indicated levels of elevated BOD, COD, ammonia, metals and sulphate.

8.2.5 Celtic stated that monitoring of ground gases recorded elevated concentrations of methane and carbon dioxide (although concentrations were not reported by Celtic), although gas exit velocities appeared to be low (<0.1 m/s).

8.3 Celtic Technologies Ltd: “Desk Study, Ten Acres Lane, Newton Heath, Greater Manchester” (report ref: R1077/06/2958) – July 2006

8.3.1 The main contaminants of concern from the desk study were identified as arsenic, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium, zinc,

cyanide, total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAH), phenols, asbestos and ground gases (methane and carbon dioxide) that had been attributed to the infilling operations of the clay pits excavated during the sites operation as a brickworks between 1894 and 1966. Evidence indicated that waste disposal within the clay pits was known to cover approximately 85% of the site area and was carried out between 1949 and 1990.

- 8.3.2 Risks to human health included trespassers encountering potentially contaminated materials at the site surface (low risk), potential for off-site migration of ground gases (high risk) and from a variety of pathways should the site be redeveloped (medium to high risk).
- 8.3.3 Risks to Controlled Waters included discharge of perched waters to Rochdale Canal (medium risk) and migration of perched waters to true groundwater within the underlying Principal Aquifer (high risk).
- 8.3.4 Further site investigation works were recommended as the risks posed by the site were considered to be high.

8.4 **Celtic Technologies Ltd: “Interpretative Report, Former Jacksons Brickworks, Ten Acres Lane, Newton Heath, Greater Manchester” (report ref: R1077/08/3328) – February 2008.**

- 8.4.1 Celtic were commissioned to undertake an assessment of the site to support a future residential development. A desk-based assessment of the site was undertaken, followed by an intrusive ground investigation that included 72 No. trial pits, 22 No. windowless sample boreholes, 20 No. cable percussion boreholes and 6 No. rotary open hole boreholes, as well as geophysical survey.
- 8.4.2 Soil and groundwater samples were also obtained for environmental and geotechnical laboratory testing and 3 No. ground gas / groundwater monitoring rounds, that incorporated 39 No. monitoring installations, were undertaken between 26th June and 18th July 2007.

Ground Conditions

- 8.4.3 Ground conditions included significant thicknesses of variable Made Ground (dominated by the following fill types; ash fill, clinker waste, landfill waste and brick waste) between 0.5m to >10m bgl, underlain by Glacial Till comprising firm to stiff, locally soft to firm, slightly sandy, gravelly Clay and to a lesser extent yellow and grey,

gravelly, coarse Sand to depths of between 16.5m and >22m bgl, which were in turn underlain by solid geology comprising weathered mudstone and sandstone to depths of between 25m and 27m bgl. It should be noted that the solid geology recorded by Celtic has since been proven to be Glacial Till.

Groundwater Conditions

- 8.4.4 Groundwater was encountered at shallow depths between 0.2m and 4.9m bgl within the Made Ground and at depths of between 1.1m and 8.2m bgl within the Glacial Deposits. Celtic stated that the groundwater was likely laterally confined perched water. Deeper groundwater was also encountered in what Celtic had interpreted as bedrock (now proven to be Glacial Till) where groundwater levels were recorded to have risen to between 0.7 m bgl to 5.5m bgl within monitoring wells. Celtic suggested that this was indicative of confined conditions.
- 8.4.5 Groundwater monitoring indicated that shallow perched waters within Made Ground and underlying shallow Glacial Till were at depths of between 0.4m and 7.1m bgl (between 84.69 and 71.12m AOD) and Celtic stated that these elevations were indicative of a hydraulic gradient to the south west. Deeper groundwater within what Celtic were calling bedrock (now proven to be Glacial Till) was recorded at depths of between 0.7m and 5.5m bgl (between 79.86m and 74.28m AOD) and Celtic stated that these elevations were generally indicative of a hydraulic gradient to the south west.
- 8.4.1 Celtic noted that certain areas of the site were prone to small-scale flooding events during periods of heavy rainfall. A high-water table in the south west of the site was noted to be consistent with local marshy ground conditions and growth of indigenous plant species in waterlogged soils.

Visual and Olfactory Evidence of Contamination

- 8.4.2 Visual and olfactory evidence of contamination was recorded in several areas of the site within Made Ground. This included frequent hydrocarbon odours and sheens, occasional iridescent sheens, rare / isolated putrid, chemical, solvent, sulphurous and organic odours, along with rare / isolated red dye and yellow dye staining. Celtic noted a significant 'plume' in the southwest of the site, with black staining on soils and hydrocarbon sheens on water. Three other contaminant plumes were identified across the site, with hydrocarbon odours / sheens in the soil and water.

8.4.3 Celtic state that non-aqueous phase liquid (NAPL) was not encountered during the fieldwork.

Contamination Assessment – Soils

8.4.4 Celtic obtained 146 No. soil samples from across the site that were tested for potential contaminants of concern. An independent review of the laboratory results against current screening criteria for a residential land use with plant uptake was undertaken (assuming 1% SOM for the reasons outlined in Section 13) and exceedences are summarised in Table 8.1, but further details can be found in the detailed exceedence tables contained within Appendix I.

Table 8.1: Summary of Celtic 2007 Contaminant Exceedences in Soil					
Contaminant	Min. Recorded (mg/kg)	Max. Recorded (mg/kg)	GAC (mg/kg)	No. of Exceedences MG	No. of Exceedences NG
Metals					
Arsenic	<3	190	37 ¹	21	2
Lead	5	4,300	200 ¹	24	2
Nickel	6	360	130	2	-
Inorganics					
Total Cyanide	<1	920	20 ²	4	1
TPH					
Aromatics > EC16-EC21	0.29	890	260	4	-
Aromatics > EC21-EC35	4.10	8,300	1,100	3	-
Polycyclic Aromatic Hydrocarbons (PAH)					
Naphthalene	<0.013	30	2.3	6	3
Acenaphthene	<0.014	230	210	-	1
Fluorene	0.015	200	170	-	1
Phenanthrene	0.049	590	95	-	1
Benz(a)anthracene	0.017	31	7.2	6	1
Chrysene	<0.100	33	15	4	-
Benzo(b)fluoranthene	<0.016	24	2.6	11	3
Benzo(a)pyrene	<0.012	22	2.2	11	2
Dibenzo(a,h)anthracene	<0.008	3.5	0.24	13	2
Semi Volatile Organic Compounds (SVOC) and Volatile Organic Compounds (VOC)					
Dibenzofuran	<0.1	81	4.8 ⁴	3	1
Carbazole	<0.1	70	6.7 ⁴	1	1
2-Methylnaphthalene	<0.1	180	10 ⁴	2	1

Table 8.1: Summary of Celtic 2007 Contaminant Exceedances in Soil					
Contaminant	Min. Recorded (mg/kg)	Max. Recorded (mg/kg)	GAC (mg/kg)	No. of Exceedances MG	No. of Exceedances NG
2,4-Dinitrotoluene	<0.1	13	1.5 ³	1	-
Chloromethane	<0.007	0.013	0.0083 ³	1	-
Trichloroethene	<0.009	0.06	0.0093 ¹	1	-
2,4-Dimethylphenol	<0.1	27	19	1	-
Notes: MG = Made Ground, NG = Natural Ground Generic Assessment Criteria Used: LQM/CIEH S4ULs for Human Health Risk Assessment (3rd edition, 2015), unless otherwise stated. ¹ Category 4 Screening Levels. ² Value for thiocyanate. ³ EIC/AGS/CL:AIRE Soil GAC for Human Health Assessment (January 2010). ⁴ Wardell Armstrong derived GAC.					

- 8.4.5 Celtic state that contamination within soils was generally found in shallow Made Ground within hotspot areas, however some hotspots extended deeper into the Made Ground. Minimal contamination impacts were found within the deeper natural ground. Asbestos was not identified in any of the thirty samples screened. However, analytical techniques at the time of testing were not as accurate / advanced as they are currently, so asbestos fibres may have been present.

Groundwater Assessment – Waters

- 8.4.6 Celtic obtained 12 No. groundwater samples from across the site that were tested for potential contaminants. An independent review has been undertaken with results screened against UK Drinking Water Standards (DWS) or equivalent values, as the site is underlain by a Principal Aquifer. The exceedances are summarised in Table 8.2 , but further details can be found in the detailed exceedence tables contained within Appendix I.

Table 8.2: Summary of Celtic 2007 Contaminant Exceedances in Groundwater						
Contaminant	Min. Recorded (µg/l)	Max. Recorded (µg/l)	GAC ¹ (µg/l)	No. of Ex. MG	No. of Ex. GT	No. of Ex. BR*
Metals						
Arsenic	<1	11	10	1	-	-
Boron	86	6,100	1000	2	3	1
Manganese	<1	3,100	50	4	6	2
Selenium	<1	29	10	-	-	1
Iron	50	1,200	200	2	3	-

Table 8.2: Summary of Celtic 2007 Contaminant Exceedances in Groundwater						
Contaminant	Min. Recorded (µg/l)	Max. Recorded (µg/l)	GAC ¹ (µg/l)	No. of Ex. MG	No. of Ex. GT	No. of Ex. BR*
Other						
Sulphate	26,000	520,000	250	-	3	1
Total Ammonium NH ₄	<200	9,400	0.5	4	2	3
Phenol						
Phenol	<1	3	0.5	-	-	1
Phenol Monohydric	<10	50	0.5	2	1	1
Total Petroleum Hydrocarbons (TPH)						
Total Aliphatics & Aromatics >C5-35	<10	97	10 ²	1	-	-
Notes: ¹ UK Drinking Water Standard (2016) values as used by Celtic in their assessment unless noted. ² Environment Agency (2009), 'Petroleum hydrocarbons in groundwater: supplementary guidance for hydrogeological risk assessment' values used unless noted. Ex = Exceedences, MG = Perched Groundwater within Made Ground, GT = Perched Groundwater within Glacial Till and BR = Groundwater within "Bedrock". * It should be noted that what Celtic interpreted as "bedrock" groundwaters have since been proven to be perched groundwater within Glacial Till.						

8.4.7 Celtic stated that low concentrations of contaminants in perched waters demonstrated low leaching potential of solid phase contaminants in Made Ground. Notably, levels of contaminants observed within Made Ground were not reflected within shallow or deep natural deposits suggesting that contaminants were relatively immobile within Made Ground and that the overlying clay deposits did not provide an active pollutant pathway linkage to deeper natural deposits.

Groundwater Assessment – Leachates

8.4.8 Celtic also obtained 10 No. soil samples from across the site for leachate analysis to assess the potential risks to controlled waters from impacted soils. The results have also been independently screened against Environmental Quality Standards (EQS) and DWS values and the exceedences are summarised in Table 8.3.

Table 8.3: Summary of Celtic 2007 Contaminant Exceedances in Leachate						
Contaminant	Min. Recorded (µg/l)	Max. Recorded (µg/l)	DWS (µg/l)	EQS (µg/l)	No. of Ex. DWS	No. of Ex. EQS
Metals						
Nickel	<1	56	20	4 ¹	1	2
Sulphate	4,000	1,000,000	250,000	-	2	-
Chromium	<1	13	-	4.7	-	2
Lead	<1	3	-	1.2 ¹	-	2
Zinc	<3	110	-	10.9 ¹	-	2
Copper	<1	7	-	1 ¹	-	9
Phenol						
Phenols Monohydric	<10	20	0.5	7.7	1	1
PAH						
Anthracene	0.015	0.14	-	0.1	-	2
Benzo(b)fluoranthene	0.023	0.16	0.1	-	1	-
Benzo(a)pyrene	0.009	0.15	0.01	0.00017	4	4
Indeno(123cd)pyrene	0.014	0.19	0.1	-	1	-
Benzo(ghi)perylene	0.016	0.39	0.1	-	1	-
Fluoranthene	0.017	0.26	-	0.0063	-	10
Notes: ¹ Parameters not obtained at the time to allow for an MBAT calculation to be undertaken so bioavailable screening criteria used. Ex = Exceedences						

8.4.9 Further details can be found in the detailed exceedence tables contained within Appendix I.

Groundwater Assessment – Surface Waters

8.4.10 Celtic obtained 2 No. surface water samples from the Rochdale Canal (sample references Canal A and Canal B, taken upstream and downstream, respectively) to assess the potential risks to the canal. The results have also been independently screened against EQS values and the exceedences are summarised in Table 8.5.

Table 8.5: Summary of Exceedences in Surface Water				
Contaminant	Min. Recorded (µg/l)	Max. Recorded (µg/l)	GAC ¹ (µg/l)	Number of GAC Exceedences
Metals				
Lead	3	4	1.2	2
Copper	6	9	1 ²	2
Nickel	<1	4	4 ²	1
Notes: ¹ Environmental Quality Standards (2015) values unless noted. ² Parameters not obtained at the time to allow for an MBAT calculation to be undertaken so bioavailable screening criteria used.				

8.4.11 A tentative review of the limited dataset indicates that concentrations of the above contaminants were slightly elevated at the downstream sampling location. Further details can be found in the detailed exceedence tables contained within Appendix I.

Ground Gas Assessment

8.4.12 Gas monitoring was undertaken between 27th June 2007 to 23rd July 2007 and recorded concentrations of carbon dioxide between <0.1% and 14.3% (typically between <0.1% and 9.8%), methane concentrations up to 30.5% (typically <0.1%) and gas flow rates of up to 2.3 l/hr.

8.4.13 Celtic undertook a risk assessment in accordance with recommendations documented in CIRIA 659 and concluded that for carbon dioxide a ground gas screening value (GSV) of 0.225 l/hr was indicated, which characterised the site as 'Amber 1' in the 'Traffic Light' risk derived system. Based on the highest recorded methane concentration and the maximum flow rates, a worst case GSV of 0.704 l/hr was indicated for methane, which characterised the site as 'Amber 2'.

Vapour

8.4.14 It should be noted that the Celtic data is over 15 years old at the time of writing and due to the volatile nature of the contaminants of concern, their vapour assessment is not reflective of the current site situation and a betterment is envisaged. However, it is useful to review their assessment, so that comparisons can be drawn.

8.4.15 Celtic stated that the outcome of the CLEA UK simulation modelling undertaken showed that there was no risk to critical receptors from indoor or outdoor vapour exposure from soil sources. However, this model was based upon the risk derived from

ground below a minimum depth of 200 mm and a maximum depth of 600 mm capping of clean soils across the site. They also assumed that a capping layer, including topsoil in soft cover / garden areas, would be incorporated as part of any future development.

Geotechnical Testing

8.4.16 Geotechnical testing undertaken as part of the Celtic site investigation included regular standard penetration testing within boreholes and laboratory testing that included 11 No. moisture content tests, 6 No. Atterberg Limit tests, 6 No particle size distribution tests, 3 No. laboratory California Bearing Ratio tests, 4 No undrained shear strength in triaxial compression tests and 15 No. BRE SD1 Concrete Suites.

8.4.17 To avoid repetition, these results are discussed in more detail in Section 12 as they have been used to supplement the geotechnical testing undertaken as part of the WA site investigations.

8.5 Previous WA Investigations (2019 – 2022)

8.5.1 To avoid repetition, these works, and their findings, are discussed in Section 10 onwards and have been combined with the most recent WA site investigation data, to ensure that a full assessment of all the data is undertaken. Reference should be made to the original reports outlined in Section 1.5.2 for the independent findings and assessments undertaken as part of these investigations. Independent contamination results from the WA 2020 site investigation can be found in the detailed exceedence tables contained within Appendix I.

9 PRELIMINARY CONCEPTUAL SITE MODEL

9.1 Background

9.1.1 Following a review of the information presented in this updated report a preliminary CSM has been prepared to show the characteristics of the site and the relationships between possible contaminants, pathways, and receptors.

9.1.2 This updated preliminary CSM is based upon an assumed residential end use and considers all the information available at the point of the original WA Combined Phase I and Phase II Ground Investigation report dated May 2020. This is to ensure that the preliminary CSM is consistent with previous reporting in the public domain enabling a comparison to be drawn following the findings of the additional site investigation works and the subsequent revised CSM.

9.2 Potential Sources of Contamination On-Site

- Made Ground associated with the site's former use as a historical and registered landfill. A significant thickness of Made Ground was encountered across the site during previous phases of ground investigation (up to 14.8m bgl) with widespread to localised / isolated exceedences of metals (arsenic, lead, nickel, copper, zinc), total cyanide, inorganics, TPH, PAH, BTEX (benzene, toluene, ethylbenzene and xylene), asbestos, polychlorinated biphenyls (PCB's), SVOC and VOC above screening values indicated. Elevated concentrations of ground gases were also noted that were indicative of Characteristic Situation 2 and a worst-case possible scenario of CS4.
- In soil leachate there are widespread exceedences of the DWS and EQS screening values for metals (nickel, chromium VI, cadmium, chromium, copper, zinc, arsenic, and lead) and PAH and localised / isolated exceedences of TPH, total cyanide, phenol, and sulphate.
- In perched groundwater within the Made Ground there were widespread exceedences of the DWS or equivalent screening values for metals (arsenic, boron, cadmium, manganese, nickel, and iron), relatively widespread exceedences for PAH and TPH, relatively isolated exceedences for phenol and benzene and an isolated exceedance for cyanide. Exceedences of 1,4-Dichlorobenzene, Chlorobenzene and 1,2-Dichlorobenzene were also recorded from the

groundwater seepage within the southern section of the site (also from perched waters within the Made Ground).

- In perched groundwater sampled from response zones that screened Glacial Till there were relatively widespread exceedances of the DWS or equivalent screening values for metals (arsenic, boron, manganese, selenium and iron), relatively widespread exceedances for PAH and TPH and isolated exceedances of phenol and benzene.
- In perched groundwater within bedrock there were exceedances of the screening values for metals (manganese, selenium and iron), PAH compounds, TPH and sulphate.
- In surface water samples taken from the Rochdale Canal from upstream, midstream and downstream, there were exceedances of DWS equivalent screening values for chromium, lead, nickel, copper, TPH and PAH compounds (benzo(a)pyrene and fluoranthene).
- During the WA 2020 investigation water levels were measured using a product / water interface probe. No free phase product was detected. Celtic also state that no non-aqueous phase liquid (NAPL) was encountered during their fieldwork. However, hydrocarbon sheens were occasionally observed to shallow perched groundwaters mostly within the north western section of the site during trial pitting.
- Historic brickworks that were present on-site. Possible contaminants include metals, metalloids and their compounds; acids / bases; asbestos; solvents; PCB's and hydrocarbons (fuels).
- Fly-tipped materials. Possible contaminants include asbestos, metals and metalloids, fuel oils etc.
- The former reservoir (possibly infilled and within the central northern section of the site) and could constitute a ground gas source if infilled with Made Ground.

9.3 Potential Sources of Contamination Off-Site

- Surrounding historical industrial uses within the immediately surrounding area that includes the Park Engineering Works, Avro Works, Brickworks and associated clay pits, Ten Acres Mill, Bleach Works, Livingston Mills (cotton), Galvanising Works, Glass Works, Dye Works, Tannery, Laundry, Timber Yard; most of which

are located to the north of the site on the opposite bank of the Rochdale Canal. Moderate to high contaminative potential indicated.

- Surrounding current industrial land uses and fuel stations within the immediately surrounding area. For most current sources the contaminative potential is reduced due to modern working practices and extensive areas of hardstanding materials.
- Surrounding historical landfills and areas of potentially infilled ground (e.g. ponds and excavations).
- Cemetery.

9.4 Potential Pathways

- Human health – inhalation of soil dust and vapours / ground gas, dermal contact and ingestion of soils, dust, and waters. Possible consumption of homegrown vegetables and ingestion of soil attached to vegetables following development of the site.
- Controlled waters – vertical and lateral migration of leached / dissolved contaminants in groundwater through the ground via permeable strata, discontinuities, or man-made features (e.g. foundations and service trenches) and surface water run-off / overland flow over low permeability strata at the surface.
- Ground gas – migration, ingress, and accumulation with both vertical and lateral migration via permeable strata and man-made features (e.g. foundations and services) and lateral migration via groundwater.
- Buildings/infrastructure – direct contact of contaminated soils / groundwater with building materials and ground gas ingress / accumulation.
- Flora and Fauna – ingestion and root uptake.

9.5 Potential Receptors

- Human health – current site users, future site users / occupiers, construction workers, and the general public / adjacent site users (includes residential properties and the school to the south).
- Controlled waters – groundwater within superficial Secondary A and Secondary Undifferentiated Aquifers, groundwaters within bedrock Principal Aquifer and Secondary B Aquifer and surface waters (Rochdale Canal and River Medlock). Groundwater within the deeper Principal Aquifer is considered to be the most

sensitive groundwater receptor. Moston Brook has been discounted on the basis that it lies on the other side of the Rochdale Canal, is mostly culverted and is not located within influencing distance of the site.

- Buildings / infrastructure (existing and proposed).

9.5.1 For further details about pathways, receptors etc. please refer to the WA Combined Phase I & Phase II Ground Investigation Report dated May 2020. To avoid repetition the pathways, receptors and identified contaminant linkages are also discussed in further detail in the revised CSM undertaken in Section 16.

9.6 Preliminary Environmental Risk Assessment

9.6.1 In accordance with the EA Land Contamination: Risk Management June 2019 (LCRM) guidance, the information gathered throughout this report has been used to carry out a Preliminary Risk Assessment.

9.6.2 The CIRIA document Contaminated Land Risk Assessment – A Guide to Good Practice C552, 2001 defines the ‘Consequence of Risk’, ‘Probability of Risk Being Realised’ and ‘Risk Classification Definition’. These definitions are provided in Appendix E and are used to provide a preliminary qualitative risk assessment for each identified source, pathway, receptor linkage.

9.6.3 The combined CSM and preliminary qualitative risk assessment for each identified source, pathway, receptor linkage can be found in the Table 9.1.

Table 9.1: Combined CSM & Preliminary Quantitative Environmental Risk Assessment

Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
Contamination in soil/shallow perched groundwater noted in the CSM originating from the following on-site sources: 1. Made Ground associated with site's former historic uses. 2. Site's former use as brickworks with clay extraction pits. 3. Site's former uses as historic	Human Health (inhalation, dermal contact and ingestion).	Future site users	Moderate	Likely	Moderate (Low with mitigation)	The most sensitive receptor in this scenario would be a child. Hardstanding in the form of roads and pavements will be present across most of the site, reducing the potential for most pathways to be present. However, pathways could still be present in gardens and areas of soft landscaping. Remediation and mitigating measures will be required to protect future site users, and this would likely include clean cover systems within private gardens / areas of soft landscaping. Following remediation, the consequence of any risk being realised would be reduced.
		Current site users	Medium	Low	Low to Moderate	The site is derelict and has infrequent use (e.g. trespassers, dog walkers). Fly tipped materials are present, but pathways and long-term exposure are limited.
		Construction workers	Medium	Likely	Moderate (Low with mitigation)	Less sensitive receptor in this instance (adult). Increased risk to construction workers due to acute interaction with soils. Asbestos fibres have been recorded within soils above the threshold for human health and airborne fibres could be generated. No acute GAC exceedences noted. Risk to construction workers can be managed through the

Table 9.1: Combined CSM & Preliminary Quantitative Environmental Risk Assessment

Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
and registered landfill. 4. Former reservoir (possibly infilled) 5. Perched groundwater within the made ground / landfill. 6. Fly tipped materials & bund along the site's eastern boundary						use of appropriate and safe working procedures, the use of appropriate PPE and suitable mitigating measures to deal with asbestos fibres.
		Adjacent site users	Medium	High Likelihood	High (Low with mitigation)	The most sensitive receptor is a child. Contaminated shallow perched groundwaters have been historically observed seeping out of the ground and migrating to sensitive off-site receptors following heavy rainfall. However, an impermeable bund and drainage channel has since been installed to divert these waters back onto the site and away from off-site receptors. During development of the site contaminated soils and shallow perched groundwaters will likely be exposed and the risk of migration to off-site receptors (e.g. windblown soils or surface water run-off) would be increased. However, it is unlikely that contaminants from on-site would migrate off-site in large quantities or at the concentrations recorded on-site. Risks could be reduced by undertaking development works in accordance with a CEMP. Some form of leachate / shallow perched groundwater mitigation may be required to prevent future groundwater seepage to off-site receptors.

Table 9.1: Combined CSM & Preliminary Quantitative Environmental Risk Assessment

Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
	Controlled waters (migration of groundwater through the ground and surface water run-off / overland flow).	Bedrock Principal Aquifer	Medium/Severe	Unlikely	Low	Increased risk to the Principal Aquifer due to its sensitivity. However, there are no sensitive licenced groundwater abstractions within 1km of the site and the site does not lie within an SPZ. A substantial covering thickness of low-permeability cohesive Glacial Till (i.e. a geological barrier) is indicated from BGS data with previous WA site investigation data also indicating a substantial thicknesses of Glacial Till (between 25m and 40m thick) that confines the underlying Principal Aquifer.
		Bedrock Secondary B Aquifer	Mild	Unlikely	Very Low	The bedrock Secondary B Aquifer is not considered to be overly sensitive and is likely acting as a barrier to groundwater flow for the Principal Aquifer. As outlined above, it is also covered by a substantial thickness of predominantly low permeability Glacial Till (i.e. a geological barrier).
		Superficial Secondary Undifferentiated Aquifer	Mild	Low	Low	The superficial Secondary Undifferentiated aquifer is not considered to be overly sensitive and typically comprises low permeability Glacial Till. However, pathways do exist in places from the landfill to sand and gravel lenses within the till, where these directly underlie the landfill, and

Table 9.1: Combined CSM & Preliminary Quantitative Environmental Risk Assessment

Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
						exceedences of contaminants have been recorded but the levels of contaminants observed within Made Ground were generally not reflected within shallow or deep natural deposits. Furthermore, the granular lenses are indicated to be discontinuous and not in continuity with other groundwater or surface water bodies, so the overall impact is indicated to be relatively localised.
		Superficial Secondary A Aquifer	Medium	Unlikely	Low	The superficial Secondary A Aquifer encroaches slightly into the north western section of the site and is likely to be of limited extent. Pathways are considered unlikely for the reasons outlined above for the Secondary Undifferentiated Aquifer.
		Rochdale Canal	Medium	Low	Low to Moderate (Low with mitigation)	The Rochdale Canal is moderately sensitive (WFD Cycle 2 2019 Overall Classification: Moderate) but is assumed to be clay lined and natural glacial clays are indicated along the northern boundary of the site negating most lateral migration pathways of groundwater from the site. No outfalls are recorded from the site to the canal. However, the site is slightly elevated from the canal along its northern boundary so surface waters and very shallow perched groundwater with leached contaminants could

Table 9.1: Combined CSM & Preliminary Quantitative Environmental Risk Assessment						
Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
						migrate to the canal at this location. Elsewhere, surface waters will migrate downgradient to the south west. Furthermore, significant leaching is unlikely to occur as any waters are likely to migrate to the canal fairly quickly. While groundwater flooding has not been observed adjacent to the canal there is a possibility that this could occur, but this is considered relatively unlikely as perched groundwater is indicated to be migrating away from the canal. Increased risks to the canal are envisaged during development of the site, but this could be mitigated through the use of a CEMP.
		River Medlock	Mild	Unlikely	Very Low	The River Medlock is not overly sensitive (WFD Cycle 2 2019 Overall Classification: Moderate), and pathways are limited due to the distance to the receptors, the presence of predominantly low permeability Glacial Till between the site and the river and in some instance's barriers to surface water runoff / overland flow. While granular lenses are present within the Glacial Till, the ground model for the site indicates that these are relatively isolated, and continuity is not indicated over such a large distance.

Table 9.1: Combined CSM & Preliminary Quantitative Environmental Risk Assessment

Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
	Buildings / Infrastructure (Direct contact)	Future and existing buildings and water pipes	Mild	Likely	Low to Moderate (Low with mitigation)	Elevated and widespread concentrations of aggressive contaminants (e.g. sulphates and PAH) are widespread and would have the ability to degrade concrete or water pipes. Mitigating measures could include concrete design to withstand chemical attack and barrier pipe / ductile pipes for water supply pipes.
	Flora and Fauna	Existing vegetation and potential fauna on site and future vegetation	Minor	Likely	Low	Vegetation clearance has recently been undertaken but grasses, shrubs and tree stumps etc. still remain that have developed within contaminated soils. Future vegetation may be planted at the site and may come into contact with contaminated soils.
On-site ground gas sources and vapour sources including Made Ground / landfill, former infilled reservoir and groundwaters.	Buildings (gas / vapour migration, ingress and accumulation).	Future site users	Severe	Likely	High (Low with mitigation)	Significant thicknesses of Made Ground (up to 14.8m) have been identified within the historical landfill with abundant degradable constituents. A moderate ground gas generation potential is envisaged, based on the age of the landfill and the recorded waste types.
	Human Health (inhalation)	Future on-site buildings	Severe	Likely	High (Low with mitigation)	Elevated ground gas concentrations and flow rates have been recorded and previous WA monitoring visits are generally indicative of CS2 and a worst-case possible scenario of CS4. Previous WA data also indicates that there is a risk vapours could be generated from soils and

Table 9.1: Combined CSM & Preliminary Quantitative Environmental Risk Assessment

Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
						groundwater. SVOC/VOC concentrations were also noted from the groundwater seepage sample from the perched groundwaters within the Made Ground. Ground gas and vapour protection are envisaged for new buildings on-site and this could mitigate the risk.
		Current site users	Mild	Unlikely	Very low	Current site users are infrequent (e.g. trespassers, dog walkers) and activities are undertaken in open atmosphere so the risk to current site users is very low.
		Adjacent site users	Severe	Unlikely	Low to Moderate (Low with mitigation)	Based on previous and more recent site investigations, pathways to off-site receptors are considered unlikely due to the natural clay deposits that are indicated along the site's boundaries. Possible pathways are indicated within the south easternmost corner of the site where historic excavations appear to have extended off-site.
		Adjacent buildings	Severe	Unlikely	Low to Moderate (Low with mitigation)	However, these are indicated to be relatively isolated from the main excavations that occurred on-site, and recent data indicates that only low gas concentrations have been recorded in this area. Mitigation measures could include gas venting trenches along site boundaries to reduce the risk.

Table 9.1: Combined CSM & Preliminary Quantitative Environmental Risk Assessment

Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
Off-site historic and current sources as outlined in the CSM.	Inhalation, dermal contact and ingestion	Future site users	Medium	Low	Low to Moderate (Low with mitigation)	It is unlikely that soil bound contaminants from off-site (unless fully exposed) have made their way to site in large quantities. However, contamination from historic surrounding land uses may have been landfilled at the site. Most of the surrounding area is also developed, so any significant sources of contamination are likely to have been removed or covered thereby breaking the pollutant pathway linkage.
		Current site users	Medium	Low	Low to Moderate (Low with mitigation)	
		Construction workers	Medium	Low	Low to Moderate (Low with mitigation)	
	Migration of groundwater through the ground and surface water run-off / overland	Bedrock Principal Aquifer	Medium/Severe	Unlikely	Low	In most cases migration of contaminants to the site via surface water / overland flow is unlikely due to the distance of the sources from the site, the presence of physical barriers and that interception by local drainage in developed areas is likely to occur. Migration of groundwater through the ground is unlikely due to the
		Bedrock Secondary B Aquifer	Mild	Unlikely	Very Low	

Table 9.1: Combined CSM & Preliminary Quantitative Environmental Risk Assessment

Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
	flow to those receptors beneath the site	Superficial Secondary A Aquifer	Medium	Unlikely	Low	predominantly low permeability of the surrounding Glacial Till (i.e. a geological barrier). High permeability is envisaged for the Principal Aquifer, but a significant cover of low permeability Glacial Till is present. The geological fault and Manchester Marls could also be acting as a geological barrier to lateral groundwater flow for deep groundwater within bedrock. While outfalls to the canal may be present from off-site sources, continuity between the groundwater beneath the site and the Rochdale Canal is not indicated.
		Superficial Secondary Undifferentiated Aquifer	Mild	Unlikely	Very Low	
		Rochdale Canal	Medium	Unlikely	Low	
	Direct contact	Existing and future buildings and water pipes	Mild	Unlikely	Very Low	See previous sections regarding the contaminative potential for off-site sources and the potential pathways for soils and groundwater that may be aggressive to buildings and water pipes.
Other off-site ground gas and vapour sources including: 1. Potential areas of infilled land	Gas migration, ingress, and accumulation	Future site users	Medium	Unlikely	Low (Very low with mitigation)	These sources are anticipated to have a low to moderate ground gas generation potential, so the consequence is reduced. However, pathways to the site are unlikely due to the predominantly low permeability of the surrounding Glacial Till. Gas concentrations recorded for those monitoring wells adjacent to the site's south eastern boundary are relatively low and indicate that the
		Current site users	Medium	Unlikely	Low	

Table 9.1: Combined CSM & Preliminary Quantitative Environmental Risk Assessment						
Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
2. Historic landfills 3. Cemetery					(Very low with mitigation)	potential for ground gas generation / migration from the infilled ground adjacent to the site’s south eastern boundary is limited. Ground gas protection is likely to be required to mitigate the ground gas risk from on-site sources so this will further reduce the risk from off-site sources.
		Existing and future buildings	Medium	Unlikely	Low (Very low with mitigation)	
Notes						
*1 Considers both the potential severity of the hazard and the sensitivity of the receptor. Where applicable, the most sensitive receptor / hazard has been used for the overall assessment.						
*2 Considers both the presence of the hazard and the integrity of the pathway. Where applicable, the most likely hazard / pathways have been used for the overall assessment.						

10 GROUND INVESTIGATION DETAILS

10.1 Introduction

10.1.1 In addition to historical third-party investigations as outlined in Section 8, WA has now undertaken four phases of investigation at the site. Each phase of WA investigation is summarised below. Although the historical third-party investigation data is useful for comparison, given the time that has elapsed and potential changes which have occurred at the site since it was undertaken, the results from the recent WA investigations have been relied upon to assess the current condition of the site.

10.1.2 Drawing LD10385-003 shows the most recent and previous WA exploratory hole locations, as well as the third-party exploratory hole locations.

10.2 2019 WA Ground Investigation

10.2.1 WA were commissioned by Vertase FLI Ltd (Vertase) to undertake a ground investigation at the site to assess the geotechnical nature of the ground, investigate the depth / nature of the Made Ground, and confirm the findings of previous site investigation works. Briefly, the works comprised:

- Investigation works were carried out between the 19th to 28th June 2019.
- Excavation of 35 No. trial pits to depths of between 0.80m and 6.70m bgl (TP01, TP03-04, TP06-07, TP09, TP12, TP14-19, TP22-27, TP29-30, TP34-36, TP38-41, TP44-46, TP49, TP53-54 and TP58).
- Drilling of 6 No. cable percussion boreholes to depths of between 5.70m and 11.50m bgl (BH01 to BH06).
- Drilling of 3 No. windowless sample boreholes to depths of between 2.00m and 8.00m bgl (WS01 to WS03).
- Installation of 4 No. monitoring wells (BH02, BH04, BH05 and BH06) for future groundwater and gas monitoring / sampling.
- 4 No. soil samples and 2 No. groundwater samples were obtained from site and delivered to an independent UK Accreditation Services (UKAS) accredited laboratory under the instruction of Vertase FLI.

10.2.2 For further details please refer to the WA “Factual Site Investigation Report” dated July 2019.

10.3 2020 WA Ground Investigation

10.3.1 WA were commissioned by YHG to undertake a comprehensive ground investigation at the site to address specific items identified from a gap analysis undertaken in June 2020 and to undertake a qualitative risk assessment and identify the potential geo-environmental risks and liabilities associated with the site. Briefly, the works comprised:

- Investigation works were carried out between the 5th October and 6th November 2020.
- Excavation of 50 No. trial pits to depths of between 1.2m and 5.4m bgl (TP101-150).
- Drilling of 19 No. cable percussion boreholes to depths of between 8.0m and 20.4m bgl (CP101-110, CP112-114 and including four predrills for RH103, RH108-110).
- Drilling of 7 No. rotary open hole and cored boreholes to depths of between 19.5m and 45m bgl (RH101-103, RH106 and RH108-110).
- Drilling of 14 No. windowless sample boreholes to depths of between 4.45m and 5.45m bgl (WS101-109, WS111-113 and WS119-120).
- Excavation of 5 No. trial pits for soakaway testing purposes to depths of between 1.70m and 2.00m bgl (SA01-05).
- Installation of 25 No. monitoring wells for future groundwater and gas monitoring / sampling.
- 91 No. soil samples, 14 No. groundwater samples (following development and purging), 3 No. surface water samples and a single “groundwater seepage” sample were obtained from site and delivered to an independent UK Accreditation Services (UKAS) accredited laboratory for a standard suite of brownfield determinands, as well as likely contaminants of concern (CoC) identified in previous site investigation reports.
- Regular samples were screened on site for the presence of ionisable volatile organic compounds using a photo-ionisation detector (PID) with a 10.6 eV lamp.

- In-situ testing that included regular hand shear vane and Standard Penetration Testing (SPT) with sampling and subsequent geotechnical laboratory testing of the underlying natural superficial deposits and Made Ground.
- 9 No. Post fieldwork ground gas and groundwater monitoring visits were carried out between the 30th November 2020 and 25th March 2021.
- During the ground investigation works many of the originally planned investigation positions had to be altered or were terminated due to areas being inaccessible (mostly due to dense vegetation, ecological constraints, or the presence of Japanese knotweed) and to take account of changes to the ground model as the works progressed.

10.3.2 For further details, including those other works that were undertaken (e.g. mitigation measures for ecology), please refer to the WA “Combined Phase I and Phase II Ground Investigation Report” dated May 2021.

10.4 **2021 WA Ground Investigation**

10.4.1 WA were commissioned by YHG to undertake additional site investigation works that had been conditioned by the regulators to address information gaps associated with the delineation of previously identified “free phase” products at the site. Briefly, the works comprised:

- Investigation works were carried out between the 2nd and 6th August 2021.
- 48 No. Optical Interface Probing (OIP) tests and 12 No. Membrane Interface Profiling tool (MIP) tests between ground level and 10.2m bgl. These tests were undertaken using a 20-tonne tracked CPT crawler rig.

10.4.2 For further details, please refer to the WA “Ground Investigation Report” dated September 2021.

10.5 **2022 WA Ground Investigation**

10.5.1 The most recent ground investigation commissioned by YHG was carried out by WA between 14th March and 9th May 2022 and comprised additional site investigation works to address planning conditions imposed by the regulators. The investigation was designed to take account of previous third party and WA investigation information and the investigation points were positioned to primarily target those areas that were previously inaccessible during previous phases of site investigation.

10.5.2 The scope of the works was submitted to the EA in a letter dated 13th January 2022 (ref: JC/LD10385/LET-001) to which they responded in a letter dated 16th February 2022 (ref: SO/2020/120757/05-L01) agreeing with the scope and investigation methodologies proposed for the works.

10.5.3 The investigation, including sampling techniques, were carried out in general accordance with BS5930:2015, Code of Practice for Ground Investigations, BS10175: 2017 Investigation of Potentially Contaminated Sites and the investigation methodologies agreed with the EA as outlined above.

Pre-ground Investigation Works

10.5.4 Pre-ground investigation works were undertaken at the site early March 2022 and the scope of these works were generally as follows:

- Production of Risk Assessments and Method Statements (RAMS) and Construction Design and Management (CDM) documentation to ensure compliance with CDM Regulations 2015. The main drilling contractor (Geotron UK Limited) adopted the role of Principal Contractor and undertook all the necessary duties and produced the relevant documentation to comply with CDM 2015 Regulations.
- Vertase FLI provided a document “Japanese Knotweed Control Measures to Prevent the Spread of JKW” for working within the areas where JKW was known to be present and provided a JKW Specialist for the duration of the ground investigation works. All the JKW elements associated with the additional ground investigation works were the responsibility of Vertase FLI.
- Surveying of all exploratory hole positions by GPS with utility clearance that was undertaken by appropriately qualified third-party surveyors.
- Vegetation clearance was undertaken by a third party, but these works were ongoing at the time of the additional site investigation. While most areas were accessible there were some areas that could not be accessed at various points during the investigation and some positions had to be relocated as outlined in 10.5.8.

Ground Investigation Works

10.5.5 The ground investigation was undertaken at the site between the 14th March and 09th May 2022 and the scope of these works was generally as follows:

- 58 No. trial pit excavations to depths of between 0.60m and 5.50m bgl using a tracked excavator and a JCB 3CX, to further establish the thickness, extent, and characteristics of the underlying Made Ground within those areas that were inaccessible during previous investigations and to identify / delineate buried highwalls.
- 10 No. cable percussion boreholes to depths of between 14.95m and 20.10m bgl to prove the depth of the Made Ground in areas that were inaccessible during the previous stages of investigation and to further establish the characteristics of the underlying natural superficial deposits. Groundwater monitoring installations, with response zones at various depths, were constructed within these boreholes.
- 6 No. rotary boreholes to depths of between 41.50m and 50.30m bgl to validate the depth to rockhead and increase confidence in the superficial thickness model. Groundwater monitoring installations, with response zones at various depths within the underlying Principal Aquifer, were constructed within these boreholes. Cable percussion drilling was used to drill through the landfill materials and upon encountering the natural superficial deposits, rotary coring commenced primarily using water flush and Geobore S (i.e. wireline drilling) to recover high quality core samples from the natural superficial deposits and solid geological strata. This method also enabled the borehole to be fully cased at all times to optimise stability in areas of weak geology and minimised the transmission of pollutants while drilling.
- 18 No. windowless sample boreholes to depths of between 2.45m and 5.45m bgl to enable the installation of new groundwater monitoring wells with response zones within the shallow perched groundwater within Made Ground. A series of windowless sample boreholes were also drilled in the vicinity of the groundwater seepage and along the site's southern boundary to further quantify the risks in this area.
- Installation of 34 No. groundwater and ground gas monitoring wells within boreholes and windowless sampling holes (50mm diameter standpipe installations) with response zones intersecting either perched waters within Made Ground, perched waters within the natural superficial deposits or groundwater within the underlying Principal Bedrock Aquifer.

- Environmental sampling of soils from exploratory hole positions to enable laboratory analysis to be carried out to inform the assessment of the contamination within those areas that have previously not been investigated, enabling the risks to human health and controlled waters to be further quantified. 90 No. Samples were obtained in accordance with best practice and / or in line with the general guidance outlined within WA and Vertase FLI investigation methodologies that were enclosed with the scope of works submitted to the EA prior to the commencement of the works.
- In-situ testing (e.g. hand shear vane and SPT), sampling and subsequent geotechnical laboratory testing was also undertaken to obtain further geotechnical parameters to inform foundation design, road design, earthworks and to provide outline assessments for any ground related risks. SPT calibration certificates are included within Appendix P.
- Full time supervision by suitably qualified and experienced WA geoenvironmental / geological engineers.
- Provision of full-time security (day and night) for the duration of the works.
- Supervision and documentation by a suitably qualified Japanese knotweed Specialist for those exploratory hole positions and works that were to be undertaken within areas where Japanese knotweed was present.

10.5.6 The investigation was carried out in accordance with the Construction Design and Management (CDM) Regulations 2015, a WA site-specific Health & Safety Plan and Geotron's Construction Phase Plan.

10.5.7 Immediately prior to the commencement of intrusive works the exploratory hole locations were scanned using a calibrated Cable Avoidance Tool (CAT) and service inspection pits were hand excavated to 1.20m bgl.

10.5.8 During the site investigation works many of the original positions had to be altered slightly because the areas were inaccessible due to the vegetation clearance not having been completed for all areas of the site (i.e. they were ongoing while the site investigation works progressed) and due to constraints associated with the larger stands of Japanese Knotweed. Notable changes (relocation greater than 10m from the original position) are as follows:

- CP201 had to be relocated c. 45m north east since the original position was inaccessible.
- TP201 had to be relocated c. 12m north east since the original position was inaccessible.
- TP202 had to be relocated c. 35m south since the original position was inaccessible.
- TP211 had to be relocated c. 27m south east since the original position was inaccessible.
- TP218 had to be relocated c. 23m north west since the original position was inaccessible.
- TP219 had to be relocated c. 17m west since the original position was inaccessible.
- TP220 had to be relocated c. 15m north east since the original position was inaccessible.
- TP225 had to be relocated c. 15m east since the original position was inaccessible.
- TP225 had to be relocated c. 15m east since the original position was inaccessible.
- TP230 had to be relocated c. 25m west since the original position was on the main haul road that led from the compound area.
- TP234 had to be relocated c. 20m west since the original position was inaccessible.
- TP256 had to be relocated c. 10m south since the original position was inaccessible.
- WS304 had to be relocated c. 10m north east since the original position was inaccessible.
- WS308 had to be relocated c. 45m south east since the original position was inaccessible.
- WS313 had to be relocated c. 35m south east since the original position was inaccessible.

Post Ground Investigation Works

10.5.9 Post fieldwork activities included the following.

- 6 No. post fieldwork groundwater monitoring visits between the 5th May 2022 and 1st August 2022. Groundwater level monitoring was undertaken using a Solinst interface meter.
- Well development was undertaken between the 5th and 6th May 2022 using an inertial pumping system comprising high flow inertial HDPE pump tubing and foot valves operated by a Waterra Groundwater Sampling Pump System. Due to the depth of the monitoring installations within the rotary boreholes these were developed using air-lifting techniques. Development records are contained within Appendix K.
- 2 No. rounds of groundwater sampling have been undertaken. The first round of groundwater sampling was undertaken on the 19th May 2022 and the second round was undertaken between the 15th and 22nd June 2022. In all instances, monitoring wells were purged before sampling. Low flow sampling, using a peristaltic pump was undertaken for shallow monitoring wells and those monitoring wells where samples were to be obtained for PFAS laboratory analysis. For the deeper monitoring wells samples were obtained using the previously mentioned Waterra Pump System. In both instances, parameters were measured using an Aquaread Probe. Purging records are contained within Appendix K.

10.6 Laboratory Testing

10.6.1 Details of the sampling and laboratory testing carried out across all four phases of WA investigations are summarised in Table 10.1.

Environmental / Chemical Laboratory Testing

10.6.2 Soil samples were submitted for laboratory analyses to establish the type, level and distribution of the possible contaminants that may be present on the site. Samples were obtained at regular depths, changes in strata, where visual and / or olfactory evidence of contamination was encountered and at other discrete horizons recognised as having a high potential to retain contaminants.

10.6.3 Samples were also selected to provide sufficient data to facilitate a quantitative human health risk assessment, inform controlled waters risk assessment and to provide an early indication of potential remedial requirements.

10.6.4 The schedule of samples obtained by WA and analysed for each stage of ground investigation is presented below in Tables 10.1 and 10.2.

Table 10.1: Summary of Soil Chemical Analysis 2020	
Substances	No. Soil Samples
General inorganics	56
Cyanide	69
Asbestos ID	56
Total Phenols	79
Speciated PAHs and Total PAHs	75
Metals/Metalloids	56
Total Petroleum Hydrocarbons (TPH)	71
Soil Organic Matter (SOM)	56
Benzene, Toluene, Ethylbenzene and Xylene (BTEX)	68
Methyl Tertiary Butyl Ether (MTBE)	68
Semi Volatile Organic Compounds (SVOC)	15
Volatile Organic Compounds (VOC)	13
Polychlorinated Biphenyls (PCB)	21
Leachate	9

Table 10.2: Summary of Soil Chemical Analysis 2022	
Substances	No. Soil Samples
General inorganics	65
Cyanide	65
Asbestos ID	73
Total Phenols	65
Speciated PAHs and Total PAHs	65
Metals/Metalloids	65
T Total Petroleum Hydrocarbons (TPH CWG)	78
Soil Organic Matter (SOM)	65
Benzene, Toluene, Ethylbenzene and Xylene (BTEX)	78
Methyl Tertiary Butyl Ether (MTBE)	79
Semi Volatile Organic Compounds (SVOC)	77
Volatile Organic Compounds (VOC)	77
Polychlorinated Biphenyls (PCB)	65
PFAS	19
PFAS (Post Oxidation)	4

10.6.5 All soil chemical analysis were undertaken by ALS Environmental in their UKAS and MCERTs accredited laboratory. The results of the soil chemical analyses are attached at Appendix H.

Chemical Analysis of Waters

10.6.6 During the 2020 WA site investigation, a total of 14 No. groundwater samples, 3 No. surface water samples and a single groundwater seepage sample were submitted for environmental laboratory analyses to establish the type, level and distribution of the possible harmful contaminants that may be present within groundwater and surface waters.

10.6.7 Samples were obtained following purging with sampling being undertaken using an inertial pumping system comprising high flow inertial HDPE pump tubing and foot valves operated by a Waterra Groundwater Sampling Pump System as previously described.

10.6.8 The schedule of samples obtained by WA and analysed during the 2020 ground investigation are presented below in Table 10.3 .

Table 10.3: Summary of Groundwater / Surface Water Chemical Analysis Schedule 2020	
Substances	No. Samples
General Parameters and Inorganics	15
Total Phenols	15
Speciated PAHs	15
Metals/Metalloids	15
TPH CWG	15
SVOC	15
VOC	15

10.6.9 During the 2022 WA site investigation, a total of 20 No. groundwater samples and three surface water samples were submitted for environmental laboratory analyses to establish the type, level and distribution of the possible harmful contaminants that may be present within groundwater and surface waters.

10.6.10 Samples were obtained following purging and using a mixture of low flow sampling techniques and an inertial pump system as outlined previously.

10.6.11 The schedule of samples obtained by WA and analysed during the 2020 ground investigation are presented below in Table 10.4 .

Table 10.4: Summary of Groundwater / Surface Water Chemical Analysis Schedule 2022	
Substances	No. Samples
General Parameters and Inorganics	20
Total Phenols	20
Speciated PAHs	20
Metals/Metalloids	20
TPH CWH	15
SVOC	20
VOC	20
PFAS	9
PFAS (Post Oxidation)	7

10.6.12 All tests were performed in UKAS accredited laboratories. The results of the groundwater chemical analyses are attached at Appendix H.

10.7 Geotechnical Laboratory Testing

10.7.1 During the 2020 WA site investigation, samples were submitted to Professional Soils Laboratory (PSL) for geotechnical testing. All the tests were performed in accordance with BS1377:1990 'Soils for Civil Engineering Purposes'.

10.7.2 A summary of the geotechnical testing undertaken during the 2020 WA site investigation is presented in Table 10.5 .

Table 10.5: Summary of Geotechnical Laboratory Testing 2020	
Geotechnical Test	No. of Tests
Natural moisture content	19
Particle size distribution (PSD)	13
PSD sedimentation	12
Atterberg limits	17
Compaction (2.5kg rammer)	18
One Dimensional Consolidation Test	7
Unconsolidated Undrained Triaxial Compression	12
BRE full suite	13
Calorific value	3
Determination of the potential expansion of steel slags	3

10.7.3 During the 2022 WA site investigation, samples were submitted to Professional Soils Laboratory (PSL) for geotechnical testing. All the tests were performed in accordance

with BS1377:1990 'Soils for Civil Engineering Purposes'.

10.7.4 A summary of the geotechnical testing undertaken during the 2022 WA site investigation is presented in Table 10.6 .

Table 10.6: Summary of Geotechnical Laboratory Testing 2022	
Geotechnical Test	No. of Tests
Natural moisture content	41
Particle Density	21
Particle size distribution (PSD)	41
PSD sedimentation	13
Atterberg limits	14
Compaction (2.5kg rammer)	29
One Dimensional Consolidation Test	5
Unconsolidated Undrained Triaxial Compression	5
BRE full suite	32
Organic matter	23
Determination of the potential expansion of steel slags	4

10.7.5 All tests were performed in accredited geotechnical and geochemical laboratories, in accordance with the appropriate British Standard.

10.7.6 For both the 2020 and 2022 WA site investigations, additional moisture content, organic matter and sulphate tests were undertaken as part of the environmental laboratory testing.

10.7.7 The results of the geotechnical and geochemical analyses are attached at Appendix M.

10.8 Quality Assurance (QA) and Quality Control (QC)

10.8.1 The soil samples were collected, transferred to the laboratory under chain of custody and analysed to ensure traceability and reliability of analytical results. All testing was undertaken in approved Environment Agency Monitoring Certification Scheme (MCERTS) and UK Accreditation Services (UKAS) accredited laboratories. Based on the laboratory QA data, the analytical results are considered acceptable for interpretative use unless this has otherwise been stated.

11 GROUND AND GROUNDWATER CONDITIONS

11.1 General

11.1.1 The ground and groundwater conditions encountered at the site are discussed in the sections below and are based on information obtained from the various WA site investigations undertaken between 2019 and 2022. Ground and groundwater conditions from the Celtic 2007 site investigation are summarised in Section 8 and where relevant, further details have been included below.

11.1.2 For detailed descriptions please refer to the exploratory logs contained within Appendix F. Cross sections are included within Appendix N and an overall 3D Ground Model is shown in Drawings LD10385-010 to LD10385-014.

11.2 Topsoil Fill

11.2.1 Topsoil fill occurred across most of the site and typically comprised a soft to firm, brown, slightly sandy to sandy, slightly gravelly to gravelly Clay with frequent rootlets and occasional cobble sized fragments of red brick and concrete, that was on average 0.2m thick. Gravel sized constituents mainly included red brick and to a lesser extent concrete, timber, suspected slag / clinker, ceramic and glass. Other anthropogenic constituents were encountered locally, and this included plastic, timber, coal, slate, suspected ACM, fabric and wire.

11.3 Concrete

11.3.1 An in-situ concrete slab was encountered within the eastern section of the site at the location of the eastern historical brickworks. The slab was present from ground level to a maximum depth of 0.2m bgl and is estimated to occupy an area of approximately 900m².

11.4 Made Ground

11.4.1 Made Ground was encountered across the entire site and was proven to a maximum depth of 13.85m bgl within the central south western section of the site, although Made Ground up to 14.8m bgl was proven during previous investigations. An indicative Made Ground Contour Plan is shown in Drawing LD10385-006.

11.4.2 The Made Ground has been segregated into four distinct strata based on field descriptions; suspected colliery spoil, suspected construction and demolition waste, suspected combustion waste and suspected household waste. Made Ground that did

not clearly fit into one of these distinct strata was logged either cohesive or granular Made Ground depending on its engineering behaviour and was generally found to be intermixed with the above.

- 11.4.3 The spatial distribution of the various distinct Made Ground types is shown in Drawing LD10385-021. Typical descriptions of the Made Ground, and depths encountered, are summarised below.

Cohesive and Granular Made Ground

- 11.4.4 Cohesive Made Ground was encountered across the entire site from between ground level and 8.9m bgl to a depth of between 0.3m and 10.4m bgl. The material was generally intermixed with those other types of Made Ground and was typically recovered as a soft to firm, stiff in places, brown, slightly sandy (ashy in places), slightly gravelly Clay with frequent cobble and occasional boulder sized constituents. In order of decreasing abundance, the very coarse and gravel sized constituents mainly comprised red brick, sandstone, concrete and to a lesser extent suspected clinker, plastic, glass, timber, mudstone, suspected slag, ceramics, metal, coal and slate. Exotic anthropogenic constituents such as plastic bags, plastic sheeting, fabric etc. were encountered locally. Hydrocarbon / organic odours were occasionally encountered.
- 11.4.5 Granular Made Ground was encountered across the site from between ground level and 9.00m bgl to depths of between 0.10m and 12.70m bgl. The material was generally intermixed with those other types of Made Ground and was typically recovered as a brown, sandy (ashy in places), clayey Gravel with frequent cobble and occasional boulder sized constituents. In order of decreasing abundance, the very coarse and gravel sized constituents mainly comprised red brick, concrete, plastic, timber, glass, sandstone, suspected slag, suspected clinker, ceramics, slate, mudstone, coal and tile. Exotic anthropogenic constituents including plastic sheeting, plastic bags, fabric, coils of wire, metal, glass bottles, rolls of carpet, polystyrene, rubber, hardboard, leather, electronic boards, tyres etc. were occasionally encountered. Hydrocarbon odours / staining were encountered locally.

Made Ground – Suspected Combustion Waste

- 11.4.6 Suspected combustion type wastes were mainly encountered within the north western and to a lesser extent the south western, south eastern and north easternmost sections of the site (see Drawing LD10385-021). They generally correlate

with the recorded extents of the smaller clay pit excavation within the north western section of the site and to a lesser extent the south easternmost extent of the larger clay pit excavation that occupies the remainder of the site. The exceptions being the north westernmost, south western, north easternmost and south easternmost sections of the site, where these materials were encountered outside the recorded extents of the former clay pit excavations. This material was also intermixed with other material types at isolated locations within the central section of the site.

- 11.4.7 The material was recorded from between ground level and 6.0m bgl to depths of between 0.4m bgl and 8.0m bgl (between 0.1m and 4.8m thick). Within the south western section of the site these materials were of a limited thickness (on average 0.50m thick) and occurred as a thin veneer over natural ground. This material was typically recovered as a black to brown, very sandy / ashy Gravel with frequent cobble sized constituents. In order of decreasing abundance, the very coarse and gravel sized constituents mainly comprised suspected slag and clinker, red brick, timber and to a much lesser extent inclusions of clay, glass, concrete, metal, ceramics, slate, mudstone, sandstone, tile etc. Other anthropogenic constituents such as acetate flakes, plastic bags / sheeting, white paste etc. were also noted at isolated locations.
- 11.4.8 Celtic also encountered this material within similar locations to that noted above to depths of between 0.8m and 4.2m bgl. The material was typically logged as a brown to black, sandy / ashy, clayey Gravel of clinker and brick. Cobbles comprised brick and concrete.
- 11.4.9 Visual and olfactory evidence of contamination such as hydrocarbon odours, hydrocarbon staining to soils, iridescent sheens on groundwater, red dye and tar were occasionally noted, mostly within the north western section of the site.

Made Ground – Suspected Construction and Demolition Waste

- 11.4.10 Suspected construction and demolition type wastes were mainly encountered within the central section of the site and corresponded with the recorded extents of the larger clay pit excavation within this area (see Drawing LD10385-021).
- 11.4.11 This material was generally recorded from between ground level and 9.0mbgl to depths of between 0.35m and 13.85m bgl (between 0.1m and 5.3m thick). It was typically recovered as cobble to boulder sized constituents of red brick, concrete, metal and timber in a matrix of brown, sandy, clayey Gravel or very gravelly, clayey

Sand. In order of decreasing abundance, the very coarse to gravel sized constituents included glass, sandstone, slate, suspected slag, ash, mudstone, pipe fragments and tile etc. Exotic anthropogenic constituents, in order of decreasing abundance, included plastic bags / sheeting, glass bottles, bundles of fabric, rubber, polystyrene, plastic wrappers, bundles of wire and rare tyres, paint tins, cement bags, rope etc.

11.4.12 Celtic also encountered this material at similar locations and to depths of between 4.8m and >10.1m bgl. However, it was more widespread and generally mixed with other wastes types. The material was typically described as brown, clayey, sandy Gravels and Cobbles of brick, concrete, timber, glass, pottery and plastic.

11.4.13 Visual and olfactory evidence of contamination such as hydrocarbon odours, hydrocarbon staining to soils and acrid odours were occasionally noted.

Made Ground – Suspected Colliery Spoil

11.4.14 Suspected colliery spoil type materials occurred locally and were largely restricted to the north eastern section of the site and corresponds with the north eastern section of the larger clay pit excavation that occupied the central and eastern sections of the site (see Drawing LD10385-021) and is generally delineated by a slightly raised plateau that is present within this area of the site (see Drawing LD10385-005).

11.4.15 The material was generally recorded from between 0.15m bgl and 2.70m bgl to depths of between 0.6m bgl and 6.8m bgl (between 0.20m and 6.20m thick) and was typically recovered as a grey, weathered orangish brown in places, sandy, clayey Gravel with frequent cobble and boulder sized constituents. Gravel and cobble sized fragments mainly comprised mudstone and siltstone and to a lesser extent coal, sandstone, ironstone and brick. Ash, suspected slag and suspected clinker gravel were also intermittently encountered at some of the positions.

11.4.16 Suspected colliery spoil was encountered by Celtic in 2007 within seven exploratory holes. Strata descriptions are of limited detail, but the material was typically logged as a sandy, occasionally ashy, Gravel of mudstone and was proven to a maximum depth of 7.9m bgl.

Made Ground – Suspected Household Waste

11.4.17 The suspected household type wastes were typically recorded within the central south western part of the site, but also generally intermixed with the suspected construction and demolition type wastes within the central north western and central eastern parts

of the site (see Drawing LD10385-021). They also generally correspond to the deeper areas of Made Ground as shown in Drawing LD10385-006.

- 11.4.18 The material was encountered between ground level and 8.0m bgl to depths of between 0.2m and 9.0m bgl (between 0.1m and 3.8m thick) and was typically recovered as cobble to boulder sized constituents in a matrix of brown, sandy, very clayey Gravel or very gravelly, very clayey Sand. Various anthropogenic constituents were noted, and in order of decreasing abundance, included red bricks, plastic bags / sheeting, timber, glass, metal, bundles of fabric, concrete, glass bottles, rolls of carpet, ceramic, suspected slag / clinker, ash, pipe fragments, slate and rare cardboard, containers / drums, hardboard, wire, rope, flooring, polystyrene, rubber, disposable cups, toys etc.
- 11.4.19 Visual and olfactory evidence of contamination such as hydrocarbon odours, hydrocarbon staining to soils and water and putrid odours from shallow perched waters were noted.

11.5 Glacial Till Deposits

- 11.5.1 Glacial Till deposits were encountered across the site and were encountered from between ground level and 13.85m bgl to proven depths of between 34.8m and 44.5m bgl. This stratum predominantly comprised cohesive and to a lesser extent contained intermittent and laterally impersistent granular lenses as described below.
- 11.5.2 The cohesive Glacial Till deposits predominantly comprised firm to stiff (locally soft), brown, slightly gravelly, slightly sandy Clay with variable cobble and boulder content. Relatively isolated / localised lenses of a firm to stiff, laminated, brown, silty Clay were also encountered at varying depths.
- 11.5.3 The granular Glacial Till deposits predominantly comprised medium dense, brown, gravelly, clayey Sand and locally as medium dense brown, sandy Gravel; both of which were locally water bearing. It was generally encountered within cohesive Glacial Till as intermittent / discontinuous lenses that varied in thickness between 0.05m and 12m thick (on average 2.4m thick). These lenses were generally encountered within the eastern section of the site as shown in the cross sections contained with Appendix N and the 3D model screenshots in Drawings LD10385-010 to 014.
- 11.5.4 Site investigation works undertaken by Celtic identified the Glacial Till as firm to stiff, locally soft, brown, slightly sandy to sandy, gravelly Clay and to a lesser extent yellow

/ grey, gravelly coarse Sand. The granular materials were also encountered within cohesive Glacial Till as intermittent / discontinuous lenses that were proven between 0.4m and 13.8m in thickness. It should be noted that the solid geology recorded by Celtic has since been proven to be Glacial Till and corrections have been made to identify the above trends.

11.6 Bedrock – Collyhurst Sandstone Formation and Chester Formation

11.6.1 During the WA 2020 and 2022 site investigation, bedrock was encountered in eight of the rotary boreholes from between 38.5m and 48.51 bgl and proven to depths of between at least 40.0m and 50.3m bgl. The full depth or thickness of bedrock was not proven during these site investigation works. However, the depth to rockhead is generally indicated to increase to the south west as illustrated in Drawing LD10385-008 and 009.

11.6.2 Bedrock of the Collyhurst Sandstone Formation was encountered in seven of the rotary boreholes and where intact core was recovered it typically comprised extremely weak to weak, laminated, reddish brown, fine to coarse grained Sandstone with well-rounded “millet seed” grains. Where core was non-intact it was typically recovered as a damp, reddish brown, gravelly Sand with well-rounded “millet seed” grains and to a lesser extent reddish brown, angular, fine to coarse GRAVEL of extremely weak, reddish-brown sandstone.

11.6.3 Bedrock of the Chester Formation was encountered in a single rotary borehole (RH206) within the north westernmost section of the site. No core could be recovered, but material from the flush returns it comprised reddish brown, fine to medium Sand with black, red, white and green grains and rare angular, fine, black gravel.

11.6.4 In both instances; where core was non-intact, this has been attributed to weaker / weathered material at rockhead and possibly scrubbing of the poorly cemented sandstone by the drill bit. In all such instances drillers noted that sandstone had been encountered and / or that drilling resistance had increased significantly.

Changes between WA 2020 and 2022 Site Investigations

Following the completion of the WA 2020 site investigations, a third-party site investigation was undertaken in December 2021 for the land immediately to the west of the site (former Mathers Foundry and Park Work). Several deep boreholes were

undertaken that indicated bedrock at c. 40m bgl as shown in Drawing LD10385-008 and 009.

In light of this additional information, these boreholes, and other surrounding BGS boreholes were reviewed. A bedrock contour was produced from this data, and it was evident that there were some anomalies in the WA 2020 dataset; most notably RH101 where the drillers had noted Mudstone at 15.0m bgl.

During the 2022 WA site investigation, another borehole (RH206) was drilled c. 8m east of RH101 and, upon encountering natural strata, was continuously rotary cored using Geobore – S drilling techniques. Solid core comprising cohesive Glacial Till and to a lesser extent non-intact core recovered as granular Glacial Till was encountered to a depth of 45m bgl, where sandstone bedrock was indicated. This was consistent with the local boreholes, the Site’s geological setting and the surrounding glacial landforms from BGS records (e.g. Buried Glacial Valley). Consequently, the “Mudstone” recorded at RH101 must have been stiff, overconsolidated, cohesive Glacial Till and this borehole log has since been corrected. Furthermore, a distinctive cobble layer comprising a variety of different rock types was often encountered directly overlying bedrock and this was absent at RH101.

Following the drilling of the 2022 rotary boreholes, RH108 and RH110 from the WA 2020 site investigation were also reviewed and for the same reasons as outlined above (including the absence of distinctive cobble layer) these logs have since been corrected to granular Glacial Till.

Comparisons with Celtic Site Investigation

- 11.6.5 During the 2007 Celtic investigation, bedrock comprising weathered mudstone and sandstone was encountered at depths of between 16.6m and 21.5m bgl and comprised beds of brown and yellow sandstone and brown mudstone. However, this information was based on rotary open hole information and no coring was undertaken.
- 11.6.6 Rotary coring was regularly undertaken during the WA 2020 site investigation and continuous rotary coring using Geobore – S drilling techniques was undertaken during the WA 2022 site investigation. The information collected from these boreholes, which were often in close proximity to the Celtic boreholes (e.g. RH106 was located

30m north of R1), and the multiple lines of evidence outlined above, have definitely proven the Celtic information to be incorrect.

11.7 Obstructions and Voids

11.7.1 Concrete and brick obstructions (including an above ground concrete slab) were occasional noted within the easternmost and north westernmost sections of the site where the former brick works buildings were located. Further unrecorded obstructions such as foundations and below ground infrastructure associated with the former brick works buildings may also be present.

11.7.2 Abundant cobble to large boulder sized constituents were also present within the various Made Ground types. Occasional obstructions in the form of natural cobbles and boulders were also encountered at varying depths within the Glacial Till Deposits.

11.7.3 No voids were encountered during the various stages of site investigation works that were undertaken. However, unrecorded voids may be present, possibly associated with poorly graded and compacted landfill materials, hollow anthropogenic materials or possible unrecorded basements beneath the former brickwork's buildings.

11.8 Groundwater

Water Strikes

11.8.1 During the WA 2019, 2020 and 2022 site investigations numerous shallow perched waters were encountered within Made Ground during the drilling of exploratory holes at depths of between 0.1m and 8.2m bgl (between 85.15m and 73.27m AOD). Shallow to deep perched groundwater strikes within the underlying natural superficial deposits were also encountered between 1.00m and 15.00m bgl (between 85.70m and 64.73m AOD). Water strikes within bedrock are suspected to have been encountered, but this could not be accurately determined due to the rotary drilling techniques used. Water strike elevations are shown in Drawing LD10385-017 and further details can be found within the exploratory hole logs contained within Appendix F.

11.8.2 During the 2007 Celtic site investigations numerous shallow perched waters were encountered within Made Ground during the construction of exploratory holes at depths of between 0.2m and 4.9m bgl. Shallow perched groundwater strikes within the underlying natural superficial deposits were also encountered between 1.1m and 8.2m bgl. Refer to Section 8 for further details.

Groundwater Monitoring

- 11.8.3 10 No. groundwater monitoring visits were undertaken by WA between November 2020 and March 2021 with a further 6 No. monitoring visits undertaken between May 2022 and August 2022.
- 11.8.4 Perched / shallow groundwater elevations within Made Ground were recorded between 85.11m and 75.43m AOD. Hydraulic gradients were variable but were generally noted to flow towards the deepest parts of the former clay pit excavations as shown in Drawing LD10385-019. For those wells where monitoring was undertaken during both periods of WA monitoring, elevations recorded from the 2022 dataset were generally noted to have dropped by between 0.23m and 1.15m (on average 0.50m). This is most likely due to seasonal variation, as the second round of monitoring was undertaken during late spring / early summer, while the former was undertaken during the autumn / winter period.
- 11.8.5 Perched groundwater elevations within Glacial Till were recorded between 83.25m and 63.32m AOD with variable hydraulic gradients being indicated (likely due to the isolated nature of these perched groundwaters) as shown in Drawing LD10385-020. For those wells where monitoring was undertaken during both periods of WA monitoring, elevations recorded from the 2022 dataset were generally noted to have dropped by between 0.46m and 2.06m (on average 1.35m). This is most likely due to seasonal variation, as the second round of monitoring was undertaken during late spring / early summer, while the former was undertaken during the autumn / winter period. The exception being CP113 where groundwater levels were noted to have risen by 1.23m.
- 11.8.6 Groundwater elevations within bedrock were recorded between 75.76m and 54.38m AOD and are generally indicative of a hydraulic gradient to the west south west as shown in Drawing LD10385-015; although it appears that the fault may be influencing the groundwater flow directions within the north westernmost section of the site.
- 11.8.7 Groundwater monitoring undertaken as part of the 2007 Celtic investigation indicates that shallow perched waters within Made Ground and underlying shallow Glacial Till were encountered at elevations of between 84.69 and 71.12m AOD. Celtic stated that these elevations were indicative of a hydraulic gradient to the south west. Deeper groundwaters within Glacial Till were recorded at elevations of between 79.86m and 74.28m AOD. Celtic stated that these elevations were generally indicative of a

hydraulic gradient to the south west and to a lesser extent the south east. For further details refer to Section 8.

- 11.8.8 During the WA 2020 and 2022 groundwater monitoring rounds, water levels were measured using a product / water interface probe. No free phase product was detected. Celtic also state that non-aqueous phase liquid (NAPL) was not encountered during the fieldwork and that no visual or olfactory evidence of contamination was noted.
- 11.8.9 The results from the groundwater monitoring that has been undertaken at the site from the WA 2020 and 2022 monitoring periods are summarised in Table 11.1 and 11.2. For further details refer to the groundwater monitoring results attached within Appendix J.

Table 11.1: Groundwater Elevations (m AOD) WA 2020 Dataset

Position	Dates										Response Zone Depths	Strata Screened
	09-11/11/20	30/11/20	14/12/20	06/01/21	21/01/21	01/02/21	16/02/21	25/02/21	08/03/21	25/03/21		
CP103a	80.56	80.71	80.84	81.18	81.5	81.48	81.33	81.27	81.16	80.93	8m to 10m	GT
CP103b	80.62	80.72	80.87	81.19	81.54	81.41	81.35	81.27	81.14	78.77	2m to 6m	MG
CP107	80.24	80.12	80.35	80.6	81.03	80.81	80.76	80.76	80.7	-	5m to 9m	MG
CP108	76.16	76.59	72.88	76.24	76.62	76.42	76.23	76.19	76.15	80.64	2m to 5m	MG
CP109	80.18	80.23	80.42	80.61	80.97	80.73	80.7	80.69	80.64	-	9m to 13m	MG
CP110	77.8	77.82	77.88	77.94	78.03	77.94	77.93	77.96	77.92	-	1m to 4m	MG
CP112/ RH103	76.76	69.99	76.08	80.52	80.99	80.75	80.59	80.5	80.48	77.71	27m to 30m	GT
CP113	79.38	79.16	Dry	79.49	80.03	79.84	79.58	79.78	79.35	-	2m to 3m	GT
RH101	67.3	74.58	75.04	74.86	75.38	75.28	75.15	74.97	74.9	80.47	17m to 20m	GT
RH102	79.95	80.01	80.1	80.28	80.78	80.49	80.46	80.42	80.27	80.93	12m to 13.5m	GT
RH106	54.75	54.1	54.31	-	-	-	-	-	-	-	39m to 42m	BR
CP114/ RH108	76.81	76.71	-	76.92	-	-	-	-	-	-	26m to 28m	GT
CP101/ RH109a	75.81	-	73.19	74.48	75.29	76.35	76.57	76.63	76.68	76.72	18m to 22m	GT
CP101/ RH109b	76.38	74.42	76.48	-	-	-	-	-	-	75.05	40m to 42.5m	BR
CP102/ RH110	62.24	62.7	-	-	-	-	-	-	-	66.13	35m to 39m	GT

Table 11.1: Groundwater Elevations (m AOD) WA 2020 Dataset

Position	Dates										Response Zone Depths	Strata Screened
	09-11/11/20	30/11/20	14/12/20	06/01/21	21/01/21	01/02/21	16/02/21	25/02/21	08/03/21	25/03/21		
WS101	83.13	83.57	83.57	83.57	83.57	83.57	81.94	83.57	83.57	-	1m to 2m	MG
WS102	83.45	83.36	83.72	83.49	83.86	83.65	83.38	83.38	83.33	75.35	1m to 2m	MG
WS103	75.85	75.8	75.91	75.96	76.22	76.08	75.6	75.83	75.81		1m to 2m	MG
WS104	79.5	79.57	79.86	79.91	80.23	80.21	80.04	79.92	79.79	79.89	1m to 2m	MG
WS105	80.44	80.48	80.56	80.81	81.19	81	81	80.91	80.89	78.82	1m to 2m	MG
WS106	78.98	78.91	79.3	79.02	79.62	79.33	79.12	79.26	78.73	84.33	1m to 2m	GT
WS107	85.44	85.41	85.69	85.38	85.69	85.53	85.39	85.47	85.23	84.53	1m to 2m	MG
WS108	83.53	-	-	85	85.05	85.01	84.99	85	84.87	77.15	1m to 2m	MG
WS109	Dry	Dry	Dry	Dry	77.06	76.44	76.25	76.24	76.21	Dry	1m to 2m	MG
WS111	78.75	78.85	79.2	79.2	79.2	79.2	79.2	79.2	78.98	79.16	1m to 2m	GT
WS112	Dry	Dry	Dry	Dry	78.4	78.14	78	Dry	Dry	Dry	1m to 2m	MG
WS113	82.65	82.66	83.97	84.11	84.09	84.12	84.6	84.12	84.1	-	1m to 2m	MG
WS119	Dry	Dry	Dry	82.88	83.05	83.05	82.84	82.87	82.85	80.32	1m to 2m	MG
WS120	80.77	80.77	80.93	80.76	81.15	80.94	80.77	80.7	80.71	83.19	1m to 2m	MG
BH04	-	81.64	81.68	81.67	81.01	81.81	81.73	81.7	81.67	-	3m to 5m	MG
BH06	-	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	2m to 4m	MG
Notes:												
MG = Made Ground, GT = Glacial Till & BR = Bedrock												

Table 11.2: Groundwater Elevations (m AOD) WA 2022 Dataset

Position	Dates									Response Zone Depths	Strata Screened
	05/05/2022	19/05/22	15/06/22	16/06/22	20/06/22	22/06/22	07/07/22	18/07/22	01/08/22		
CP101/ RH109	-	-	-	-	-	-	-	-	-	40m to 42.5m	BR
RH106	-	-	-	-	dry	-	dry	-	dry	39m to 42m	BR
RH201	-	-	-	56.722	-	56.802	56.662	56.802	56.822	39.5m to 41.5m	BR
RH202	-	54.637	-	-	-	-	-	-	54.607	46m to 50m	BR
RH203	-	-	-	54.562	-	-	54.392	54.232	54.322	47m to 50m	BR
RH204	-	54.593	-	-	-	-	54.513	54.383	-	45m to 46m	BR
RH205	-	-	54.759	54.759	54.759	-	54.649	54.759	54.759	48.1m to 49.6m	BR
RH206	-	54.962	-	-	-	-	55.242	54.922	54.972	45m to 48.1m	BR
CP201	80.546	79.946	-	79.946	-	-	79.526	79.366	79.456	2m to 7m	MG
CP202A	80.33	-	-	79.98	-	-	79.81	79.93	79.74	13m to 15m	GT
CP203	81.681	-	-	-	79.931	-	79.851	79.781	79.681	4.5 to 7.5m	GT
CP204	84.156	-	-	-	76.606	-	76.556	-	76.456	12m to 17m	GT
CP205	-	-	-	-	-	79.833	79.633	79.603	79.483	1m to 7m	MG
CP206	85.762	-	-	-	-	82.722	82.662	82.612	82.512	5m to 15m	GT
CP207	76.67	-	-	75.47	-	-	75.33	75.39	75.27	17.5m to 19m	GT
CP208	80.538	-	-	-	80.538	-	80.138	79.928	80.008	9m to 12m	GT
CP209	74.89	74.94	-	-	-	-	74.53	74.35	74.53	5m to 7m	GT
CP210	84.903	-	-	-	-	76.803	76.463	76.283	76.443	10m to 17m	GT
WS301	80.056	-	-	-	-	79.816	79.486	79.466	79.386	1m to 3m	MG

Table 11.2: Groundwater Elevations (m AOD) WA 2022 Dataset

Position	Dates									Response Zone Depths	Strata Screened
	05/05/2022	19/05/22	15/06/22	16/06/22	20/06/22	22/06/22	07/07/22	18/07/22	01/08/22		
WS302	79.133	-	-	-	79.233	-	79.273	79.173	79.183	1.5m to 5.45m	GT
WS303	80.445	-	-	-	79.895	-	79.865	79.845	79.795	1.5m to 5.45m	MG
WS304	dry	-	-	-	dry	-	dry	dry	80.602	1m to 4m	MG
WS305	-	-	-	-	75.974	-	75.614	75.444	75.504	2.5m to 4.45m	MG/GT
WS306	79.102	-	-	79.802	-	-	79.752	79.702	79.642	1m to 5m	MG
WS307	79.987	-	-	-	79.837	-	79.787	79.737	79.687	1.5m to 3.45m	MG
WS308	83.803	-	-	-	82.153	-	82.073	82.043	81.953	1m to 4m	MG
WS309	dry	-	-	-	77.562	-	77.552	77.562		2.5m to 4.45m	MG/GT
WS310	79.047	-	-	79.697	-	-	79.627	79.647	79.547	1.5m to 4.45m	MG
WS311	Dry	-	-	-	-	-	dry	dry	dry	1.5m to 2.45m	MG
WS312	83.984	-	-	-	84.064	-	83.964	83.934	83.834	2.5m to 5.45m	MG
WS313	Dry	-	-	-	-	Dry	Dry	Dry	dry	1m to 4m	MG
WS314	Dry	-	-	-	dry	-	Dry	Dry	dry	1.5m to 4.45m	MG
WS315	80.911	-	-	79.961	-	-	79.521	79.361	79.441	1m to 4m	MG
WS316	78.092	-	-	-	77.242	-	76.792	76.642	76.622	2.5m to 4.45m	MG/GT
WS317	77.939	-	-	-	-	76.639	76.779	-	76.609	1.5m to 3.5m	MG
WS318	-	75.891	-	-	-	-	75.381	75.201	75.261	2.5m to 5.45m	MG/GT
CP103a	-	-	-	-	-	-	-	-	81.10	8m to 10m	GT
CP103b	-	-	-	-	-	-	-	-	80.89	2m to 6m	MG
CP107	-	-	-	-	-	-	80.1	79.98	80.50	5m to 9m	MG

Table 11.2: Groundwater Elevations (m AOD) WA 2022 Dataset

Position	Dates									Response Zone Depths	Strata Screened
	05/05/2022	19/05/22	15/06/22	16/06/22	20/06/22	22/06/22	07/07/22	18/07/22	01/08/22		
CP108	-	-	-	-	75.83	-	-	75.57	76.25	2m to 5m	MG
CP109	-	-	-	80.22	-	-	80.1	80.05	80.50	9m to 13m	MG
CP110	-	-	-	-	-	-	-	-	77.91	1m to 4m	MG
CP112/ RH103	-	-	-	-	-	-	76.38	76.35	77.96	27m to 30m	GT
CP113	-	-	-	-	-	-	80.81	-	79.71	2m to 3m	GT
RH101	-	-	-	-	-	-	73.82	73.72	74.54	17m to 20m	GT
RH102	-	-	-	-	-	-	-	-	80.31	12m to 13.5m	GT
CP114/ RH108	-	-	-	dry	-	-	dry	76.35	76.70	26m to 28m	GT
CP101/ RH109a	-	-	-	-	-	-	-	-	75.75	18m to 22m	GT
CP101/ RH109b	-	-	-	-	-	-	-	-	75.05	40m to 42.5m	SST
CP102/ RH110	-	-	-	62.22	-	-	dry	dry	63.32	35m to 39m	GT
WS101	-	-	-	-	-	-	-	-	83.34	1m to 2m	MG
WS102	-	-	-	-	-	-	-	-	82.70	1m to 2m	MG
WS103	-	-	-	-	-	-	75.5	75.2	75.77	1m to 2m	MG
WS104	-	-	-	-	-	-	79.35	-	79.84	1m to 2m	MG

Table 11.2: Groundwater Elevations (m AOD) WA 2022 Dataset

Position	Dates									Response Zone Depths	Strata Screened
	05/05/2022	19/05/22	15/06/22	16/06/22	20/06/22	22/06/22	07/07/22	18/07/22	01/08/22		
WS105	-	-	-	-	80.42	-	80.31	80.29	80.53	1m to 2m	MG
WS106	-	-	-	-	77.99	-	DRY		79.51	1m to 2m	GT
WS107	-	-	-	-	-	-	84.32	84.1	85.11	1m to 2m	MG
WS108	-	-	-	-	-	-	dry	dry	83.83	1m to 2m	MG
WS109	-	-	-	-	-	-	dry	dry	76.44	1m to 2m	MG
WS111	-	-	-	-	-	-	DRY	dry	79.09	1m to 2m	Cohesive GT
WS112	-	-	-	-	-	-	77.84	-	78.10	1m to 2m	MG
WS113	-	-	-	-	-	-	83.59	83.5	83.74	1m to 2m	MG
WS119	-	-	-	-	-	-	-	-	82.55	1m to 2m	MG
WS120	-	-	-	-	-	-	80.77	dry	81.04	1m to 2m	MG
BH04	-	-	-						81.61	3m to 5m	MG
BH06	-	-	-						dry	2m to 4m	MG
	Notes: MG = Made Ground, GT = Glacial Till & BR = Bedrock										

11.9 Ground Gas

11.9.1 Nine ground gas monitoring rounds were undertaken for the site between 30th November 2020 and 25th March 2021 with a further two ground gas monitoring rounds being undertaken between 19th May 2022 and 18th June 2022; both using a GFM436 gas analyser.

11.9.2 Gas monitoring was undertaken in line with guidance contained within BS8485 and during varying atmospheric pressure conditions, including falling pressure as a worst-case scenario. The results of the ground gas monitoring are presented in Appendix J and are summarised below:

- Atmospheric pressure readings, taken during the bulk ground gas monitoring, varied between 966, and 1016mb;
- Measured peak methane concentrations ranged from 0.0% to 6.0% v/v (WS311);
- Measured peak carbon dioxide concentrations ranged from 0.0 % v/v to 20.2% v/v (WS107);
- Measured steady state flow rates ranged from -3.7 l/hr (WS111) to 20.9 l/hr (RH108).

11.9.3 The gas monitoring from the Celtic 2007 investigation undertaken between 27th June 2007 to 23rd July 2007 recorded concentrations of carbon dioxide between <0.1% and 14.3% (typically between <0.1% and 9.8%), methane concentrations up to 30.5% (typically <0.1%) and gas flow rates of up to 2.3 l/hr.

11.10 Observations of contamination

11.10.1 Visual and olfactory evidence of contamination within soils was recorded in several areas of the site within Made Ground and generally included the following:

- Frequent / widespread hydrocarbon odours and staining within the north western and south eastern sections of the site. More localised occurrences were noted within the north eastern and central south western sections of the site.
- Occasional / localised organic odours within the south eastern, north eastern, central northern, central south western and to a lesser extent the north westernmost sections of the site.
- Occasional / localised acrid odours within the central and south eastern sections of the site.

- Occasional / localised putrid odours within the central south eastern and central northern sections of the site. Rare / isolated occurrences were also noted in the north western and central western sections of the site.
- Occasional / localised sulphurous odours within the central south western section of the site.
- Occasional / localised chemical odours within the central south western and to a lesser extent the north western section of the site.
- Rare / isolated white spirit odours, stagnant odours, solvent odours and red / yellow dye staining were also noted in places.

11.10.2 Visual and olfactory evidence of contamination within waters was recorded in several areas of the site within the perched groundwaters within Made Ground and included

- Frequent hydrocarbon odours and iridescent sheens were noted within the north western and south eastern sections of the site. More localised occurrences were noted within the north eastern, central south western, central eastern and central northern sections of the site.
- Occasional white spirit odours, rare chemical / solvent and sulphurous odours were also noted in places.

11.10.3 During development and sampling of the groundwater monitoring installations undertaken as part of the WA 2020 and 2022 site investigations, the following visual and olfactory evidence of contamination was also noted:

- Sulphurous odours were noted at the locations of RH102, CP103A&B, CP109 and CP112.
- Grey silty water was noted at the location of CP109.
- Brown silty water was noted at the location of CP113.
- Putrid and solvent odours at the location of WS307. The odours became stronger as development progressed.
- Hydrocarbon odours at the locations of WS303, WS306 and WS310.
- Iridescent sheens / black oily water at the locations of WS301, WS306, WS308, WS316 and WS318
- Strong putrid odour with white froth at the location of CP202.
- Putrid odours at the locations of CP201, CP203, WS303, WS306 and WS310.

11.10.4 The notes from the development of the boreholes can be found in Appendix K

12 GEOTECHNICAL MATERIAL PROPERTIES

12.1 General

12.1.1 The ground conditions encountered at the site are summarised in Section 11. The material properties for the various strata encountered across the site during the WA 2019, 2020 and 2022 ground investigations, as well as the Celtic ground investigation in 2007, are outlined in the sections below.

12.1.2 Due to the high degree of variability that was encountered within the various Made Ground strata they have been divided into either cohesive or granular (including suspected construction and demolition waste and suspected household waste where the matrix was predominantly granular) based on their engineering behaviour and a range of material properties have been provided. The exception being those distinctive Made Ground strata that were relatively consistent and / or that occurred within certain sections of the site (e.g. suspected combustion type wastes or colliery spoil) and these have been separated out and the material properties discussed independently.

12.1.3 The geotechnical laboratory results are contained within Appendix M and the in-situ results are presented on the exploratory hole logs contained within Appendix F. Standard Penetration Test (SPT) plots can be found in Appendix O.

12.2 Cohesive Made Ground

12.2.1 In-situ and geotechnical / geochemical laboratory tests results undertaken on the Cohesive Made Ground are summarised in Table 12.1:

Table 12.1: Summary of Testing in Cohesive Made Ground		
Type of Test	No. of Tests	Results
In-Situ Tests:		
Standard Penetration Tests (SPT)	91	N-Value: 0– 50+ (mean: 12) N60 Value: 0 – 60 (mean: 11) ¹
Hand Shear Vane Test	24	3 – 140kN/m ² (75kN/m ²)
Laboratory:		
Moisture Content	67	0.8 – 56% (mean 23%)
Particle Size Distribution (PSD)	5	Fines: 18 - 70% (mean: 42%) Clay: 30% Silt: 40% Sand: 21 - 56% (mean: 32%)

Table 12.1: Summary of Testing in Cohesive Made Ground		
Type of Test	No. of Tests	Results
		Gravel: 8 - 33% (mean: 18%) Cobbles: 0 - 25% (mean: 8%)
Liquid Limit	9	36 – 90% (mean: 48%)
Plastic Limit	9	18 – 38% (mean: 23%)
Plasticity Index	9	17 – 52% (mean: 26%)
Weighted Plasticity Index	9	1122 – 4836% (1953%)
Laboratory Hand Vane	3	Peak: 40 – 71kN/m ² (mean: 59kN/m ²) Residual: 17 - 41kN/m ² (mean: 28kN/m ²)
Optimum Moisture Content	7	17 - 41% (mean: 22%)
CBR	1	4.5%
pH	59	5.86 – 12.8 (mean: 7.79)
Water Soluble SO ₄	46	4 – 1500mg/l (mean: 242mg/l)
Organic Matter	29	0.7 – 32.8 (mean: 7.87%)
Triaxial Tests	1	104kN/m ²
Notes: ¹ Correction for SPT hammer energy efficiency after Skempton (1986); Seed et al (1985). WA data only. Unable to calculate for Celtic data due to lack of SPT certificates. SPT refusals (50+) have been excluded for the mean calculations, corrections and correlations as they are deemed unrepresentative due to very coarse constituents that were frequently encountered within this stratum. It is possible that some of the higher N-Values recorded are also due to obstructions or oversized constituents. Any subsequent correlations need to be used with caution.		

12.2.2 Relationships between Plasticity Index (PI) and SPT N₆₀ values ($c_u = \alpha'N_{60}$, Salgado 2008; $\alpha' = 0.0475$ for a PI of 25%) for the Cohesive Made Ground indicates undrained shear strength values of between 0 and 276kN/m² (average of 48kN/m²), which is indicative of extremely low strength to very high strength materials (on average medium strength).

12.2.3 Undrained shear strength values from hand shear vane testing indicate the Cohesive Made Ground materials to be of extremely low to high strength (generally medium strength). No significant relationship between undrained shear strength and depth is indicated. However, hand shear vane tests were only undertaken at shallow depth.

12.2.4 The results from the Atterberg Limit tests indicate materials of intermediate to extremely high plasticity (typically intermediate plasticity), with the plasticity index results indicating materials of low to high shrinkage potential (typically medium

shrinkage potential). The weighted plasticity index results indicate materials of very low to high volume change potential (typically low volume change potential).

12.2.5 Relationships between PI and angle of friction (Gibson 1953) for the Cohesive Made Ground indicates an angle of friction of between 25° and 32° (average of 30°).

12.2.6 Drained stiffness (E') for the Cohesive Made Ground has been derived from SPT N60 values after Stroud 1989, which indicates values of between 0 and 52 MN/m² (average of 9 MN/m²).

12.2.7 Undrained stiffness (E_u) for the Cohesive Made Ground has been derived from SPT N60 values after Butler, 1975, which indicates values of between 0 and 58 MN/m² with a mean of 10 MN/m².

1.3.1 Coefficient of volume compressibility (mv) for the Cohesive Made Ground has been derived based on relationships with plasticity and SPT N60 values ($mv = 1/f_2N$, Stroud 1975; $f_2=0.496$ for PI of 25%) with values ranging from 0.035 – 2.407 m²/MN (very low to very high compressibility) with an average of 0.44 m²/MN (high compressibility).

1.3.2 Generally, the PSD results for the cohesive materials indicated a slightly sandy to sandy, slightly gravelly to gravelly Clay with medium cobble content, which is in line with the field descriptions. Higher sand and gravel contents and were noted in some samples, but again this is in keeping with the field descriptions.

12.2.8 The range of compaction tests and natural moisture content tests for the cohesive materials indicate that these materials are generally very slightly wet of their optimum moisture contents.

12.3 Granular Made Ground

12.3.1 In-situ and geotechnical / geochemical laboratory tests results undertaken on the Granular Made Ground (includes suspected construction and demolition type wastes and the suspected household wastes where the matrix was predominantly granular) are summarised in Table 12.2:

Table 12.2: Summary of Testing on Granular Made Ground		
Type of Test	No. of Tests	Results
In-Situ Tests:		
Standard Penetration Tests (SPT)	108	N-Value: 0 – 50+ (mean: 15) N160 Value: 0 – 77 (mean: 19) ^{1&2}
Laboratory Tests:		
Moisture Content	123	0 – 40% (mean 18.5%)
Particle Size Distribution (PSD)	10	Fines: 6 - 34% (mean: 15%) Sand: 24 - 51% (mean: 37%) Gravel: 24 - 61% (mean: 41%) Cobbles: 0 - 32% (mean: 6%)
Liquid Limit	2	-
Plastic Limit	2	Non-Plastic
Plasticity Index	2	-
Optimum Moisture Content	11	15 – 21% (mean: 18%)
pH	100	6.19 – 10.6 (mean: 8.1)
Water Soluble SO ₄	80	6 – 1974mg/l (mean: 442mg/l)
Organic Matter	60	0.4 - 46.9% (mean: 6.5%)
Calorific Value	4	1.4 – 7.1MJ/kg (mean: 3.55MJ/kg)
Notes: ¹ Correction for SPT hammer energy efficiency after Skempton (1986); Seed et al (1985). ² Correction for (N1)60 value for effective overburden pressure after Liao and Whitman (1986). WA data only. Unable to calculate for Celtic data due to lack of SPT certificates. SPT refusals (50+) have been excluded for the mean calculations, corrections and correlations as they are deemed unrepresentative due to very coarse constituents that were frequently encountered within this stratum. It is possible that some of the higher N-Values recorded are also due to obstructions or oversized constituents. Any subsequent correlations need to be used with caution.		

12.3.2 SPT N160 values indicate very loose to very dense materials (typically medium dense) and correlations for angle of friction (after Peck et al 1964) recorded values of between 27° and 53° (typically 33°).

12.3.3 Drained stiffness (E') for the granular materials has been derived from SPT N160 values after AASHTO 2004, which indicates values of between 0 and 88 MN/m² (on average 21 MN/m²).

12.3.4 The PSD results for the granular materials indicated a very sandy, clayey Gravel with medium cobble content. This differs from the field descriptions where cobble sized constituents predominated, and this fraction has likely been underestimated due to

sampling restrictions (i.e. it is generally not practicable to sample cobbles and boulder sized constituents for testing).

12.3.5 The range of compaction tests and natural moisture content tests for the granular materials indicate that these materials are around their optimum moisture contents.

12.4 Suspected Combustion Type Waste Made

12.4.1 In-situ and geotechnical / geochemical laboratory tests results undertaken on the suspected combustion type wastes are summarised in Table 12.3:

Table 12.3: Summary of Testing on Combustion Type Waste		
Type of Test	No. of Tests	Results
In-Situ Tests:		
Standard Penetration Tests (SPT)	22	N-Value: 0 – 32 (mean: 6) N160 Value: 0 – 36 (mean: 8) ^{1&2}
Laboratory Tests		
Moisture Content	88	8.7 – 42% (mean 23%)
Particle Size Distribution (PSD)	5	Fines: 11 - 24% (mean: 15%) Sand: 27 - 57% (mean: 42%) Gravel: 32 - 60% (mean: 43%) Cobbles: 0%
Liquid Limit	1	-
Plastic Limit	1	Non-Plastic
Plasticity Index	1	-
Weighted Plasticity Index	1	-
Optimum Moisture Content	5	21 – 27% (mean: 23%)
CBR	2	0.73 – 1.7%
pH	48	5.72 – 11.90 (mean: 8.19)
Water Soluble SO4	39	16.2 – 1598mg/l (mean: 285mg/l)
Organic Matter	29	2.2 – 82.9% (mean: 25.7%)
Calorific Content	5	0.51 – 6.6 MJ/kg
Emery Expansion Tests	6	Change in Height: 0.22 – 1.97mm (1.16mm)
Notes: ¹ Correction for SPT hammer energy efficiency after Skempton (1986); Seed et al (1985). ² Correction for (N1)60 value for effective overburden pressure after Liao and Whitman (1986). WA data only. Unable to calculate for Celtic data due to lack of SPT certificates. SPT refusals (50+) have been excluded for the mean calculations, corrections and correlations as they are deemed unrepresentative due to very coarse constituents that were frequently encountered within this stratum. It is possible that some of the higher N-Values recorded are also due to obstructions or oversized constituents. Any subsequent correlations need to be used with caution.		

12.4.1 SPT N160 values indicate very loose to dense materials (typically loose) and correlations for angle of friction (after Peck et al 1964) recorded values of between 27° and 53° (typically 33°).

12.4.2 Drained stiffness (E') for the granular materials has been derived from SPT N160 values after AASHTO 2004, which indicates values of between 0 and 42 MN/m² (on average 9 MN/m²).

12.4.3 The PSD results for these materials indicated a clayey / silty, very sandy Gravel. This differs slightly from the field descriptions which indicated high cobble content. It is likely that the cobble sized constituents have been underestimated due to sampling restrictions (i.e. it is generally not practicable to sample cobbles and boulder sized constituents for testing).

12.4.4 The range of compaction tests and natural moisture content tests for these materials indicate that these materials are generally at their optimum moisture contents.

12.5 Suspected Colliery Spoil

12.5.1 In-situ and geotechnical / geochemical laboratory tests results undertaken on the suspected colliery spoil are summarised in Table 12.4:

Table 12.4: Summary of Testing on Colliery Spoil		
Type of Test	No. of Tests	Results
In-Situ Tests:		
Standard Penetration Tests (SPT)	12	N-Value: 3 – 20 (mean: 13) N160 Value: 5 – 27 (mean: 16) ^{1&2}
Hand Shear Vane Test	1	140kN/m ²
Laboratory Tests:		
Moisture Content	18	7.1 – 21 (mean 13.6%)
Particle Size Distribution (PSD)	5	Fines: 7 – 50% (mean: 27%) Sand: 11 – 42% (mean 22%) Gravel: 38 – 63% (mean 48%) Cobbles: 0 – 19% (mean 4%)
Optimum Moisture Content	6	11 – 17% (15%)
pH	10	5.04 – 8.8 (mean: 7.2)
Water Soluble SO ₄	8	59 – 1965mg/l (mean: 363mg/l)
Organic Matter	3	3.9 – 33.3% (mean: 14%)
Calorific Content	6	<2 – 9 MJ/kg
Notes:		
¹ Correction for SPT hammer energy efficiency after Skempton (1986); Seed et al (1985).		

Table 12.4: Summary of Testing on Colliery Spoil		
Type of Test	No. of Tests	Results
² Correction for (N1)60 value for effective overburden pressure after Liao and Whitman (1986). WA data only. Unable to calculate for Celtic data due to lack of SPT certificates. SPT refusals (50+) have been excluded for the mean calculations, corrections and correlations as they are deemed unrepresentative due to very coarse constituents that were frequently encountered within this stratum. It is possible that some of the higher N-Values recorded are also due to obstructions or oversized constituents. Any subsequent correlations need to be used with caution.		

12.5.2 SPT N160 values indicate loose to medium dense materials (typically medium dense) and correlations for angle of friction (after Peck et al 1964) recorded values of between 29° and 36° (typically 32°).

12.5.3 Drained stiffness (E') for the granular materials has been derived from SPT N160 values after AASHTO 2004, which indicates values of between 6 and 31 MN/m² (on average 18 MN/m²).

12.5.1 The PSD results for these materials indicated a very sandy, very clayey / silty Gravel with low cobble content which is generally in line with the field descriptions. Cobble and boulder content in the field where higher but it is likely that the cobble sized constituents have been underestimated due to sampling restrictions (i.e. it is generally not practicable to sample cobbles and boulder sized constituents for testing).

12.5.2 The range of compaction tests and natural moisture content tests for these materials indicate that these materials were generally slightly dry of their optimum moisture contents.

12.6 Glacial Deposits

12.6.1 In-situ and geotechnical / geochemical laboratory tests results undertaken on the cohesive and granular Glacial Deposits are summarised in Table 12.5:

Table 12.5: Summary of Testing on Glacial Deposits		
Type of Test	No. of Tests	Results
Cohesive Glacial Till		
In-Situ Tests:		
Standard Penetration Tests (SPT)	126	N-Value: 0 – 50+ (mean: 21) N60 Value: 0 – 59 (mean: 23) ¹
Hand Shear Vane Tests	73	22 – 120kN/m ² (mean: 78kN/m ²)

Table 12.5: Summary of Testing on Glacial Deposits		
Type of Test	No. of Tests	Results
Laboratory Tests:		
Moisture Content	183	7.7 – 42% (mean: 17.5%)
Particle Size Distribution (PSD)	20	Fines: 52 – 85% (mean: 74%) Clay: 24 - 38% (mean 33%) Silt: 28 - 48% (mean 40%) Sand: 12 - 48% (mean 21%) Gravel: 0 - 10% (mean 4.65%) Cobbles: 0%
Liquid Limit	26	27 – 48% (37%)
Plastic Limit	26	15 – 25% (18.6%)
Plasticity Index	26	12 – 23% (18%)
Weighted Plasticity Index	26	980 – 2139% (1654%)
Optimum Moisture Content	13	13 – 24% (16.7%)
Laboratory Hand Vane	4	Peak: 133 – 191kN/m ² (mean: 162kN/m ²) Residual: 23 - 58kN/m ² (mean: 44kN/m ²)
Undrained Triaxial Tests	20	22 – 226kN/m ² (mean: 103kN/m ²)
Oedometer / Consolidation	12	Applied Pressure Range: 50 – 3200kPa Mv: 0.0095 – 0.37Mv (mean: 0.093Mv) Cv (t90): 0.43 – 34 (mean: 4.46m ² /yr)
Organic Matter	26	0.35 – 15.5% (mean: 2.5%)
pH	50	5.63 – 8.93 (mean: 7.9)
Water Soluble SO ₄	47	11.6 – 739mg/l (mean: 110mg/l)
Granular Glacial Till		
In-Situ Tests:		
Standard Penetration Tests (SPT)	33	N-Value: 5 – 50+ (mean: 22) N ₁₆₀ Value: 7 – 47 (mean: 21) ^{1&2}
Laboratory Tests:		
Moisture Content	13	9.6 – 23% (mean: 17%)
Particle Size Distribution (PSD)	4	Fines: 2– 48% (mean: 35%) Sand: 29 - 98% (mean 54%) Gravel: 0 - 23% (mean 11%) Cobbles: 0%
Optimum Moisture Content	2	14 – 19% (mean: 16.5%)
Organic Matter	4	0.96 – 1.52% (mean: 1.2%)
pH	14	3.5 – 8.48 (mean: 7.94)
Water Soluble SO ₄	6	23 – 295mg/l (mean: 146mg/l)
Notes:		

Table 12.5: Summary of Testing on Glacial Deposits		
Type of Test	No. of Tests	Results
¹ Correction for SPT hammer energy efficiency after Skempton (1986); Seed et al (1985). ² Correction for (N1)60 value for effective overburden pressure after Liao and Whitman (1986). WA data only. Unable to calculate for Celtic data due to lack of SPT certificates. SPT refusals (50+) have been excluded for the mean calculations, corrections and correlations as they are deemed unrepresentative due to very coarse constituents that were frequently encountered within this stratum. It is possible that some of the higher N-Values recorded are also due to obstructions or oversized constituents. Any subsequent correlations need to be used with caution.		

- 12.6.2 Relationships between Plasticity Index (PI) and SPT N60 values ($c_u = \alpha' N_{60}$, Salgado 2008; $\alpha' = 0.0599$ for a PI of 18.11%) for the Cohesive Glacial Till indicates undrained shear strength values of between 0 and 351kN/m² (average of 123kN/m²), which is indicative of extremely low strength to very high strength materials (on average high strength).
- 12.6.3 Similarly, the undrained shear strength values from in-situ hand shear vane, undrained triaxial tests and laboratory vane tests indicate cohesive Glacial Till undrained shear strength values of between 22 and 226kN/m² (average of 133kN/m²), which is indicative of low to very high strength (generally high strength).
- 12.6.4 The results from the Atterberg Limit tests for the cohesive Glacial Till indicates materials of low to intermediate plasticity (typically intermediate plasticity), with the plasticity index results indicating materials of low to medium shrinkage potential (generally low shrinkage potential). The weighted plasticity index results indicate materials of very low to low volume change potential (generally low volume change potential).
- 12.6.5 Relationships between PI and angle of friction (Gibson 1953) for the Cohesive Made Ground indicates an angle of friction of between 30° and 33° (average of 31°).
- 12.6.6 Drained stiffness (E') for the Cohesive Glacial Till has been derived from SPT N60 values after Stroud 1989, which indicates values of between 0 and 53 MN/m² with a mean of 19 MN/m².
- 12.6.7 Undrained stiffness (E_u) for the Cohesive Glacial Till has been derived from SPT N60 values after Butler, 1975, which indicates values of between 0 and 59 MN/m² with a mean of 21 MN/m².

- 1.3.3 Coefficient of volume compressibility (m_v) for the Cohesive Made Ground has been derived based on relationships with plasticity and SPT N60 values ($m_v = 1/f_{2N}$, Stroud 1975; $f_2=0.576$ for PI of 18.11%) with values ranging from 0.03 – 2.13 m^2/MN (very low to very high compressibility) with an average of 0.14 m^2/MN (medium compressibility). The m_v from the laboratory consolidation testing recorded values ranging from 0.0095 – 0.37 m^2/MN (very low to high compressibility) with an average of 0.093 m^2/MN , which is indicative of low compressibility. The laboratory consolidation tests are considered to be more accurate.
- 12.6.8 The PSD results for these materials indicated a slightly sandy, slightly gravelly Clay which is generally in line with the field descriptions. High silt contents were noted but this is not uncommon with overconsolidated Glacial Till, and the clay fraction was noted to dominate the engineering behaviour of these soils.
- 12.6.9 The range of compaction tests and natural moisture content tests for these materials indicate that these materials are generally slightly wet of their optimum moisture contents. However, only those materials at shallow depth would need to be considered as part of any earthworks exercise at the site.
- 12.6.10 SPT N160 values indicate loose to dense materials (typically medium dense) and correlations for angle of friction (after Peck et al 1964) recorded values of between 29° and 42° (typically 34°).
- 12.6.11 Drained stiffness (E') for the granular materials has been derived from SPT N160 values after AASHTO 2004, which indicates values of between 7 and 45 MN/m^2 (on average 20 MN/m^2).
- 12.6.12 The PSD results for these materials indicated a gravelly, clayey / silty Sand which is generally in line with the field descriptions.
- 12.6.13 The range of compaction tests and natural moisture content tests for these materials indicates that these materials were normally wet (generally only slightly) of their optimum moisture contents.
- 12.7 Geotechnical Design Parameters**
- 12.7.1 Geotechnical design parameters for the principal ground conditions encountered at the site are outlined in Table 12.6. Due to the high degree of variability exhibited by the Made Ground and that the site is a historic landfill, characteristic design values

have not been provided for the Made Ground types and reference should be made to the range of results noted above.

12.7.2 The geotechnical design parameters tabulated in Table 12.6 and any correlations should be used with caution and should not be relied upon in isolation without considering the reporting in full.

Table 12.6: Summary of Geotechnical Design Parameters				
Stratum	Material Parameter	Range of Results (Average)	Characteristic Value	Rationale
Cohesive Glacial Deposits	Bulk Unit Weight (kN/m ³)	-	22	Literature value, based on descriptions
	Undrained Shear Strength (kN/m ²)	5 – 351 (120)	60 – 100	Cautious estimate from empirical relationship with SPT N60 (Salgado 2008) hand shear vane tests, laboratory tests and field descriptions.
	Angle of Friction ϕ' (°)	30 – 33 (31)	31	Cautious estimate from empirical relationship with plasticity index (Gibson 1953)

Table 12.6: Summary of Geotechnical Design Parameters				
Stratum	Material Parameter	Range of Results (Average)	Characteristic Value	Rationale
	Drained Stiffness (E') (MN/m ²)	0 – 53 (19)	19	Cautious estimate from empirical relationship with SPT N (Stroud 1989)
	Undrained Stiffness (E_u) (MN/m ²)	0 – 59 (21)	21	Cautious estimate from empirical relationship with SPT N (Butler 1975)
	Coefficient of volume compressibility m_v	0.0095 – 2.13 (0.12)	0.10 – 0.15	Cautious estimate from empirical relationship with SPT N60 (Stroud and Butler 1975) and laboratory testing.
Granular Glacial Deposits	Bulk Unit Weight (kN/m ³)	-	20	Literature value, based on descriptions
	Angle of Friction ϕ' (°)	29 – 42 (34)	31 - 34	Cautious estimate from empirical relationship with SPT N160 (Peck et al 1974)
	Drained Stiffness (E') (MN/m ²)	7 – 45 (20)	14	Cautious estimate from empirical relationship with SPT N160 (AASHTO 2004)

Table 12.6: Summary of Geotechnical Design Parameters				
Stratum	Material Parameter	Range of Results (Average)	Characteristic Value	Rationale
Collyhurst Sandstone Formation & Chester Formation	Bulk Unit Weight (kN/m ³)	-	22 - 25	Cautious estimate from literature data
	Rock Quality Designation	0 – 30% (9%)	0 – 10%	Rock Quality Designation from core logging.

13 GENERIC QUANTITATIVE RISK ASSESSMENT – HUMAN HEALTH

13.1 General

13.1.1 A total of 181 No. samples were taken from across the site and tested for potential contaminants appropriate to the site's current and former land uses. This included 91 No. samples from the WA 2020 investigation and 90 No. samples from the WA 2022 site investigation. 146 No. soil samples from across the site were also tested as part of the Celtic 2007 investigation.

13.1.2 The WA samples taken were tested for potential contaminants appropriate to the site's current and former land uses. As the receptor is human health, the most relevant risk assessment model for the assessment of human health is the CLEA model. The model estimates child and adult exposures to soil contaminants via dermal, ingestion and inhalation pathways for those potentially living, working and / or playing on contaminated sites over long time periods and has been used to derive Generic Assessment Criteria (GAC) for those commonly encountered contaminants in UK soils.

13.1.3 For the purposes of this updated Generic Quantitative Risk Assessment (GQRA) contaminant concentrations recorded from the WA 2020 and 2022 WA site investigations have been compared with GAC's for a residential end use with private gardens, as most of the site is being considered for residential development and this also provides an initial conservative assessment for the proposed school. This first tier of assessment determines if the concentrations recorded have the potential to adversely impact those human health receptors identified within the CSM.

13.1.4 The Celtic data has been reviewed independently from the more recent WA dataset and these findings are outlined in Section 8. Comparisons have been made between the datasets where relevant, but it is the WA data that has primarily been relied upon to undertake the updated assessments, as this information is reflective of current site conditions.

13.2 Assessment Criteria

13.2.1 The GAC considered appropriate for GQRA and used in this assessment, in general order of preference, in accordance with the EA Land Contamination Risk Management (LCRM) guidance, include:

- Category 4 Screening Levels (C4SL), screening values for chronic exposure to soil contamination published by DEFRA, 2014;
- Suitable for Use Levels (S4UL), screening values for chronic exposure to soil contamination published by LQM/CIEH, 2015;
- Acute Generic Assessment Criteria (AGAC), screening values for acute exposure to soil contamination published by SoBRA, 2020; and
- Generic Assessment Criteria for Assessing Vapour Risks (GACgwvap), screening values for chronic exposure to groundwater contamination published by SoBRA, 2017.

13.2.2 Potential for contaminants to be dissolved in groundwater at the site has also been identified in the CSM. This contamination has the potential to volatilise and affect human health through inhalation of vapours indoors and outdoors. Work has been undertaken by the Society of Brownfield Risk Assessment (SoBRA) to produce a series of screening values to assess the potential significance of dissolved contaminants in groundwater beneath a site.

13.2.3 SoBRA have also produced useful assessment criteria for a number of potential contaminants which consider risk to human health from acute (short term) exposure. While risk to human health is usually more sensitive to chronic exposure to potential contaminants (and therefore assessment using criteria which are protective against chronic exposure will also be protective against acute exposure), where acute exposure is considered the most sensitive route appropriate criteria are employed.

13.2.4 The soil samples obtained for subsequent chemical analysis have not been sampled on a systematic basis and, as such, the dataset is not suitable for statistical analysis in accordance with CL:AIRE (2020) Professional Guidance: Comparing Soil Contamination Data with a Critical Concentration.

13.2.5 Generally, only soils and groundwater within the top c. 1.0m are considered for site users, as the probability of human exposure via the direct contact pathways are significantly reduced, leaving inhalation of volatile compounds as the dominant pathway with regard to human health risks. However, the final depth below the proposed development levels is unknown at this stage and as earthworks and cut and fill are likely to be undertaken at the site, as part of the proposed development,

consideration has also been given to deeper soils and groundwaters at this GQRA stage.

13.2.6 The geometric mean soil organic matter (SOM) content for all the Made Ground strata at the site is 13.2%. However, organic materials that are not degradable (e.g. ash and coal) were noted within all the Made Ground strata and these could have resulted in high total organic carbon contents that are not indicative of SOM. Consequently, a conservative approach has been adopted and GAC values have been derived using 1% SOM. The pH of these soils ranged from 5.43 in TP227 at 1.0m to 12.8 in TP139 at 1.50m.

13.2.7 The mean SOM content for those natural soils at the site is 2.4%. However, GAC values derived using the 1% SOM have been selected in the first instance, so that a conservative assessment can be undertaken. The pH of these soils ranged from 5.63 in TP136 at 0.8m bgl to 8.93 in RH205 between 11.0m and 12.0m bgl.

13.2.8 Any exceedance of the adopted GAC value for a particular Contaminant of Concern (CoC) may indicate that additional risk assessment is necessary or that some sort of remediation may be required.

13.3 Screening of Soils

13.3.1 A summary of the exceedences of the GAC for a residential end use with private gardens from both the 2020 and 2022 WA datasets are presented in Table 13.1. A summary of exceedences from the 2007 Celtic dataset are summarised separately in Table 8.1. A summary of the exceedences in relation to each strata type is outlined further in Section 16.

13.3.2 Specific details regarding the location, depth, contaminant concentrations and strata for each exceedance are included within Appendix I and the analytical laboratory results of the soil and groundwater chemical analyses are attached at Appendix H.

Table 13.1: Summary of Contaminant Exceedances (WA 2020 & 2022)					
Contaminant	Min. Recorded (mg/kg)	Max. Recorded (mg/kg)	GAC (mg/kg)	No. of Exceedances MG	No. of Exceedances NG
Metals					
Chromium VI	<0.6	26	21 ¹	1	0
Arsenic	2.16	1,930	37 ¹	19	1
Beryllium	0.213	4.87	1.7	10	0

Table 13.1: Summary of Contaminant Exceedances (WA 2020 & 2022)					
Contaminant	Min. Recorded (mg/kg)	Max. Recorded (mg/kg)	GAC (mg/kg)	No. of Exceedances MG	No. of Exceedances NG
Cadmium	<0.02	37.4	22	1	0
Copper	6.9	9,990	2400	3	0
Lead	4.98	28,700	200 ¹	53	1
Nickel	2	535	130	10	0
Zinc	15.7	7290	3700	3	0
Inorganics					
Total Cyanide	<1	499	20 ²	10	0
TPH including BTEX					
Aliphatics >C8-C10	<0.01	703	27	1	0
Aromatics >EC8-EC10	<0.01	469	34	1	0
Aromatics > EC10-EC12	<1	6,110	74	3	0
Aromatics > EC12-EC16	<1	5,210	140	6	0
Aromatics > EC16-EC21	<1	10,900	260	9	0
Aromatics > EC21-EC35	<1	17,800	1,100	6	0
Aromatics > EC35-EC44	<1	1,680	1,100	1	0
Benzene	<0.009	2.74	0.0087	1	0
p/m-Xylene	<0.01	219	56	1	0
o-Xylene	<0.01	114	60	1	0
PAH					
Naphthalene	<0.009	13,100	2.3	27	1
Acenaphthylene	<0.012	315	170	1	0
Acenaphthene	<0.008	341	210	1	0
Fluorene	<0.01	656	170	2	0
Phenanthrene	<0.015	1550	95	6	0
Fluoranthene	<0.017	1290	280	5	0
Pyrene	<0.015	1120	620	1	0
Benz(a)anthracene	<0.014	432	7.2	31	2
Chrysene	<0.01	432	15	15	0
Benzo(b)fluoranthene	<0.015	461	2.6	56	2
Benzo(k)fluoranthene	<0.014	173	77	3	0
Benzo(a)pyrene	<0.015	376	2.2	67	2
Indeno(1,2,3-cd)pyrene	<0.018	255	27	7	0
Dibenzo(a,h)anthracene	<0.023	51.6	0.24	60	2
SVOC and VOC					
Pentachlorophenol	<0.1	<5	0.22	1	0
Dibenzofuran	<0.1	114	4.8 ⁴	3	0

Table 13.1: Summary of Contaminant Exceedances (WA 2020 & 2022)					
Contaminant	Min. Recorded (mg/kg)	Max. Recorded (mg/kg)	GAC (mg/kg)	No. of Exceedances MG	No. of Exceedances NG
Carbazole	<0.1	64.8	6.7 ⁴	2	0
2-Methylnaphthalene	<0.1	97.4	10 ⁴	1	0
1,2,4-Trimethylbenzene	<0.009	1.8	0.35 ³	2	0
Trichloroethene	<0.009	1.8	0.016 ¹	1	0
PCB's					
PCB congener 28	<0.003	0.388	0.008 ⁵	6	0
PCB congener 52	<0.003	0.492	0.008 ⁵	7	0
PCB congener 101	<0.003	0.523	0.008 ⁵	6	0
PCB congener 118	<0.003	0.275	0.008 ⁵	6	0
PCB congener 138	<0.003	0.298	0.008 ⁵	6	0
PCB congener 153	<0.003	0.224	0.008 ⁵	5	0
PCB congener 180	<0.003	<0.150	0.008 ⁵	3	0
Asbestos					
Positive Asbestos ID	-	-	-	21	2
Asbestos Quantification	<0.001%	5.11%	0.001%	11	1
Notes: MG = Made Ground, NG = Natural Ground Generic Assessment Criteria Used: LQM/CIEH S4ULs for Human Health Risk Assessment (3rd edition, 2015), unless otherwise stated. ¹ Category 4 Screening Levels (March 2014). ² Value for thiocyanate ³ EIC/AGS/CL:AIRE Soil GAC for Human Health Assessment (January 2010). ⁴ Wardell Armstrong derived GAC. ⁵ Environment Agency Soil Guideline Values for dioxins, furans and dioxin-like PCBs in soil.					

- 13.3.3 Most of the recorded concentrations for those other SVOC's and VOCs were either at concentrations that were below their respective screening criteria and / or were recorded at concentrations below the limits of detection (LOD). While the screening values for some of the contaminants were below the LOD (which was raised in some samples), in the absence of any positive concentrations above the screening value, the concentrations (if present) are likely to be low and not pose an unacceptable risk.
- 13.3.4 Exceedences of 2,4-Dinitrotoluene, Chloromethane and 2,4-Dimethylphenol were noted within the 2007 Celtic dataset, but due to their volatile nature and the absence of these contaminants above the screening values and / or below the LOD in the more recent WA dataset, these concentrations are not considered to be reflective of current site conditions.

Metals and Metalloids

- 13.3.5 Lead exceedences are indicated to be widespread across the site and are predominantly associated with the shallow (<3.0m bgl) suspected combustion type wastes and suspected construction and demolition type wastes. Concentrations were typically recorded at the same order of magnitude as the screening value. However, 7 No. samples recorded concentrations at one order of magnitude greater than the screening value and 2 No. samples (TP114 at 3.4m and TP242 at 2.5m) recorded concentrations at two orders of magnitude above the screening value.
- 13.3.6 Arsenic exceedences are indicated to be localised to within the north western, south western, and south eastern sections of the site, but also at relatively isolated locations within the north eastern section of the site. They are predominantly associated with the shallow (<3.0m bgl) suspected combustion type wastes. Concentrations were typically recorded at the same order of magnitude as the screening value. However, 3 No. samples (TP108 at 2.3m, TP128 at 3.6m and TP139 at 1.5m) were recorded at one order of magnitude greater than the screening value and a single sample (TP126 at 0.5m) was recorded at two orders of magnitude above the screening value.
- 13.3.7 Beryllium exceedences are indicated to be localised to within the north western section of the site and to a lesser extent at isolated locations within the central and north eastern sections of the site. They are predominantly associated with the shallow (<3.0m bgl) suspected combustion type wastes. Concentrations were recorded at the same order of magnitude as the screening value.
- 13.3.8 Nickel exceedences are indicated to be localised to within the central western section of the site and to a lesser extent to isolated locations within the north western section of the site. They are predominantly associated with the shallow (<3.0m bgl) suspected construction and demolition type wastes. Concentrations were recorded at the same order of magnitude as the screening value.
- 13.3.9 Copper exceedences are indicated to be relatively localised to within the central southern section of the site and at an isolated location within the north western section of the site. They are predominantly associated with the shallow (<3.0m bgl) suspected construction and demolition type wastes. Concentrations were recorded at the same order of magnitude as the screening value.

- 13.3.10 Zinc exceedences are indicated to be relatively localised to within the central southern section of the site and are predominantly associated with the shallow (<3.0m bgl) suspected construction and demolition type wastes. Concentrations were recorded at the same order of magnitude as the screening value.
- 13.3.11 Chromium VI and cadmium exceedences are restricted to individual locations (CP106 at 1.8m and TP231 at 0.6m) within suspected combustion waste and cohesive Made Ground, respectively. Concentrations were recorded at the same order of magnitude as the screening value.
- 13.3.12 Arsenic and lead exceedences were also restricted to a single location within natural cohesive strata / possibly reworked natural ground (WS102 at 2.8m). Concentrations were only marginally above the screening values.
- 13.3.13 Multiple exceedences of arsenic and lead and rare exceedences of nickel were noted within the Made Ground from the Celtic 2007 dataset. For these determinands similar trends were observed, except that the arsenic and lead exceedences were predominantly associated with cohesive Made Ground. Rather than being localised, nickel was restricted to isolated locations within the central north eastern section of the site.

Cyanide

- 13.3.14 Cyanide (total cyanide) exceedences are indicated to be relatively localised to within the north western section of the site, but also occurs at relatively isolated locations within the central section of the site. It is predominantly associated with the shallow (<3.0m bgl) suspected combustion wastes and the cohesive Made Ground. Concentrations were typically recorded at the same order of magnitude as the screening value. However, 2 No. samples (TP108 at 2.3m and TP139 at 2.4m) were recorded at one order of magnitude above the screening value.

A reduced number of total cyanide exceedences within Made Ground were noted from the Celtic 2007 dataset. Similar trends were observed, except that there was a single exceedence recorded in one sample from natural cohesive strata (possibly reworked ground).

Total Petroleum Hydrocarbons

- 13.3.15 Aromatics > EC16-EC21 are indicated to be relatively localised to within the north western section of the site, but also occur at relatively isolated locations within the

south western and easternmost sections of the site. They are predominantly associated with the shallow (<3.0m bgl) cohesive Made Ground. Concentrations were typically recorded at the same order of magnitude as the screening value. However, 2 No. samples (TP126 at 0.5m and TP139 at 2.4m) were recorded at one order of magnitude above the screening value and a single sample (WS309 at 3.2m) was recorded at two orders of magnitude above the screening value.

- 13.3.16 Aromatics > EC21-EC35 are indicated to be relatively isolated to within the western and eastern sections of the site and are predominantly associated with the shallow to intermediate (<4.2m bgl) suspected combustion wastes, suspected construction and demolition waste and the cohesive Made Ground. Concentrations were typically recorded at the same order of magnitude as the screening value. However, 2 No. samples (WS309 at 3.2m and TP117 at 4.2m) were recorded at one order of magnitude above the screening value.
- 13.3.17 Aromatics > EC12-EC16 are indicated to be relatively isolated within the western and north eastern sections of the site and are predominantly associated with the shallow to intermediate (<4.2m bgl) cohesive Made Ground and the suspected combustion wastes. Concentrations were typically recorded at the same order of magnitude as the screening value. However, 2 No. samples (TP117 at 4.2m and TP139 at 2.4m) were recorded at one order of magnitude above the screening value.
- 13.3.18 Aromatics > EC10-EC12 are indicated to be restricted to isolated locations within the western and north eastern sections of the site and are predominantly associated with the shallow to intermediate (<4.2m bgl) suspected combustion wastes, cohesive Made Ground and suspected construction and demolition waste. Concentrations ranged from the same order of magnitude as the screening value at WS309 to two orders of magnitude above the screening value at TP139.
- 13.3.19 The other TPH fractions (aliphatic >C8-C10, aromatic <EC8-10 and aromatic EC35-44) are restricted to individual locations (TP139 at 2.4m and WS309 at 3.2m) within the north western sections of the site and are predominantly associated with the shallow suspected combustion waste. Aliphatic >C8-C10 and aromatic <EC8-10 were recorded at one order of magnitude above the screening value. Aromatic > EC35-EC44 was recorded at the same order of magnitude as the screening value.
- 13.3.20 A reduced number of TPH exceedences within Made Ground were noted from the Celtic 2007 dataset and only included exceedences of aromatics > EC16-EC21 and

aromatics > EC21-EC35. Similar trends were observed, except that they were predominantly associated with the cohesive Made Ground.

Polycyclic Aromatic Hydrocarbons (PAH)

- 13.3.21 PAH compounds are typically formed as a result of pyrolytic processes, especially the incomplete combustion of organic materials (e.g. ash, clinker etc) or can be present within petroleum hydrocarbon substances (e.g. oils, greases etc).
- 13.3.22 PAH contamination (notably naphthalene, benz(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene and dibenzo(a,h)anthracene) are indicated to be widespread across the site and are predominantly associated with the shallow (<3.0m bgl) suspected combustion wastes within the western section of the site and suspected construction and demolition wastes within the central and eastern sections of the site. Concentrations were typically recorded at the same order of magnitude as the screening value, but were also frequently recorded at between one and two orders of magnitude greater than the screening value. The greatest exceedences were typically noted within the suspected combustion wastes.
- 13.3.23 Indeno(1,2,3)pyrene, fluoranthene and phenanthrene exceedences were localised to within the western and north eastern sections of the site and are predominantly associated with the shallow to intermediate (<4.2m bgl) suspected combustion wastes. Concentrations were typically recorded at the same order of magnitude as the screening value but were also frequently recorded at one order of magnitude greater than the screening value. A single sample (TP117) was recorded at two orders of magnitude greater than the screening value.
- 13.3.24 The other PAH exceedences (benzo(k)fluoranthene, pyrene, acenaphthylene, acenaphthene and fluorene) were isolated and restricted to individual locations (TP117 at 4.2m, TP139 at 2.4m and WS309 at 3.2m) within the north western and north eastern sections of the site. Concentrations were recorded at the same to one order of magnitude greater than the screening values.
- 13.3.25 Those PAH compounds recorded within natural ground (possibly reworked ground) were isolated and restricted to a single location (WS102 at 2.8m). Concentrations were typically recorded at the same order of magnitude as the screening value.
- 13.3.26 A reduced number of PAH exceedences were noted from the Celtic 2007 dataset and this included exceedences for naphthalene, benz(a)anthracene, chrysene,

benzo(b)fluoranthene, benzo(a)pyrene and dibenzo(a,h)anthracene. For these determinands similar trends were observed, except that they were predominantly associated with cohesive and granular Made Ground, concentrations were generally lower and that fewer exceedences were recorded within the central sections of the site. The differences can likely be explained by how the soils were logged and that areas were likely inaccessible at the time of the Celtic site investigation. An increased number of exceedences were also noted from natural cohesive strata (possibly reworked ground), but these were still relatively isolated to specific locations.

Benzene, Toluene, Ethylbenzene and Xylene (BTEX)

- 13.3.27 BTEX exceedences (benzene, p/m-xylene and o-xylene) are indicated to be isolated and restricted to a single location (TP139 at 2.4m) within the north western section of the site and within the suspected combustion type wastes. Concentrations were recorded at one to two orders of magnitude greater than the screening value.
- 13.3.28 It should be noted that most of the samples tested for BTEX were recorded below their LOD (which was raised in some samples) and, in these instances, this was greater than the screening value. As positive exceedences have been noted a conservative approach is warranted and it is possible that other unrecorded benzene exceedences may be present.
- 13.3.29 No BTEX exceedences were recorded from the 2007 Celtic dataset.

Semi Volatile and Volatile Organic Compounds

- 13.3.30 Dibenzofuran is indicated to be relatively isolated to within the north eastern and the north western sections of the site and was predominantly encountered at shallow to intermediate depths (<4.2m bgl) and within a variety of Made Ground types. Concentrations ranged from the same order of magnitude to two orders of magnitude greater than the screening value.
- 13.3.31 The other VOC and SVOC exceedences are indicated to be isolated and are generally restricted to specific locations within the north eastern, north western and south eastern sections of the site. The exceedences generally occurred at shallow depth to intermediate depth (<4.2m bgl) and were predominantly encountered within the suspected construction and demolition wastes. Concentrations were typically recorded between one and two orders of magnitude greater than the screening values.

- 13.3.32 Regular PID testing was also undertaken during the 2020 WA investigation and only very low concentrations (between 0.0ppm and 13.8ppm) were recorded from soils which generally supports the observations noted above. The PID results can be found in Appendix L.
- 13.3.33 12 No. Membrane Interface Probe (MIP) tests were undertaken as part of the WA 2021 investigation, which indicated some form of VOC contamination that was localised to the north western and central south western sections of the site as shown in Drawing LD10385 – 024. The result can be found in Appendix Q.
- 13.3.34 Similar trends were observed from the 2007 Celtic dataset except that exceedances of 2,4-Dinitrotoluene, Chloromethane and 2,4-Dimethylphenol were also noted and that they occurred within a more varied range of strata types, which included one sample from natural cohesive strata (possibly reworked ground). No exceedances of pentachlorophenol or 1,2,4-Trimethylbenzene were noted.

Polychlorinated Biphenyls (PCB)

- 13.3.35 PCB exceedances are indicated to be localised to within the central section of the site and are predominantly associated with the shallow (<3.0m bgl) to deeper (>5.0m bgl) suspected construction and demolition wastes. Concentrations were typically recorded at one order of magnitude greater than the screening value. However, 9 No. samples were also recorded at two orders of magnitude greater than the screening value.
- 13.3.36 It should be noted that most of the samples tested for PCB's were recorded below their LOD (which was raised in some samples) and in these instances this was greater than the screening value. As positive exceedances have been noted a conservative approach is warranted and it is possible that other PCB exceedances may be present. It should be noted that the screening value used is already conservative, as it is the sum of Dioxins, Furans and Dioxin-Like PCBs and assumes a typical mixture that will be worse than the PCB congeners recorded at the site.

Asbestos

- 13.3.37 Possible ACMs were encountered during the site investigation works as outlined in Section 11. A total of 129 No. samples were screened for asbestos and a summary of results where asbestos was confirmed by laboratory analysis is provided in Table 13.2.

Table 13.2: Summary of Asbestos Identified				
Location	Depth (m)	Strata	Type & Comments	Quantification
CP103	2.00 – 3.00	MGC	Chrysotile & Crocidolite – fibre bundles and ACM debris in soil	0.0046%
CP107	4.50	MGG	Amosite – soil containing ACM debris	-
CP109	7.50	MG-CDW	Chrysotile & Amosite – fibre bundle and material typical of asbestos cement debris in soil	5.11%
CP202	6.70	MGG	Chrysotile – fibre bundle in soil	<0.001%
RH203	4.00 – 5.00	MG-CDW	Chrysotile – fibre bundle in soil	<0.001%
TP102	1.60	MG-CDW	Chrysotile – soil containing material typical of asbestos paper	0.279%
TP104	1.80	MG-CDW	Chrysotile – loose fibres in soil	-
TP126	0.50	MG-CW	Chrysotile – fibres in soil	<0.001%
TP138	1.60	MG-CDW	Chrysotile – soil containing ACM debris.	-
TP149	0.50	MG-CW	Chrysotile – loose fibres in soil	<0.001%
TP203	1.00	MGC	Chrysotile & Amosite – fibre bundle in soil	0.0607%
TP203	2.90	MG-CDW	Chrysotile & Amosite – ACM debris in soils	<0.001%
TP204	2.50	MGC	Chrysotile – loose fibres in soil	<0.001%
TP207	3.00	MG-HW	Chrysotile – ACM debris in soil	0.0173%
TP211	1.80	MGC	Chrysotile – fibre bundles in soil	<0.001%
TP212	1.50	MG-CW	Amosite – loose fibres in soil	0.0031%
TP224	1.40	MG-CDW	Amosite – loose fibre in soil	0.0053%
TP229	3.00	MG-CDW	Chrysotile & Crocidolite – loose fibres in soil	0.0489%
TP239	1.40	MGC	Chrysotile – fibre bundle in soil	<0.001%
TP242	2.50	MGG	Amosite – ACM fragment in soil	<0.001%
TP245	2.00	MG-CDW	Chrysotile & Amosite – loose fibres in soil	0.0647%
TP249	1.50	MG-HW	Chrysotile & Crocidolite – fibre bundle in soil	0.0019%
TP251	2.00	MGC	Chrysotile – ACM debris in soil	<0.001%
WS310	2.80	MGC	Crocidolite – fibre bundle in soil	<0.001%
WS311	1.40	MGC	Amosite – fibre bundles in soil	0.0199%
WS112	0.90	MG-CW	Chrysotile – ACM debris in soil	0.109%
Notes:				

Table 13.2: Summary of Asbestos Identified

Location	Depth (m)	Strata	Type & Comments	Quantification
MGC = Predominantly Cohesive Made Ground, MGG = Predominantly Granular Made Ground, MG-CW = Suspected Combustion Waste, MG-CDW = Suspected Construction and Demolition Waste, MG-CS = Suspected Colliery Spoil Waste, MG-HW = Suspected Household Waste				

13.3.38 Asbestos fibre concentrations above the human health screening value of 0.001% were generally localised to within the central south western section of the site and to a lesser extent the central north eastern section of the site. Exceedences were predominantly associated with the shallow (<3.0m bgl) suspected construction and demolition type wastes. Concentrations were typically recorded at the same or one order of magnitude greater than the screening value. However, 2 No. samples (TP102 at 1.6m and WS112 at 0.9m) were recorded at two orders of magnitude greater than the screening value and a single sample (CP109 at 7.5m) was recorded at three orders of magnitude greater than the screening value.

13.3.39 No asbestos was identified as part of the 2007 Celtic site investigation, but this is likely due to a change in laboratory analytical techniques and / or the techniques not being as accurate / sensitive at the time that these tests were undertaken.

13.4 Assessment of Vapours – Soils (Human Health)

13.4.1 Based on the ground conditions and contamination encountered it is anticipated that soil vapours could pose a risk to those identified receptors and that this may need to be dealt with by the inclusion of passive vapour protection measures in new buildings, which is line with third party assessments, and / or by source reduction (e.g. remediation of heavily impacted soils). However, further detailed risk assessment will be required in line with current guidance to specify the precise requirements for vapour protection / remediation and this is discussed further at the DQRA stage. Ultimately, the final choice for mitigation will be in conjunction with specialist remediation contractors and will be subject to agreement with relevant regulators.

13.5 Assessment of Vapours – Groundwater (Human Health)

13.5.1 Chemical contaminants in groundwater can volatilise into soil gas and migrate through unsaturated soils upward into overlying buildings through cracks and gaps in the building floors, foundations etc. The vertical screening distance is the minimum thickness of unsaturated zone between a vapour source and the overlying building

foundation (i.e. vertical separation distance) as defined in guidance document Petroleum Vapour Intrusion, ITRC, 2014).

13.5.2 Several empirical studies have defined vertical screening distances for petroleum hydrocarbon compounds in dissolved phase groundwater sources. The vertical screening distance used to derive the Groundwater Vapour GAC by SOBRA in 2017 is relatively shallow with the depth to source assumed to be 0.65m bgl.

13.5.3 Concentrations of volatile contaminants in groundwater from the WA 2020 & 2022 site investigation have been screened against residential end use GAC for assessing vapour risks to human health from volatile contaminants in groundwater (SOBRA 2017). A summary of the recorded groundwater volatile vapour exceedances is provided in Table 13.3.

Table 13.3: Groundwater Vapour Exceedences					
Determinand	Location (Date)	Response Zone m bgl	Groundwater Body Screened	SoBRA GAC _{gw vap} (µg/l)	Recorded Concentration µg/l
TPH Aliphatic Fraction C10-C12	CP109 (2020)	9.00 – 13.00	MG	37	117
	CP109 (2022)	9.00 – 13.00	MG	37	81
Notes: MG = Perched Groundwaters within Made Ground					

13.5.4 The sample was obtained from a response zone that screened deep perched waters within the Made Ground (between 9.00m and 13.00m bgl) and a potentially significant risk is only envisaged if foundations were to extend to within 0.65m of the source (i.e. vertical screening distance noted above) or if the source area was more widespread. Additional consideration will to be given to the potential vapour risk represented by dissolved concentrations of aliphatic C10-C12 TPH in the further vapour DQRA works that will be required.

13.5.5 The remainder of the volatile contaminants were recorded below their respective LOD and / or screening criteria. While some screening values were below the raised limit of detection applied to some samples, in the absence of any positive exceedences, the concentrations are considered likely to be low and to not pose an unacceptable risk.

13.6 Assessment of Contamination – Groundwater (Human Health)

13.6.1 Based on the groundwater conditions encountered and the seepage within the central southern section of the site, it is anticipated that shallow perched groundwaters within the Made Ground could pose a risk to those identified receptors. However, due to the intermittent nature of the seepage any long-term exposure to these contaminated waters is unlikely and the risk is slightly to be significantly reduced or removed following development of the site.

13.7 Human Health Risk Assessment – Construction Workers

13.7.1 The CLEA Soil Guideline Values only apply to the protection of health for long term chronic exposure. Construction workers are more likely to be at risk from a high single exposure (i.e. an acute dose, which can result in contaminant poisoning). Procedures for the calculation of for acute lethal doses are outlined in SoBRA 'Development of Acute Generic Assessment Criteria for Assessing Risks to Human Health from Contaminants in Soil' dated April 2019.

13.7.2 None of the samples contained concentrations of arsenic, benzene, cadmium, free cyanide, phenol, trichloroethene and vinyl chloride that were elevated with respects to an acute lethal dose. No acute lethal dose value is given for lead.

13.7.3 Under CDM Regulations 2015 and the Health and Safety at Work Act (1974) appropriate PPE will be required for all construction workers. At the very least, this would reduce any dermal and ingestion pathways and will help to mitigate any risk.

Asbestos

13.7.4 Groundworks may be carried out at different phases of a site development including enabling works, site preparation or installation of underground services. These activities typically generate some soil derived dusts and construction arisings. If soil derived dusts are generated in areas containing asbestos in soil, then respirable asbestos fibres may be released into the air which pose a risk to human health.

13.7.5 As possible ACM's and low to high concentrations of asbestos fibres have been detected in Made Ground across the site (between 0.0018% and 5.11%), it is considered necessary for an asbestos management plan (AMP) to be developed, to fully detail how soils impacted with asbestos can be dealt with, in accordance with the Control of Asbestos Regulation 2012 (CAR 2012), and to protect construction workers and the public from exposure to asbestos fibres during the redevelopment works. The

presence of potential ACM will need to be considered when determining the correct work category and need for mitigation to comply with CAR 2012 in developing the AMP for the site works.

- 13.7.6 It is recommended that a watching brief for ACM is maintained during groundworks across the site, particularly within the suspected construction and demolition type waste that are present within the central sections of the site. Where possible the groundworks on site should be designed and planned to minimise the exposure of workers to contaminated soil and to minimise potential generation of airborne fibres. This should be considered in the Health and Safety plan under the CDM Regulations and include appropriate method statements and risk assessments prior to undertaking any works at the site (i.e. remedial / earthworks / construction works) that could generate airborne fibres from contaminated soils.
- 13.7.7 Where risks cannot be removed entirely at the planning stage, mitigation measures should include procedures to control the potential release of asbestos fibres during groundworks at the site (e.g. damping down haul roads, stockpiles and excavations, as required) and the use of PPE including gloves and respiratory facemasks to protect groundworks. All mitigation measures incorporated during the remedial works / earthworks / construction works as outlined above, should be in accordance with requirements in CAR 2012 and the AMP which will be developed for the site.

13.8 Free Product in Soils

- 13.8.1 Hydrocarbon odours and staining to soils were frequently noted across the site during both the WA and Celtic site investigation works as outlined in Section 11 and section 8, respectively. Multiple exceedences of the soil saturation concentrations for Aliphatics >C12-C44 were also noted from the laboratory results, as shown in Table 13.4:

Table 13.4: Summary of Soil Saturation Concentrations (WA 2020 & 2022)				
Contaminant	Min. Recorded (mg/kg)	Max. Recorded (mg/kg)	GAC _s (mg/kg)	No. of Exceedances
Aliphatics >C12-C16	<1	276	24	17
Aliphatics >C16-C21	<1	773	8.48	38
Aliphatics >C21-C35	<1	3590	8.48	82
Aliphatics >C35-C44	<1	1610	8.48	43
Notes:				
s Soil Saturation Limits; LQM/CIEH S4ULs for Human Health Risk Assessment (3rd edition, 2015).				

- 13.8.2 It should be noted that an exceedence of the soil saturation limit only indicates that the theoretical concentration at which pore water has become fully saturated has been exceeded. Under these conditions there is the potential for NAPL / free product to be present, but there are numerous other site-specific factors that need to be considered.
- 13.8.3 As part of the WA 2021 investigation, 48 No. Optical Image Profiler (OIP) tests were undertaken across the site to delineate possible NAPL / hydrocarbon fuels / oils. 14 No. OIP “blips” were recorded predominantly within the suspected combustion wastes within the north western and south eastern sections of the site and the suspected construction and demolition type wastes within the central and southern sections of the site; both of which are shown in Drawing LD10385-024. The result can be found in Appendix Q.
- 13.8.4 Frequent groundwater level monitoring has also been undertaken using a product / water interface probe in areas where visual and olfactory evidence of contamination has been recorded, where OIP “blips” have been recorded and where exceedences of the soil saturation limits have been recorded. No NAPL or free product was detected with the interface probe nor was any visual evidence of free product recorded during development, purging and groundwater sampling. Celtic also state that no NAPL was encountered during their works.

14 GENERIC QUANTITATIVE RISK ASSESSMENT – CONTROLLED WATERS

14.1 General

- 14.1.1 Four rounds of groundwater sampling were undertaken by WA between December 2020 and June 2022 from shallow and deep monitoring wells that had response zones specifically targeting perched groundwater within the Made Ground, perched groundwater within the Glacial Till and deep groundwater within bedrock. 39 No. purged groundwater samples were obtained and tested for potential CoC appropriate to the former land uses.
- 14.1.2 A single round of groundwater sampling was also undertaken by Celtic in June 2007. 12 No. purged groundwater samples were obtained and tested for a range of contaminants that Celtic considered to be appropriate to the site's former land uses. This data has been reviewed independently from the more recent WA dataset and these findings are outlined in Section 8. Comparisons have been made between the datasets where relevant, but it is the WA data that has primarily been relied upon to undertake the updated assessments.
- 14.1.3 During the most recent round of groundwater sampling many of the historical boreholes could not be sampled due to the positions being vandalised, destroyed, silted up or being lost. However, additional monitoring wells were installed during the WA 2022 site investigation to provide coverage across the main areas of concern identified from the previous investigations.

14.2 Assessment Criteria

- 14.2.1 In order to assess the risk to controlled waters, the recorded groundwater and soil concentrations have been compared with relevant assessment criteria that are protective of those controlled waters receptors identified within the preliminary CSM outlined in Section 9 and that are compatible with the findings from the most recent 2022 WA site investigations, that have proven that bedrock occurs at depths of c. 45m bgl and is overlain by between c. 35m and 45m of predominantly cohesive Glacial Till (i.e. a geological barrier).
- 14.2.2 For groundwater with bedrock, the UK Drinking Water Standards (UK DWS) or best equivalent values (e.g. World Health Organisation) have been used as these would be the most relevant for the protection of the Principal Aquifer that is present beneath the site. Based on the preliminary CSM and the depth to bedrock from the most recent

2022 site investigation, it is highly unlikely that groundwater is in continuity with those identified surface water receptors, so the use of GAC that would be protective of surface water is not considered to be applicable for these deeper groundwater.

- 14.2.3 For soil leachates and perched groundwater within the Made Ground and Glacial Till, samples have been compared with Environmental Quality Standard (EQS) values that would be protective of the surface water environment, as the preliminary CSM and the most recent WA 2022 site investigation data indicates that pathways to the deeper groundwater within bedrock / Principal Aquifer are highly unlikely. Where EQS values are not available, results have been compared to UK DWS or a best equivalent values.
- 14.2.4 For the above, assessments have also been undertaken using the simplified Metal Bioavailability Assessment Tool (M-BAT) to calculate the amounts of bioavailable copper, zinc, nickel, manganese and lead and associated Predicted No Effect Concentrations (PNECs). Parameters from the Rochdale Canal were obtained during sampling. Parameters from the River Medlock have been obtained from the EA's Water Quality Archive from a sampling location approx. 1.5km south east and upstream of the site.
- 14.2.5 For those determinands included in the analytical suite which do not have a corresponding assessment criteria from the above sources, reference is made to a hierarchy of international guidance in accordance with EA guidance.

14.3 Screening of Groundwaters

- 14.3.1 A summary of the exceedences of the screening criteria for groundwaters from both the 2020 and 2022 WA datasets are presented in Table 14.1. A summary of exceedences from the 2007 Celtic dataset are summarised separately in Table 8.2. A summary of the exceedences in relation to each groundwater receptor (e.g. perched groundwater within Made Ground and deeper groundwater within bedrock) is outlined further in Section 16.
- 14.3.2 Specific details regarding the location, depth, contaminant concentrations and strata for each exceedance are included within Appendix I and the analytical laboratory results of the soil and groundwater chemical analyses are attached at Appendix H. Parameters obtained from groundwater are contained within Appendix K.

Table 14.1: Summary of WA 2020 & 2022 Contaminant Exceedances in Groundwater							
Contaminant	Min. Recorded (µg/l)	Max. Recorded (µg/l)	GAC ¹ (µg/l)	No. of Exceedences			
				MG	MG/GT	GT	BR*
Metals							
Arsenic	0.829	35.6	10 ³	-	-	-	1
Boron	42.6	54,800	100	11	2	4	0
Cadmium	<0.08	11	0.25	1	0	1	-
Chromium	<1	10.7	4.7	5	1	0	-
Copper to Canal	<0.3	140	18.62 ⁶	1	-	-	-
Copper to River			21.46 ⁶	1	-	-	-
Lead to Canal	<0.2	13.9	6.55 ⁶	-	-	2	-
Lead to River			6.78 ⁶	-	-	2	-
Manganese to Canal	37.2	3,880	132.8 ⁶	13	5	9	-
Manganese to River			173.54 ⁶	13	5	-	-
Manganese to Aquifer			50 ³	-	-	-	8
Nickel to Canal	<0.4	130	9.73 ⁶	4	2	-	-
Nickel to River			12.16 ⁶	2	-	-	-
Selenium	<1	11.8	10 ³	-	-	-	1
Zinc to Canal	<1	54.5	29.61 ⁶	2	1	-	-
Zinc to River			30.20 ⁶	2	1	-	-
Iron	<19	11,000	1000	2	1	1	-
TPH							
Total Aliphatics & Aromatics >C5-35	<10	6,590	10 ¹	8	3	3	4
PAH							
Naphthalene	<0.01	4.3	2	2	0	0	-
Fluoranthene	<0.005	19.7	0.0063	16	6	9	-
Anthracene	<0.005	5.21	0.1	11	2	4	-
Benzo(b)fluoranthene	<0.005	33.2	0.1 ³	-	-	-	5
Benzo(k)fluoranthene	<0.005	14.9	0.1 ³	-	-	-	3
Benzo(a)pyrene	<0.002	23	0.00017	12	4	7	-
			0.01 ³	-	-	-	6
Benzo(g,h,i)perylene	<0.005	23.2	0.1 ³	-	-	-	3
Indeno(1,2,3-cd)pyrene	<0.005	22.1	0.1 ³	-	-	-	3
SVOC / VOC							
Phenol	<1	370	7.7	2	1	1	-
Chloroform	<1	2.96	0.1 ⁴	-	-	-	4

bis(2-Ethylhexyl) phthalate	<2	104	8 ⁵	-	-	-	1
PFAS							
Total PFOS	<0.65ng/l	102ng/l	0.65ng/l	6	1	0	-
Total PFOS (Post Ox.)	<2ng/l	129ng/l	0.65ng/l	6	1	0	-
Other							
Sulphate	<2,000	807,000	250,000 ³	2	1	4	3
Total Cyanide	<50	180	1	4	0	1	-
Complex Cyanide	<50	180	1	2	0	0	-
Thiocyanate	<50	120	1	2	0	0	-
Notes: Ex = Exceedences, MG = Perched Groundwater within Made Ground, GT = Perched Groundwater within Glacial Till and BR = Groundwater within Bedrock, Bold = groundwater body from which the maximum recorded concentrations were noted. ¹EQS values used unless noted otherwise. ²Environment Agency (2009), 'Petroleum hydrocarbons in groundwater: supplementary guidance for hydrogeological risk assessment' values used unless noted. ³UK Drinking Water Standard (2016). ⁴The Water Supply (Water Quality) Regulations 2000, ⁵World Health Organization Guidelines for Drinking Water Quality. ⁶Lowest PNEC calculated from M-BAT tool for those samples that exceeded bioavailable EQS.							

- 14.3.3 Most of the recorded concentrations for those other SVOC's and VOC's were either at concentrations that were below their respective screening criteria and / or were recorded at concentrations below the limits of detection (LOD). While the screening values for some of the contaminants were below the LOD (which was raised in some samples), in the absence of any positive concentrations above the screening value, the concentrations (if present) are likely to be low and not pose an unacceptable risk.

Metals and Metalloids

- 14.3.4 Metal exceedences (notably boron, manganese, nickel and chromium) were predominantly encountered within the shallow perched waters within Made Ground (response zones <5.0m bgl), that was generally localised to the central south western and central western sections of the site. Zinc, iron, cadmium and copper were isolated and were predominantly encountered within shallow perched groundwaters in the north western section of the site. The highest concentrations were most abundant within these perched groundwaters, although exceedences were typically recorded at the same order of magnitude as the screening value. The most notable exception being from the deeper perched waters within Made Ground at the location of CP109 (response zone between 9.0m and 13.0m bgl), where concentrations of boron,

chromium and nickel were recorded at an order of magnitude above the screening value.

- 14.3.5 Metal exceedences were generally less frequent within the perched groundwaters within the underlying Glacial Till, but they were generally recorded at similar locations to those exceedences within the perched groundwaters within the Made Ground (i.e. the central south western and central north western sections of the site), principally where continuity between the two groundwater bodies is indicated. The most notable exceptions are 3 No. isolated locations within the north westernmost and north easternmost sections of the site, that are outside of recorded extent of the clay pit excavations. Boron, manganese and selenium were also elevated above the concentrations recorded within perched groundwaters within the Made Ground with a single zinc exceedence also being elevated.
- 14.3.6 For the groundwater within bedrock, different screening criteria have been used, so the exceedences recorded are not comparable. However, most of metal concentrations are indicated to be greatly reduced, the exception being selenium, which was typically recorded at an order of magnitude greater than the concentrations recorded within the overlying perched groundwaters. This general decreasing concentration of metals is generally observed from the shallow to the deeper groundwaters, the exceptions being boron, manganese and selenium, which appear to increase in concentrations with depth.

Total Petroleum Hydrocarbons

- 14.3.7 TPH exceedences were predominantly recorded within the perched groundwater within Made Ground that was localised to the central north western and central south western sections of the site. The highest concentrations were most abundant within these perched groundwaters, with exceedences typically being recorded at one order of magnitude greater than the screening value. The most notable exceptions being two locations within the north western (WS305) and south eastern (WS308) sections of the site, where concentrations within shallow perched groundwaters (response zones <5.0m bgl) were recorded at two orders of magnitude above the screening value. The highest TPH concentration in the entire dataset was also recorded within these perched groundwaters at WS308.
- 14.3.8 TPH exceedences within the perched groundwaters within Glacial Till were generally restricted to individual locations but were generally recorded at similar locations to

those exceedences within the perched groundwaters within the Made Ground (i.e. the central south western, central eastern and central south eastern sections of the site). This was typically within the areas of deeper Made Ground where continuity with the overlying perched groundwaters is indicated. Concentrations were typically reduced from those recorded within the overlying perched waters within the Made Ground, but still generally at one order of magnitude above the screening values. The most notable exception being a single isolated location within the north easternmost section of the site (RH108) and outside of the recorded extents of the clay pit excavations, where a concentration at two orders of magnitude above the screening value was noted within deep groundwater within Glacial Till (response zone between 26.0m and 28.0mbgl). This concentration was also the second highest TPH concentration within the entire dataset.

- 14.3.9 TPH exceedences within the deep groundwater within bedrock were localised to the eastern section of the site and restricted to a single location within the south western section of the site (RH106). Concentrations were generally elevated from those within the overlying perched groundwater within the Glacial Till and were typically recorded at one order of magnitude above the screening value, with a single sample (RH203) recording exceedences at two orders of magnitude above the screening value. The highest concentrations were recorded from RH203, which is located upgradient of the indicated south westerly groundwater flow direction within bedrock. Conversely the lowest concentration was recorded from RH106, which was located downgradient.

Polycyclic Aromatic Hydrocarbons (PAH)

- 14.3.10 For the purposes of the risk assessment for perched water within Made Ground and Glacial Till, anthracene, benzo(a)pyrene, fluoranthene and naphthalene are the only PAH compounds with an EQS AA screening value. In the absence of an EQS AA value for benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene and Indeno(1,2,3-cd)pyrene; benzo(a)pyrene has been used as a marker for these PAH compounds.
- 14.3.11 For the purposes of the risk assessment for the deeper groundwater within bedrock, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene and Indeno(1,2,3-cd)pyrene are the only PAH compounds with screening values for the protection of aquifer resources. Consequently, these PAH compounds have been

used as surrogates to assess the degree of risk posed by PAH compounds within the groundwater.

- 14.3.12 PAH exceedences were frequently encountered within the perched groundwater within Made Ground. Using Benzo(a)pyrene as a surrogate, indicates that PAH exceedences are relatively localised to the central south western, central north western and north western sections of the site. The most notable exception was a single sample recovered from the south eastern section of the site (WS308) which was also in an area where elevated TPH concentrations were recorded. Concentrations were typically two to four orders of magnitude above the screening value.
- 14.3.13 Similarly, PAH exceedences were also frequently encountered within the perched groundwater within Glacial Till. Using Benzo(a)pyrene as a surrogate, indicates that PAH exceedences are concentrated within the central south western and central southern sections of the site. This was typically within the areas of deeper Made Ground, where continuity with the overlying perched groundwater is indicated. Concentrations were typically higher than the overlying perched groundwater within Made Ground and were recorded at three to five orders of magnitude above the screening value. The most notable exception being a single isolated location within the north easternmost section of the site (RH108) and outside of the recorded extents of the clay pit excavations, where a concentration at five orders of magnitude above the screening value was noted within deep groundwater within Glacial Till (response zone between 26.0m and 28.0mbgl). This concentration was also the highest benzo(a)pyrene concentration within the entire dataset.
- 14.3.14 For the groundwater within bedrock, different screening criteria have been used, so the exceedences recorded are not comparable. Using Benzo(a)pyrene as a surrogate indicates that PAH concentrations were generally lower than those encountered within the overlying perched groundwaters. However, at isolated locations within the eastern section (RH201 and RH203) and the south western (RH106) sections of the site, concentrations were comparable to those recorded in the overlying perched groundwaters. Notably RH106 and RH201 are located outside of the recorded clay pit extents and the lowest and second highest concentrations were recorded downgradient and upgradient, respectively, of the indicated groundwater flow direction within bedrock.

Volatile and Semi Volatile Organic Compounds

- 14.3.15 Phenol exceedences within perched groundwaters within the Made Ground were restricted to single locations within the central south western and north western sections of the site. Concentrations were recorded at two orders of magnitude above the screening values. Similarly, exceedences within the perched groundwater within Glacial Till were also isolated to within the central south western section of the site and in areas of deep Made Ground, where continuity with the overlying perched groundwater within Made Ground is indicated. Concentrations were also similar, although decreasing slightly, and were recorded at between one and two orders of magnitude greater than the screening value. Phenol concentrations were all below the LOD within the samples taken from bedrock groundwater.
- 14.3.16 Elevated concentrations of chloroform and bis(2-Ethylhexyl) phthalate were recorded within deep groundwater within bedrock at isolated locations within the central, south western and north western sections of the site and also within the north easternmost section of the site at RH108 within deep groundwater within Glacial Till (response zone between 26.0m and 28.0m bgl). These determinands were all recorded below the LOD within the perched groundwater within Made Ground and the shallow perched groundwater within Glacial Till. Concentrations were recorded at one order of magnitude greater than the screening value, with the lowest concentrations being recorded downgradient of the indicated groundwater flow direction within bedrock. RH108 is also located outside of the recorded clay pit extents.
- 14.3.17 It should be noted that most of the concentrations for the above were recorded at the LOD, which was above the screening value. Considering that positive exceedences have been recorded it is possible that some of the recorded concentrations below the LOD (which were raised in some samples) could exceed the screening value.

PFAS

- 14.3.18 Total PFOS (including post ox.) exceedences were predominantly recorded within perched groundwaters within the Made Ground that were localised to the central south western, central north western and north western sections of the site. Concentrations were highest within these perched water and were typically recorded at two to three orders of magnitude above the screening values. The highest concentrations were recorded within the central south western sections of the site

where suspected household type waste predominated, and the lowest concentrations were recorded within the north western section of the site where suspected combustion waste predominated.

14.3.19 Only a single exceedence was recorded within the shallow perched groundwater within the Glacial Till that was restricted to a single location (CP203), within the central southern section of the site and where continuity with the overlying perched groundwater within the Made Ground is indicated. Concentrations were typically reduced, but still recorded at two orders of magnitude greater than the screening values.

14.3.20 PFAS concentrations were not detected above the LOD within the deeper perched groundwater within Glacial Till or bedrock.

Inorganics

14.3.21 Sulphate exceedences within the perched groundwater in the Made Ground were relatively localised to the central sections of the site; most notably the central southern section of the site. Concentrations were recorded at the same order of magnitude as the screening values. Conversely, sulphate exceedences within the perched groundwater within the Glacial Till were more frequent, at higher concentrations, and their distribution was more widespread. Exceedences within the deep bedrock groundwater was localised to the north eastern section of the site, but concentrations were noted to be reduced and decreasing downgradient, but still generally higher than those recorded within the perched groundwater within the Made Ground.

14.3.22 Cyanide exceedences were largely restricted to the perched groundwater within the Made Ground and were relatively localised to the central north western and to a single location within central south western section of the site. Concentrations were typically recorded at two orders of magnitude above the screening value. Only a single exceedence, but at a reduced concentration, was recorded from the perched groundwater within the Glacial Till, from a single location (CP203), where continuity with the overlying perched waters within the Made Ground was indicated. Cyanide exceedences were absent within the deeper perched groundwater within Glacial Till and bedrock.

14.4 Non-Aqueous Phase Liquids or Free Product

14.4.1 OIP testing has indicated the presence of NAPL / hydrocarbon fuels / oils with “blips” generally being recorded within the suspected combustion wastes within the north western and south-eastern sections of the site and the suspected construction and demolition type wastes within the central and southern sections of the site; both of which are shown in Drawing LD10385-024.

14.4.2 During the WA site investigations, hydrocarbon sheens were also occasionally observed to shallow perched groundwater, mostly within the north western section of the site during trial pitting. During development and sampling of the monitoring wells hydrocarbon odours and putrid odours were also frequently encountered.

14.4.3 However, frequent groundwater level monitoring has been undertaken using a product / water interface probe in areas where the OIP testing was undertaken and where sheens were observed. No NAPL or free product was detected with the interface probe nor was any visual evidence recorded during development, purging and groundwater sampling. Celtic also state that no NAPL was encountered during their works.

14.5 Discussion of Groundwater Results

14.5.1 Those metal, TPH, PAH, SVOC / VOC and sulphate exceedences recorded within groundwater from bedrock and deeper Glacial Till merit further discussion, as the ground conditions at the site indicate that pathways or continuity between perched water within Made Ground and / or directly underlying granular Glacial Till are highly unlikely, due to the significant thicknesses of low permeability Glacial Till (i.e. a geological barrier) that have been recorded between the various groundwater bodies that are present beneath the site.

Background Concentrations

14.5.2 For those metal (boron, manganese, selenium) and sulphate exceedences that were recorded, the highest / most elevated concentrations were recorded within deep groundwater from bedrock and / or deep perched groundwaters within Glacial Till. This does not correlate with the concentrations recorded at the source (i.e. Made Ground and perched waters within the Made Ground), which were found to be significantly lower.

- 14.5.3 A review of “Baseline Report Series: 8. The Permo-Triassic Sandstones of Manchester and East Cheshire” indicates that high baseline concentrations for manganese, sulphate and selenium (up to 1790 µg/l, 666 mg/l and 4.7 µg/l respectively) have been regionally recorded for the groundwater within the Principal Aquifer that is present beneath the site. Consequently, those exceedences recorded for manganese, sulphate and selenium are likely to be representative of baseline conditions and once the baseline concentrations are accounted for, many of the concentrations are recorded at negligible concentrations.
- 14.5.4 A similar situation to that outlined above is also apparent for the boron and manganese exceedences that were recorded within the deep perched water from Glacial Till. While relatively high concentrations have been recorded within perched groundwater within Made Ground and immediately underlying groundwater within Glacial Till, a plausible pathway to the deeper perched groundwater is not indicated. Many of the higher concentrations were also recorded within boreholes that were outside of the recorded clay pit extents and were elevated above those concentrations recorded within the perched groundwater within the Made Ground. This suggests that background concentrations within the deeper Glacial Till may also be elevated and is indicative of confined conditions.

Presence and Absence of Specific Determinands

- 14.5.5 Many of the determinands noted within the perched groundwaters within Made Ground were absent within bedrock. This included cyanide, cadmium, chromium, phenol, BTEX, multiple SVOC / VOC compounds, sulphide and PFAS. Furthermore, concentrations of chloroform and bis(2-Ethylhexyl) phthalate were present within bedrock, but were absent, along with their precursors, from the perched groundwaters within Made Ground. Elevated concentrations of chloroform were also detected at RH108 within deep groundwaters within Glacial Till (response zone between 26.0m and 28.0m bgl).
- 14.5.6 Both of the above are supportive of a lack of continuity between the deeper groundwater within bedrock and deeper perched water within Glacial Till, with the latter also being indicative of another source of contamination other than the site and / or in baseline conditions within the Principal Aquifer or deeper confined waters within the Glacial Till.

Increased Concentrations of Contamination Upgradient of the Site and Outside of the Recorded Clay Pit Extents

Within the deep groundwater within bedrock, there were several determinands (TPH, PAH, sulphate, chloroform and bis[2-ethyhexyl]phthalate) that were recorded at increased concentrations upgradient of the indicated groundwater flow direction to the south west. Often these were also at elevated concentrations to those within the overlying perched groundwaters. The lowest concentrations for the above were also recorded from the downgradient boreholes. Furthermore, many of the elevated concentrations within bedrock and deep perched groundwater within Glacial Till (RH108) were located outside of the recorded clay pit extents, where only limited thicknesses of Made Ground were encountered. If the site were to be the source of the contamination within the deeper groundwaters, the opposite trend should have been observed.

TPH & PAH

- 14.5.7 Generally, TPH and PAH concentrations within bedrock were lower than those recorded within the perched groundwater within Made Ground, but elevated concentrations were recorded at RH106, RH201 and RH203 that were comparable, or elevated, to those concentrations recorded within the overlying perched groundwater. Significantly elevated TPH and PAH was also recorded at RH108 within deep perched groundwater within Glacial Till.
- 14.5.8 During the 2020 site investigation, a second round of groundwater sampling and testing was undertaken from RH106 and RH108 and in both instances the second round of testing recorded significantly reduced total TPH concentrations that were below the LOD, with significantly reduced PAH concentrations also being recorded from RH108.
- 14.5.9 While PAH concentrations were significantly reduced, exceedences at the same order of magnitude as the screening values were still recorded. However, the screened sections from the 2020 WA boreholes were noted to be fully silted up, and in some cases, this extended a significant distance up the standpipe. This particulate matter could account for those PAH exceedences that have been recorded. These boreholes could not be sampled during the 2022 site investigation, as they had become completely silted up almost to ground level and were dry.

14.5.1 Regardless, as noted above, many of these boreholes were located outside of the recorded extents of the clay pit excavation and for those that screened bedrock, the highest (RH201 & RH203) and lowest (RH106) TPH and PAH concentrations were noted upgradient and downgradient, respectively, of the indicated south westerly groundwater flow direction. Despite the potential for interference from particulate matter within the 2020 boreholes, this suggests another source of contamination other than the site and / or in baseline conditions within the Principal Aquifer or deeper confined waters within the Glacial Till.

Summary

14.5.2 There are multiple lines of evidence to suggest that those metal (boron, manganese and selenium), TPH, PAH, SVOC / VOC and sulphate exceedences recorded within groundwater from bedrock and deeper Glacial Till are unlikely to be representative of contamination leaching from and originating from the site. Furthermore, due to the significant thickness of low permeability Glacial Till (i.e. a geological barrier) that has been recorded, any contamination within perched groundwater in Made Ground is unlikely to represent an ongoing or potential future significant risk to the deeper groundwater or the sensitive Principal Aquifer, due to the lack of a pathway. Following development, a betterment is also envisaged with a c. 70% increase in hardstanding areas, which will further reduce vertical migration with most surface waters / rainwater being captured by drainage.

14.6 Assessment of Contamination – Leachate

14.6.1 A total of 20 No. soil samples from Made Ground were analysed for leachate to assess the potential risks to controlled waters from impacted soils. This included 10 No. samples from the 2020 WA investigations and 10 No. samples from the 2007 Celtic investigation.

14.6.2 A summary of the exceedences of the screening values from the 2020 WA dataset presented in Table 14.2. The exceedences from the Celtic 2007 dataset are summarised in Table 8.3. A summary of the exceedences in relation to each strata type is outlined further in Section 16.

14.6.1 Specific details regarding the location, depth, contaminant concentrations and strata for each exceedance are included within Appendix I and the analytical laboratory results of the soil and groundwater chemical analyses are attached at Appendix H.

Table 14.2: Summary of Leachate Exceedences in Soil (WA 2020)				
Contaminant	Min. Recorded (µg/l)	Max. Recorded (µg/l)	EQS GAC (µg/l)	No. of Exceedences
Metals				
Chromium VI	<3	53.4	3.4	3
Arsenic	0.53	73.4	50	1
Chromium	<1	1,500	4.7	4
Cadmium	<0.08	0.349	0.08	2
Copper to Canal	0.71	35.8	18.62 ²	1
Copper to River			21.46 ²	1
Lead to Canal	<0.2	108	6.55 ²	2
Lead to River			6.78 ²	2
TPH				
Total Aliphatics & Aromatics >C5-35	<10	65	10 ¹	2
PAH				
Benzo(a)pyrene	<0.002	0.0398	0.00017	4
Fluoranthene	0.0106	1.63	0.0063	10
Anthracene	<0.005	1.18	0.1	1
Inorganics				
Total Cyanide	<50	70	1	1
Sulphate	2,200	279,000	250,000 ³	1
Notes:				
¹ Environment Agency (2009), ‘Petroleum hydrocarbons in groundwater: supplementary guidance for hydrogeological risk assessment’ values used unless noted. ² Lowest PNEC calculated from M-BAT tool for those samples that exceeded bioavailable EQS. ³ UK Drinking Water Standard (2016).				

- 14.6.2 Most of the contaminants were recorded below their respective LOD and / or screening criteria. While some screening values were below the LOD, in the absence of any positive exceedences, the concentrations are considered to be low enough to not pose an unacceptable risk.
- 14.6.3 Following a receptor specific assessment using the M-BAT tool, the bioavailable concentrations for nickel and manganese were all found to be below the EQSbioavailable screening value.

Metals and Metalloids

- 14.6.4 Exceedences of metals (chromium VI, cadmium, chromium, copper, arsenic and lead), were generally localised to the north western section of the site, but also occurred at isolated locations across the entire site. They were generally recorded at the same order of magnitude as the screening values and were mostly found within the suspected combustion type wastes and to a lesser extent the suspected construction and demolition type wastes.

Total Petroleum Hydrocarbons (TPH)

- 14.6.5 Exceedences of TPH were recorded at individual locations within the central section of the site and were generally found within the suspected construction and demolition type waste and suspected household type waste. Concentrations were recorded at the same order of magnitude as the screening value.

Polycyclic Aromatic Hydrocarbons (PAH)

- 14.6.6 Exceedences of PAH were frequent and generally localised to the north western, south western and south eastern sections of the site, where they were associated the suspected combustion type wastes and to a lesser extent the suspected construction and demolition type wastes. Relatively isolated exceedences were also noted within the north east and central parts of the site. Concentrations were generally recorded at one order of magnitude greater than the screening value.

Inorganics

- 14.6.7 Exceedences of total cyanide were restricted to a single location (TP123) within the north western section of the site. It was recorded at one order of magnitude greater than the screening value within the suspected combustion type wastes.
- 14.6.8 Exceedences of sulphate were restricted to a single location (TP112) within the central south western sections of the site and associated with the suspected construction and demolition wastes. Concentrations were generally recorded at the same order of magnitude as the screening value.

Phenols

- 14.6.9 Exceedences of phenol monohydric were recorded within the Celtic 2007 dataset at a single location within the north eastern section of the site and was associated within

cohesive Made Ground. It was recorded at the same order of magnitude as the screening value.

Limitations

- 14.6.10 It should be noted that for all the PAH compounds assessed, cyanide and phenol monohydric, most of the concentrations were recorded at the LOD, which was above the screening value. Considering that positive exceedences have been recorded it is possible that some of the recorded PAH, phenol monohydric and cyanide concentrations below the LOD could also exceed the screening value.

Discussion of Leachate Results

- 14.6.11 The recorded exceedences for PAH compounds, sulphate, cyanide and phenol in soil leachate generally correlate with those recorded exceedences in perched groundwater within Made Ground. The spatial distribution and concentrations recorded are generally similar and indicate that the leachates generated from the Made Ground at the site (particularly those from the suspected combustion type wastes) could be contributing to the concentrations of these contaminants in shallow perched groundwaters at the site.
- 14.6.12 While the recorded exceedences for metals in soil leachate only loosely correlate with those exceedences recorded within shallow perched groundwater within Made Ground, the concentrations themselves do generally correlate. This indicates that the leachates generated from the Made Ground at the site (particularly those from the suspected combustion type wastes) may be contributing to the concentrations of these contaminants in shallow perched groundwater at the site.
- 14.6.13 The recorded exceedences of TPH in soil leachate do not correlate with those recorded exceedences in groundwater. Exceedences within soil leachate were relatively isolated and occurred at relatively low concentrations, while those within groundwater were relatively widespread and occurred at much higher concentrations. This disparity could be due to limitations with the laboratory methods used or it could indicate that leachates generated from the Made Ground at the site are not significantly contributing to TPH contamination within groundwater.

14.7 Assessment of Contamination – Surface Waters

- 14.7.1 Three rounds of surface water sampling and testing have been undertaken from the Rochdale Canal that forms the northern boundary of the site.

- The first round was undertaken by Celtic in 2007, with two samples being obtained (Canal A and Canal B taken upstream and downstream, respectively).
- The second round was undertaken by WA in December 2020, with three samples being obtained (SW01, SW02, SW03; taken midstream, upstream and downstream along the canal, respectively).
- The third round was undertaken by WA in June 2022, with three samples being taken midstream, upstream and downstream along the canal.

14.7.2 A summary of the exceedences of the screening criteria from both the 2020 and 2022 WA dataset are presented in Table 14.3. A summary of the exceedences of the screening criteria from the Celtic 2007 dataset are presented in Table 8.5. A summary of the exceedences in relation to each strata type is outlined further in Section 16.

14.7.3 Specific details regarding the location, depth, contaminant concentrations and strata for each exceedance are included within Appendix I and the analytical laboratory results of the soil and groundwater chemical analyses are attached at Appendix H. Parameters obtained from surface water are contained within Appendix K.

Table 14.3: Summary of Exceedences in Surface Water (WA 2020 & 2022)				
Contaminant	Min. Recorded (µg/l)	Max. Recorded (µg/l)	GAC (µg/l)	Number of GAC Exceedences
Metals				
Chromium	<1	6.25	4.7	1
TPH				
Total Aliphatics & Aromatics >C5-35	<10	83	10 ¹	3
PAH				
Fluoranthene	0.024	0.485	0.0063	6
Benzo(a)anthracene	0.0109	0.182	0.01	6
Benzo(a)pyrene	0.0107	0.186	0.00017	6
PFAS				
Total PFOS	1.87ng/l	<6.5ng/l	0.65ng/l	1
Total PFOS (Post ox.)	<2.19ng/l	<10ng/l	0.65ng/l	1
Notes: Environmental Quality Standards (2015) values unless noted. * ¹ Environment Agency (2009), 'Petroleum hydrocarbons in groundwater: supplementary guidance for hydrogeological risk assessment' values used unless noted.				

14.7.4 Most of the contaminants were recorded below their respective LOD and / or screening criteria. While some screening values were below the limit of detection, in the absence of any positive exceedences, the concentrations are likely to be low enough to not pose an unacceptable risk.

14.7.5 Following a site-specific assessment using the M-BAT tool, the bioavailable concentrations for lead, nickel, manganese and copper were all found to be below the EQSbioavailable screening value.

Metals and Metalloids

14.7.6 Marginal exceedences of chromium were recorded on a single occasion from midway along the canal from the WA 2020 surface water testing. The remainder of samples were recorded below the LOD.

14.7.7 Marginal exceedences of lead, copper and nickel were recorded upstream and downstream from the Celtic 2007 surface water testing with the highest concentrations typically being recorded from upstream. However, no parameters were obtained to allow for M-BAT screening to be undertaken, so the screening criteria used were not receptor specific and in light of updated information, these can be discounted.

14.7.8 No other exceedences were recorded from either dataset, but arsenic, boron, manganese, iron and nickel were found to be at slightly higher concentrations upstream of the site. Chromium, copper, lead, zinc and iron concentrations were generally found to be at slightly higher downstream. The remainder were recorded below the LOD.

Total Petroleum Hydrocarbons

14.7.9 Marginal exceedences of TPH were recorded midstream and downstream from the WA datasets, with the highest concentrations being recorded from midstream. The remainder of the TPH concentrations from both the Celtic and WA datasets were recorded below the LOD.

Polycyclic Aromatic Hydrocarbons

14.7.10 PAH compounds (benzo(a)pyrene and fluoranthene) were recorded within all samples from both rounds of WA testing with the lowest concentrations being recorded downstream of the site. The highest concentrations were recorded midstream, but

elevated concentrations were also noted upstream, indicating that there are background concentrations of PAH compounds within the canal. PAH concentrations from the Celtic dataset were recorded below the LOD.

PFAS

- 14.7.11 A single total PFOS exceedence at an order of magnitude greater than the screening value was recorded midstream along the canal. Results from upstream and downstream were below the LOD.

Discussion of Surface Water Results

- 14.7.12 The contaminants recorded within surface water are generally not reflective of those encountered within shallow perched groundwater within Made Ground or soil and leachate contaminants. Contaminants recorded within perched groundwater within Made Ground that are absent from the canal are numerous and include phenol, BTEX, multiple SVOC / VOC compounds, cadmium, selenium and cyanide.
- 14.7.13 The above is likely due to a lack of hydraulic continuity that is indicated between the canal and shallow perched groundwaters within Made Ground; the canal is confined by those natural clay deposits (i.e. a geological barrier) that have been recorded around the periphery of the site; water levels in the canal are elevated from perched groundwater levels and the canal is likely clay lined. Shallow perched groundwater flow directions are also indicated to be away from the canal and towards the deeper parts of the clay pit excavations as shown in Drawing LD10385-019. The possibility of groundwater flooding and overspill into the canal is considered to be highly unlikely due to the topography, the indicated groundwater flow directions and information from the Envirocheck Report indicates a limited potential for groundwater flooding to occur.
- 14.7.14 As the site is slightly elevated from the canal along its northern boundary, some surface water run-off with leached contaminants could be migrating towards the canal along the site's northern boundary. This is loosely supported by the highest concentrations of contaminants in surface water generally being recorded from the midpoint of the canal. However, the potential for significant leaching to occur is low. due to the limited amount of time these waters would have to percolate through the soils before entering the canal.

14.7.15 Furthermore, elevated concentrations of some contaminants (notably PAH) were recorded from upstream of the site and this indicates that some of the background concentrations of contaminants within the canal may already be elevated (e.g. fuel leaks from passing canal boats or general detritus that has been tipped into the canal over the years).

14.8 **Assessment of Contamination – Groundwater Seepage**

14.8.1 During a ground gas and groundwater monitoring round that was undertaken on the 21st January 2021 and following a sustained period of heavy rainfall, an upwelling of groundwater, with associated groundwater flooding at the surface, was noted within the central south western section of the site adjacent to the site's southern boundary (see Drawing LD10385-22). The water was observed to be migrating in a southern direction towards the site's southern boundary, with most of the water being captured by the off-site drainage that runs parallel to the site's southern boundary.

14.8.2 The upwelling was occurring via three observable fissures / cracks in the ground and had a notable putrid / sulphurous odour. When first observed, it had a slight orange tinge to it, but during subsequent visits a light bluish grey sheen / film was noted instead, with the submerged sediment coloured similarly. Some light bluish grey particulate matter was also noted flowing out of the upwelling and some similarly coloured scum / foam was noted in areas where the flow of water was reduced.

14.8.3 To quantify the risks and establish the source of this groundwater upwelling, a single water sample was obtained from the main point of upwelling on the 25th January 2021 and was submitted for laboratory testing. It should be noted that no recent excavations or excavations from previous stages of site investigation were recorded within the area of seepage.

14.8.4 The results were initially compared to the United Utilities (UU) water quality data for the Newton Heath area to ascertain if the waters could be from a burst unrecorded water pipe. Chlorine, Cyanide, Thiocyanate, Chromium VI, mercury, cadmium, copper, lead, selenium, zinc, TPH and most of the PAH, SVOC and VOC compounds were recorded below the limit of detection.

14.8.5 Determinands recorded above the LOD that could pose a risk to human health and controlled waters are summarised in the Table 14.4:

Table 14.4: Summary of Concentrations Above the LOD from Groundwater Seepage Sample		
Contaminant	Recorded Concentration	Max. UU Concentrations
Carbon		
Carbon, Organic	17.4 mg/l	2.3 mg/l
Inorganics		
Conductivity	1.61 mS/cm	0.156 mS/cm
Total Dissolved Solids	1300 mg/l	-
Dissolved Oxygen	3.44 mg/l	-
Redox Potential	173 mV	-
Alkalinity as Total CaCO ₃	897 mg/l	12
Fluoride	0.679 mg/l	0.05 mg/l
pH	7.25	7.88
Sulphate	236 mg/l	43.4 mg/l
Sulphide	0.613 mg/l	-
Metals		
Arsenic	1.5 µg/l	<0.48 µg/l
Boron	15,700 µg/l	<0.0146 µg/l
Chromium	7.22 µg/l	<0.830 µg/l
Manganese	533 µg/l	3.51 µg/l
Nickel	3.49 µg/l	2.30 µg/l
Calcium	379 µg/l	16,600 µg/l
Iron	1.89 µg/l	16.1 µg/l
PAH		
Naphthalene	0.127 µg/l	-
Acenaphthene	2.38 µg/l	-
Acenaphthylene	2.39 µg/l	-
Fluoranthene	0.268 µg/l	-
Anthracene	0.057 µg/l	-
Phenanthrene	0.0479 µg/l	-
Fluorene	0.167 µg/l	-
Chrysene	0.0146 µg/l	-
Pyrene	0.171 µg/l	-
SVOC & VOC		
1,4-Dichlorobenzene	1.15 & 1.57 µg/l	-
Chlorobenzene	8.7 µg/l	-
1,2-Dichlorobenzene	1.15 µg/l	-
Notes:		
UU Concentrations obtained from the UU website. UU note PAH concentrations (sum of Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(g,h,i)perylene and Indeno(1,2,3-cd)pyrene) as 0 µg/l.		

- 14.8.6 Analytical laboratory results for the full groundwater chemical analyses are attached at Appendix H.

Discussion of Groundwater Seepage Results

- 14.8.7 Most of the concentrations recorded from the groundwater seepage were significantly elevated above the UU water quality data, effectively ruling out a burst drinking water supply pipe as the cause of the seepage.
- 14.8.8 With the exception of 1,4-Dichlorobenzene and 1,2-Dichlorobenzene, the concentrations correlate with the concentrations of those determinands recorded from the perched groundwater within the Made Ground that is present at the site. Furthermore, the seepage was recorded to be occurring close to one of the buried highwalls of the former clay pit excavations (see Drawing LD10385-022), from an area where perched groundwater elevations are indicated to be high and, in a location, where the perched groundwater in this general area is indicated to be flowing towards (see Drawing LD10385-019). Consequently, the lines of evidence suggest that it is likely that the groundwater seepage is from the perched shallow groundwater within the Made Ground that is present within this part of the site.

15 GROUND GAS RISK ASSESSMENT

15.1 Background

15.1.1 The preliminary CSM has identified the following on-site possible ground gas sources; made ground associated with the former land uses (e.g. historic and registered landfill and brickworks) and a potentially infilled reservoir within the central northern section of the site. Off-site possible ground gas sources include areas of possibly infilled ground (e.g. ponds, excavations and the extension of those on-site excavations off-site), other historic landfills and other areas of Made Ground.

15.2 Assessment Criteria

15.2.1 It is currently understood that the form of many of the proposed residential structures are unlikely to conform to the model low rise housing type used for the NHBC Traffic Light System assessment. Consequently, the ground gas risk assessment has been undertaken by calculating Gas Screening Values (GSV) for each location and the site as a whole and comparing the results to the Characteristic Gas Situations (CS) as outlined in BS8485.

15.2.2 Calculations have been undertaken using the maximum steady flow and peak carbon dioxide and methane concentrations for each monitoring location and the site as a whole, from both the Celtic and WA dataset, so that a worst-case assessment can be undertaken. Where initial peak flows and negative flows have been recorded, but judged unrepresentative, this has been noted and / or discussed.

15.3 Results and Assessment

15.3.1 The gas monitoring results from WA ground gas monitoring undertaken between 30th November 2020 to 25th March 2021 and 19th May 2022 to 18th June 2022 have recorded concentrations of methane up to 6.0% by volume and concentrations of carbon dioxide up to 20.2% by volume and variable flow rates ranging from -3.7l/hr to 20.9/hr.

15.3.2 The gas monitoring from the Celtic 2007 investigation undertaken between 27th June 2007 to 23rd July 2007 recorded concentrations of carbon dioxide between <0.1% and 14.3% (typically between <0.1% and 9.8%), methane concentrations up to 30.5% (typically <0.1%) and gas flow rates of up to 2.3 l/hr.

15.3.3 11 No. visits have been undertaken by WA and 3 No. visits were undertaken by Celtic. Atmospheric pressures were below 1000mb for four of the WA visits and two of the

Celtic visits, with a minimum pressure of 966mb being recorded during the most recent round of monitoring. The WA data was collected through the late autumn to early spring 2021 and late spring to early summer 2022. The Celtic data was collected during summer 2007. Two of the visits were undertaken during periods of falling atmospheric pressure. Therefore, the data collected is believed to cover the worst-case conditions and the frequency and period of monitoring undertaken is considered to be sufficient.

15.3.4 The results and the subsequent GSV calculations from both the WA and Celtic data are included within Table 15.1.

Table 15.1: Summary of Ground Gas Monitoring Data						
Borehole ID	Max Steady Flow Rate (l/hr)	Max Peak CH ₄ (% v/v)	Max Peak CO ₂ (% v/v)	Max. BH Qhg (CH ₄)	Max. BH Qhg (CO ₂)	Characteristic Situation (CS)
WA Data 2020 & 2022						
CP103a	-2.40 ^{*2}	1.2	1.3	0.0288	0.0312	CS2 ^{*3}
CP103b	-2.40 ^{*2}	1.5	3	0.036	0.072	CS2
CP107 [#]	-2.40 ^{*2}	0.1	1.3	0.0024	0.0312	CS1
CP108 [#]	-2.80 ^{*2}	0	1.7	0	0.0476	CS1
CP109 [#]	2.50	3.1	0.3	0.0775	0.0075	CS2
CP110	-3.00 ^{*2}	0	6.3	0	0.189	CS2
CP112 [#]	-2.40 ^{*2}	5.8	5.8	0.1392	0.1392	CS2
CP113 [#]	-3.00 ^{*2}	0	2.6	0	0.078	CS2
RH101 [#]	-2.50 ^{*2}	0	0.8	0	0.02	CS1
RH102 [#]	-2.80 ^{*2}	0	1.7	0	0.0476	CS1
RH106	-2.10 ^{*2}	0	4.4	0	0.0924	CS2
RH108 [#]	20.9	0	2.8	0	0.5852	CS2
RH109a [#]	-2.50 ^{*2}	0	7.3	0	0.1825	CS2
RH109b	-2.30 ^{*2}	0	6.7	0	0.1541	CS2
RH110	-2.50 ^{*2}	0	1	0	0.025	CS1
WS101 [#]	-2.40 ^{*2}	0	3.1	0	0.0744	CS2
WS102	-2.20 ^{*2}	0	10.7	0	0.2354	CS2
WS103	-2.70 ^{*2}	0	5.1	0	0.1377	CS2
WS104	-2.50 ^{*2}	0	1.6	0	0.04	CS1
WS105 [#]	-2.50 ^{*2}	0.5	1.7	0.0125	0.0425	CS1
WS106 [#]	-2.70 ^{*2}	0	1.5	0	0.0405	CS1
WS107 [#]	-3.00 ^{*2}	0	20.2	0	0.606	CS2
WS108 [#]	-3.70 ^{*2}	0	4.9	0	0.1813	CS2

Table 15.1: Summary of Ground Gas Monitoring Data

Borehole ID	Max Steady Flow Rate (l/hr)	Max Peak CH ₄ (% v/v)	Max Peak CO ₂ (% v/v)	Max. BH Q _{hg} (CH ₄)	Max. BH Q _{hg} (CO ₂)	Characteristic Situation (CS)
WS109 [#]	-2.20 ^{*2}	0	7	0	0.154	CS2
WS111 [#]	-3.70 ^{*2}	3.8	14.8	0.1406	0.5476	CS2
WS112	-3.00 ^{*2}	0	5.9	0	0.177	CS2
WS113 [#]	-1.50 ^{*2}	0	17.4	0	0.261	CS2
WS117	0.1	0	5.8	0	0.0058	CS2 ^{*3}
WS119	-2.40 ^{*2}	0	2.4	0	0.0576	CS1
WS120	-2.40 ^{*2}	0	1.4	0	0.0336	CS1
BH04	-2.10 ^{*2}	0	13.7	0	0.2877	CS2
BH06	-2.40 ^{*2}	0	11.8	0	0.3422	CS2
WS311	0.1	6	10	0.006	0.01	CS2 ^{*3}
CP202 [#]	0.1	0.1	0.2	0.0001	0.0002	CS1
WS303 [#]	0.1	0	5.7	0	0.0057	CS2 ^{*3}
CP207 [#]	0.1	0.3	2.4	0.0003	0.0024	CS1
RH205 [#]	0.1	0	0	0	0	CS1
WS302 [#]	0.1	0.3	4.2	0.0003	0.0042	CS1
WS312 [#]	0.1	0	0.9	0	0.0009	CS1
CP203 [#]	0.1	0	0.2	0	0.0002	CS1
CP206 [#]	0.1	0	0.3	0	0.0003	CS1
CP205 [#]	0.1	0	0.3	0	0.0003	CS1
CP204	0.1	0	0.2	0	0.0002	CS1
WS313	0.1	0	2.9	0	0.0029	CS1
WS308 [#]	0.1	0	7.1	0	0.0071	CS2 ^{*3}
RH201 [#]	0.1	0	0	0	0	CS1
WS316 [#]	0.1	0	2.9	0	0.0029	CS1
WS301	0.1	0	6.6	0	0.0066	CS2 ^{*3}
CP201 [#]	0.1	0	2	0	0.002	CS1
WS315	0.1	0	2.2	0	0.0022	CS1
CP208 [#]	0.1	0	0.3	0	0.0003	CS1
CP209 [#]	0.1	0	0	0	0	CS1
WS318 [#]	0.1	0	3.3	0	0.0033	CS1
WS305 [#]	0.1	0	2.9	0	0.0029	CS1
RH204 [#]	1.5	0	0.7	0	0.0105	CS1
WS314	0.1	1.5	0.9	0.0015	0.0009	CS1
RH202 [#]	0.1	0	0.5	0	0.0005	CS1
RH203 [#]	0.1	0	0.6	0	0.0006	CS1

Table 15.1: Summary of Ground Gas Monitoring Data						
Borehole ID	Max Steady Flow Rate (l/hr)	Max Peak CH4 (% v/v)	Max Peak CO2 (% v/v)	Max. BH Qhg (CH4)	Max. BH Qhg (CO2)	Characteristic Situation (CS)
CP210 [#]	0.1	0	0.6	0	0.0006	CS1
RH206 [#]	1.2	0	0.2	0	0.0024	CS1
Celtic Data						
WS1	0.1	0	1.6	0	0.0016	CS1
WS2	0.1	0	0.8	0	0.0008	CS1
WS3	0.1	0	1.7	0	0.0017	CS1
WS4	0.1	0	5.5	0	0.0055	CS2 ^{*3}
WS5	0.1	0	5.5	0	0.0055	CS2 ^{*3}
WS6	0.1	0	4.5	0	0.0045	CS1
WS7	0.1	0	1.7	0	0.0017	CS1
WS8	0.6	0	3.3	0	0.0198	CS1
WS9	0.1	7.6	15	0.0076	0.015	CS2 ^{*3}
WS10	0.1	0.4	6.3	0.0004	0.0063	CS2 ^{*3}
WS11	0.1	0	6.3	0	0.0063	CS2 ^{*3}
WS12	0.1	0	5.7	0	0.0057	CS2 ^{*3}
WS13	0.1	0	3.2	0	0.0032	CS1
WS14	0.1	0	1.5	0	0.0015	CS1
WS15	0.1	0	1.9	0	0.0019	CS1
WS16	0.1	0	2.6	0	0.0026	CS1
WS17	0.1	0	2.9	0	0.0029	CS1
WS18	0.1	1	8.7	0.001	0.0087	CS2 ^{*3}
WS19	0.1	2.3	7.7	0.0023	0.0077	CS2 ^{*3}
WS20	0.1	0.1	9.8	0.0001	0.0098	CS2 ^{*3}
WS21	0.1	0.8	9.6	0.0008	0.0096	CS2 ^{*3}
WS22	0.1	0.9	8.6	0.0009	0.0086	CS2 ^{*3}
BH1 [#]	0.1	30.6	8.4	0.0306	0.0084	CS2 ^{*3}
BH2 [#]	0.1	19.7	2.2	0.0197	0.0022	CS2 ^{*3}
BH3	0.1	0	0.2	0	0.0002	CS1
BH4	2.3	0	0	0	0	CS1
BH5	2.3	0	0	0	0	CS1
BH6	0.1	0.4	8	0.0004	0.008	CS1 ^{*3}
BH7	0.1	0.3	1.2	0.0003	0.0012	CS1
BH8	0.1	0	1.2	0	0.0012	CS1
BH9	0.1	0	2.1	0	0.0021	CS1
BH10	0.1	15.4	8.6	0.0154	0.0086	CS2 ^{*3}

Table 15.1: Summary of Ground Gas Monitoring Data						
Borehole ID	Max Steady Flow Rate (l/hr)	Max Peak CH4 (% v/v)	Max Peak CO2 (% v/v)	Max. BH Qhg (CH4)	Max. BH Qhg (CO2)	Characteristic Situation (CS)
BH11	0.1	15.4	8.3	0.0154	0.0083	CS2 ^{*3}
BH12	0.1	6.8	5.7	0.0068	0.0057	CS2 ^{*3}
Worst-credible Qhg (l/hr) *				0.1406	0.606	CS2
Worst-possible Qhg (l/hr) +				6.3954	4.2218	CS4
Qhg = Hazardous gas flow rate, in accordance with BS8485:2015 * Based on maximum recorded concentration and maximum flow rate applicable to any individual borehole. + Based on maximum recorded concentration and maximum flow rate across the whole site. ^{*1} Where no flow is detected, detection limits of 0.1l/hr have been used. ^{*2} Denotes where negative flow rates are the maximum flow rates recorded. As there are uncertainties regarding the reason for the negative flow rates these negative values have been reversed and used for the calculation of the GSV. ^{*3} Denotes where the characteristic situation has been increased due to methane being recorded above 1% and / or carbon dioxide being recorded above 5%. # Response zone of monitoring well flooded or partially flooded. Bold denotes concentrations above 5% for CO2 and 1% for CH4.						

15.3.5 The gas monitoring data indicates that the site should be classified as CS2 and that ground gas protection measures are required. While a highly conservative worst possible CS4 situation has been calculated for the site based on the maximum recorded concentrations and maximum flow rate across the whole site, this is not consistent with the conceptual model for the site (i.e. an old landfill with mostly inert wastes from a ground gas perspective) and is deemed to be unrepresentative for the following reasons:

- The maximum flow rate of 20.9l/hr recorded from RH108 is the main driver behind this worst possible characterisation and the response zone for this borehole is located at a depth of between 26m and 28m bgl in deep Glacial Till and is not representative of the main source of ground gas (i.e. the landfill) and pathways for flow are unlikely due to the significant thickness of glacial clay proved at this location and elsewhere.
- The peak methane and carbon dioxide concentrations used in the assessment were recorded in boreholes where the response zones were noted to be either fully flooded or partially flooded, which may have resulted in elevated carbon dioxide or methane concentrations. In such situations, when groundwater enters

the monitoring well, any dissolved gases in groundwater are able to partition from the water to the air in the well headspace until equilibrium is achieved. This gas then becomes trapped in the air space, resulting in high gas concentrations being recorded within the headspace when it is sampled during gas monitoring, with the overall gas concentration in the unsaturated zone being significantly less than that measured in the well headspace. The effect can be compounded due to additional gasses coming out of solution as the pressure drops within the monitoring well due to atmospheric effects.

15.3.6 By taking the above into consideration, the worst possible characterisation is reduced to CS2, which is more in line with the overall dataset and the conceptual model for the site.

15.3.7 Consideration has been given to the zoning of the site (specifically for the south western section of the site that lies outside of the landfill and where natural superficial strata are present at shallow depth), but the current dataset does not justify this approach (CS2 is indicated for boreholes in this area) and the presence of sand layers within the natural superficial deposits could act as pathways for ground gas from the nearby landfill.

15.3.8 The ground gas monitoring results are included at Appendix J.

15.4 **Ground Gas Protection Measures**

15.4.1 As outlined in BS8485, the proposed building types are likely to be Type A (Private) or Type B (Private or commercial / public, possible multiple) and in consideration of a CS2 situation for the site, a minimum gas protection score of 3.5 is required.

15.4.2 To achieve the points required, new structures will need to incorporate a combination of two or more types of gas protection measures in accordance with BS8485. The three general types of ground protection measures include:

- Structural barrier (within floor slab).
- Appropriate ventilation.
- Gas resistant membrane.

15.4.3 It is likely that most of the residential structures would be formed on a precast suspended segmental subfloor (i.e. beam and block). In this situation the 3.5 points

required can be achieved by incorporating the following into the floor slab construction:

- Passive Subfloor Dispersal Layer (2.5 points for very good performance and 1.5 points for good performance) that meets all the relevant criteria as set out in BS8485.
- Gas Resistant Membrane (2 points) that meets all the relevant criteria as set out in BS8485. In the event that the membrane could come into contact with organic contaminants then the resistance to such contaminants will need to be considered.

15.4.4 By incorporating the above with the floor slab construction, a maximum of 4.5 points can be achieved. While this point allocation seems like an overdesign, this is the only way that a beam and block floor slab construction can achieve the required points for a CS2 situation and incorporates a factor of safety into the design.

15.4.5 When further information about the form of the proposed residential structures is available and if a significant number of structures are found to conform to the model low rise housing type for the NHBC Traffic Light System assessment, then it may be prudent to undertake a separate assessment for those structures where this would be applicable, as the scope of the ground gas protection measures could be reduced.

15.4.6 If significant surcharging of the site is to be undertaken as part of the remedial works or the development of the site, that could result in increased ground gas generation, or if impermeable cover systems are used that could result in the build-up of gas, then additional ground gas monitoring may be required at the edges of such features to further quantify the risk.

15.5 Radon Gas

15.5.1 An initial assessment for radon gas has been carried out. The determination follows the two-stage procedure outlined in BR211 Radon: Guidance on protective measures for new dwellings (2007).

15.5.2 The assessment indicates that the site is in a lower to intermediate probability radon area where <1% to 1 to 3% of homes are estimated to be at or above the Action Level. In both instances no radon protection measures are required.

16 REVISED CONCEPTUAL SITE MODEL AND QUALITATIVE RISK ASSESSMENT

16.1 Introduction

16.1.1 In line with relevant guidance documents, plausible source, pathway and receptor linkages have been identified for the site. A preliminary CSM was presented in Section 8. At the time of writing, the CSM was largely based on the information that had been obtained before 2021 and a number of uncertainties in the CSM existed.

16.1.2 Following the completion of the most recent phases of site investigation works that have been undertaken at the site, the uncertainties have been reduced and an updated CSM is presented below.

16.2 Sources

16.2.1 The potential sources identified with the preliminary CSM are still applicable and further specific details from the WA phased site investigation works are included below. Celtic 2007 data has been referenced where this is applicable.

Soils

16.2.2 In soils, there are exceedances of screening values within:

- The suspected combustion type wastes that predominated within the north western and to a lesser extent the south western, south eastern and north easternmost sections of the site. These materials were generally found to contain frequent / widespread exceedances of metals (arsenic and lead) and PAH; occasional / localised exceedances of beryllium, nickel, total cyanide and TPH; and rare / isolated exceedances of asbestos, TPH, PCB's, hexavalent chromium, copper, zinc, benzene, p/m-xylene and o-Xylene. Total PFOS results were recorded below the LOD.
- The suspected construction and demolition type wastes that were typically recorded within the central section of the site. These materials were generally found to contain frequent / widespread exceedances of lead, PAH and PCB's; occasional / localised exceedances of TPH, asbestos, arsenic and nickel; and rare / localised exceedances of total cyanide, beryllium, copper, zinc, dibenzofuran, carbazole, 2-methylnaphthalene, trichloroethene and 1,2,4-trimethylbenzene. Elevated concentrations of Total PFOS (5.79 µg/kg) were identified in a single sample.

- The general cohesive Made Ground that was generally present across the site and intermixed with those other waste types noted above, were generally found to contain frequent / widespread exceedences of lead and PAH; occasional / localised exceedences of arsenic, total cyanide and TPH; and rare / isolated exceedences of asbestos, beryllium, cadmium, nickel, dibenzofuran and carbazole. Total PFOS results were all recorded below the LOD.
- The general granular Made Ground that was generally present across the site and intermixed with those other waste types noted above were generally found to contain frequent / widespread exceedences of lead and PAH; occasional / localised exceedences of PCB's; rare / isolated exceedences of total cyanide, beryllium, nickel, TPH, dibenzofuran and 1,2,4-trimethylbenzene. Total PFOS results were recorded below the LOD.
- The suspected household type wastes were typically recorded within the central south western part of the site, but also generally intermixed with the suspected construction and demolition type wastes within the central north western and central eastern parts of the site. In comparison to the other material types only limited testing was undertaken on these materials, but they were generally found to contain occasional / localised exceedences of asbestos and lead; rare / isolated exceedences of nickel, PAH and pentachlorophenol. Total PFOS results were recorded below the LOD.
- The suspected colliery spoil type waste was typically recorded within the north eastern section of the site. In comparison to the other material types, only limited testing was undertaken on these materials, and they were only found to have a single exceedence of naphthalene.
- Within the natural strata only a single exceedence of arsenic, a single exceedence of lead, and single exceedences of individual PAH compounds were identified at WS102 at 2.80m bgl. Total PFOS results were recorded below the LOD. Celtic noted a single exceedence of cyanide at TP67 at 2.8m bgl which was at a similar location to the above exceedance in WS102 (25m south east). Celtic also recorded an increased frequency of PAH exceedences, but these were still isolated to specific locations. The natural strata in both instances were noted to directly underlie the Made Ground strata and the descriptions were not typical of the natural strata elsewhere and hence were more likely to be reworked natural ground.

Leachate

16.2.3 In soil leachate, there are exceedances of screening values for:

- Within the suspected combustion and demolition type wastes occasional localised exceedances of hexavalent chromium, chromium, fluoranthene and benzo(a)pyrene; and rare / isolated exceedances of cadmium, total cyanide, copper and lead. The exceedances were generally localised within the north western / western section of the site. It should be noted that testing within this strata was limited.
- Within the suspected construction and demolition type waste occasional localised exceedances of fluoranthene; and rare / isolated exceedances of arsenic, cadmium, chromium, TPH, sulphates and benzo(a)pyrene. The exceedances were generally localised within the central section of the site. It should be noted that testing within this strata was limited.
- Within the suspected colliery spoil a single exceedence of fluoranthene. This exceedence was from the central eastern section of the site. It should be noted that testing within this strata was limited.
- Within the suspected household waste single exceedences of chromium, lead, TPH, Anthracene, fluoranthene and benzo(a)pyrene. This exceedence was from the central section of the site. It should be noted that testing within this strata was limited.
- Within the general cohesive Made Ground a single exceedence of hexavalent chromium and fluoranthene. This exceedence was from the site's southern boundary and in line with the school that abuts the site to the south. It should be noted that testing within this strata was limited. A single exceedence of phenol was noted from the Celtic 2007 dataset.

Groundwater

16.2.4 In groundwater there are exceedances of screening values for:

- In perched groundwater within the Made Ground there are frequent / widespread exceedances of the screening values for PAH, boron and manganese; occasional / localised exceedences of TPH, chromium, nickel, cyanide and total PFOS; rare / isolated exceedances for phenol, sulphate, zinc and iron; and a single exceedence of cadmium.

- In perched groundwater sampled from response zones that screened both Made Ground and Glacial Till, or where the Glacial Till was screened immediately below the Made Ground, there were occasional / localised exceedances of the screening values for PAH and manganese; rare / isolated exceedances for metals (boron, nickel, zinc and iron), TPH and total PFOS; and single exceedances of sulphate, chromium, zinc and phenol.
- In perched groundwater sampled from response zones that only screened deeper Glacial Till there were frequent exceedances of PAH and manganese; occasional / localised exceedances of TPH, boron and sulphate; rare / isolated exceedances of lead and single exceedances of total cyanide, phenol, iron and cadmium.
- In deep groundwater within bedrock there were frequent exceedances of the screening values for manganese; occasional / localised exceedances of PAH, TPH, chloroform and sulphate; and single exceedances of arsenic, selenium and bis(2-Ethylhexyl) phthalate. Most of the exceedances within bedrock are unlikely to be representative of contamination leaching from and originating from the site as outlined in Section 14.
- Concentrations of contaminants were significantly reduced within the Celtic 2007 dataset and most notably all PAH, SVOC / VOC's and TPH were generally recorded below the LOD. The exception being a single TPH sample within perched groundwater within Made Ground that was slightly elevated. Metal concentrations and phenol were also generally reduced, but similar trends to the WA datasets were observed.

Surface Waters

16.2.5 In surface waters there are exceedances of screening values for:

- Marginal exceedances of chromium from midstream along the canal.
- Marginal exceedances of TPH were recorded midstream and downstream with the highest concentrations being recorded from midstream.
- PAH compounds (benzo(a)pyrene and fluoranthene) were recorded within all samples from both rounds of WA testing with the lowest concentrations being recorded downstream of the site. The highest concentrations were recorded midstream, but elevated concentrations were also noted upstream.
- A single total PFOS exceedances at an order of magnitude greater than the screening value was recorded midstream along the canal.

- Concentrations of arsenic, boron, manganese, iron and nickel were found to be at slightly higher concentrations upstream. Concentrations of chromium, copper, lead, zinc and iron were generally found to be at slightly higher concentrations downstream

Non-Aqueous Phase Liquids (NAPL) / Free Product

16.2.6 Frequent groundwater level monitoring was undertaken by WA using a product / water interface probe in areas where visual and olfactory evidence of contamination has been recorded, where OIP “blips” have been recorded and where exceedences of the soil saturation limits have been recorded. No NAPL or free product was detected with the interface probe nor was any visual evidence of recorded during development, purging and groundwater sampling. Celtic also state that no NAPL was encountered during their works.

Ground Gas

16.2.7 The site investigation works indicate that the following ground gas sources are present at the site:

- Made Ground of significant thickness (up to 13.85m) within the historical landfill with abundant degradable constituents. A moderate ground gas generation potential is envisaged based on the age of the landfill.
- Made Ground of limited thickness and extent associated with the former infilled reservoir. Low degradable content. A very low ground gas generation potential is envisaged.
- The WA ground gas risk assessment undertaken is generally indicative of CS2 and a worst-case possible scenario of CS4.

16.2.8 Off-site possible ground gas sources include areas of possibly infilled ground (e.g. ponds, excavations, and the extension of those on-site excavations off-site), other historic landfills other areas of Made Ground.

16.3 Receptors

16.3.1 Several sensitive receptors were identified in the preliminary CSM included within Section 9. Following completion of the additional phased site investigation works the source-pathway-receptor linkages have been updated and there are now sufficient lines of evidence to support the removal of bedrock Principal and Secondary B

Aquifers and the Rochdale Canal as receptors. These lines of evidence are discussed further below.

Human Health

16.3.2 Human health receptors include current site users, future site users / occupiers, construction workers, and the general public / adjacent site users (includes residential properties and the school to the south).

Groundwater

16.3.3 The site is indicated to be underlain by three groundwater bodies. This includes:

- Perched groundwater within Made Ground;
- Perched shallow and deeper groundwater within the superficial Secondary A and Secondary Undifferentiated Aquifers within the Glacial Till and;
- Deeper groundwater within the Principal Aquifer and Secondary B Aquifer within the Collyhurst Sandstone Formation / Chester Formation and Manchester Marls, respectively.

16.3.4 It should be noted that the superficial Secondary A and Undifferentiated Aquifers are indicated to comprise several minor aquifers restricted to lenses of granular strata separated from each other by significant thickness of very low permeability, overconsolidated cohesive strata (i.e. a geological barrier). The perched and confined / isolated nature of the groundwater within the Made Ground and Glacial Till are highlighted within the cross sections contained within Appendix N and Drawings LD10385-017 to LD10385-020.

16.3.5 The site does not lie within a groundwater source protection zone, there are no potable groundwater abstractions within 2.0km of the site and the site's groundwater vulnerability is recorded as low.

16.3.6 The Principal Aquifer and Secondary B Aquifer within bedrock have been removed from the CSM due to the lack of a valid source-pathway-receptor linkage, as outlined by the multiple lines of evidence below:

- The site lies within a BGS Buried Glacial Valley where thick drift deposits are known to be present. This has been validated by the site investigation works where rotary coring techniques have shown that the landfill is underlain by between c. 35m and 45m of predominantly low permeability and overconsolidated glacial clay (i.e. a

geological barrier) as shown in Drawing LD10385-007, the cross sections in Appendix N and the exploratory hole logs contained within Appendix F. The depth to rockhead is also consistent with the findings from local BGS boreholes as shown in Drawings LD10387-008 and LD10387-009.

- Exceedances of the controlled waters screening values and the highest concentrations of determinands are most widespread within perched groundwater within the Made Ground. The absence of most of these determinands in the bedrock groundwater and the presence of elevated concentrations of contaminants not detected within the perched groundwater within Made Ground (see Section 14), supports the lack of continuity between the perched water within the Made Ground and the deeper groundwater within bedrock. The latter is also indicative of background / baseline conditions within the Principal Aquifer and / or another source of contamination other than the site as discussed in Section 14.
- Concentrations of boron, manganese, selenium and sulphate were higher within the deep groundwater within bedrock than they were within the soils or perched groundwater within Made Ground. This is also indicative of background / baseline conditions within the Principal Aquifer and / or another source of contamination other than the site as discussed in Section 14.
- Many of the elevated concentrations of determinands within bedrock were from boreholes located outside of the recorded extents of the clay pit excavation and the highest and lowest concentrations were noted upgradient and downgradient, respectively, of the indicated south westerly groundwater flow direction. If the site were to be the source of the contamination within the deeper groundwaters, then the opposite trend should have been observed. This is also indicative of another source of contamination other than the site and / or baseline conditions within the Principal Aquifer.
- Further evidence of the confined nature of the perched groundwater within the landfill and the lack of a vertical migration pathway to deeper groundwater is supported by the groundwater seepage that has been observed on-site during periods of heavy rainfall. If groundwater within the backfilled clay pits were infiltrating into the underlying natural strata at a significant rate, then this relationship is unlikely to have been observed. Sub artesian conditions within

deeper groundwater are also indicated and this is also indicative of confined conditions within the deeper groundwater.

- Previous third-party DQRA indicated that there was limited evidence to suggest that significant contaminants were leaching from Made Ground into the deeper groundwater at the site. This assessment was based on rockhead being encountered at c. 20m bgl but given that rockhead has been proven to be significantly deeper at c. 45m bgl, this assessment is now known to have been highly conservative and this is also supportive of excluding the deeper groundwater as a receptor.

Surface Water

16.3.7 The nearest graded watercourse is the River Medlock located 650m south and downgradient of the site. The EA has assigned a Moderate (2019) and a General Quality Assessment (Chemistry) rating of E (Poor). It is understood that there are no sensitive surface water abstractions within influencing distance of the site and that most are for non-sensitive industrial purposes.

16.3.8 The Rochdale Canal and Moston Brook have been removed from the CSM, due to the lack of a valid source-pathway-receptor linkage, as outlined by the multiple lines of evidence below:

- A lack of hydraulic continuity is indicated between the Rochdale Canal and shallow perched groundwater, as the canal is confined by those natural clay deposits (i.e. a geological barrier) that are indicated around the periphery of the site as shown by the cross sections in Appendix N. The canal is also likely to be clay lined. There is also no evidence of any land drainage from the site out falling into the canal.
- Water levels within the canal are generally elevated above the perched groundwater encountered at the site as shown in Drawings LD10385-017 and Drawings LD10385-018. The exception being TP104 where groundwater strikes were recorded at 82.7m and 81.0m AOD with the canal being at c. 81.0m AOD. However, this trial pit position was at the location of a historical reservoir, so the groundwater encountered there is likely to be localised and contained within this feature and not representative of the general perched groundwater levels within the Made Ground.

- Localised shallow perched groundwater flow directions are indicated to be away from the Rochdale Canal and towards the deeper parts of the clay pit excavations as indicated in Drawing LD10385-019. Consequently, the lateral migration and possibility of groundwater flooding and overspill into the canal is considered to be highly unlikely.
- The contaminants recorded from samples obtained from the Rochdale Canal are generally not reflective of those encountered within the shallow perched groundwater or soil leachates within the landfill as outlined in Section 14. Elevated concentrations of some contaminants (notably PAH) were also recorded from upstream of the site and this indicates that some of the background concentrations of contaminants within the canal may already be elevated and are not attributable to the site.
- The site is slightly elevated from the canal in places along the northern boundary so some surface water run-off could be migrating towards the canal in this area. However, the potential for significant leaching to occur is very low to negligible due to the limited amount of time these waters would have to percolate through the soils before entering the canal. Infiltration and interception by vegetation are also more likely to occur.
- While the Rochdale Canal has been assigned a General Quality Assessment (Chemistry) rating of B (Good) and it is listed as a Site of Biological Interest (SBI), it is not a graded watercourse and hence the River Medlock is considered to be the more sensitive receptor.
- Moston Brook has been discounted due to the lack of valid pathways (i.e. any surface waters would first be intercepted by the canal, topography generally falls to the south west and groundwater flows are away from this receptor). Furthermore, Moston Brook is culverted for most of its length.

Building and Services

16.3.9 Historic, current and future buildings and service infrastructure (including those adjacent to the site) are also potential receptors.

16.4 Potential Contaminative Linkages

Human Health

16.4.1 In terms of human health, the main potential exposure pathways are considered to be inhalation of soil dust and vapours / ground gas, dermal contact and ingestion of soils, dust, and waters. There is also the possibility of consumption of homegrown vegetables and ingestion of soil attached to vegetables following development of the site. However, the viability of these pathways varies as follows:

- Following development of the site there is expected to be an increase in hardstanding areas, which would help to minimise the dermal, ingestion and inhalation pathways (excluding vapours).
- Construction works and to a lesser extent current site users are likely to have acute interaction with soil and materials, so they are likely to be at risk from all three potential pathways whilst working on the site (i.e. dermal contact, ingestion and inhalation).
- Windblown pathways are most likely during construction of the site but will be significantly reduced following development of the site due to the increase in hardstanding areas.
- Seepage of groundwater at the surface and migration to off-site receptors. This has been mitigated in the short term by a third-party who has diverted these waters away from off-site receptors via small drainage channel. During development the seepage / shallow waters will be managed via a suitable CEMP and following development the risk of a seepage will be significantly reduced due to a c. 70% increase in hardstanding areas reducing site infiltration etc. However, further groundwater seepage could still occur due to leachate generation etc. and as such there may be a requirement for the ongoing or potential future management / mitigation of these shallow perched groundwaters.

Controlled Waters – Groundwater

16.4.2 The main pathways by which contaminants are likely to reach groundwater on-site is through the infiltration of rainwater causing vertical movement through the unsaturated zone followed by vertical and lateral movement of contaminants within groundwater as shown on Drawing LD10385-016 and described below:

- Currently, most of the site is vegetated (although tree felling has recently taken place) and derelict land with vertical migration pathways being restricted to those granular Made Ground materials confined within the backfilled clay pit excavations. During development vertical migration pathways are likely to increase following removal of vegetation and during earthworks. Following development, vertical migration pathways are likely to be significantly reduced from the baseline due to a c. 70% increase in hardstanding areas and the use of low permeability clean cover systems. Built infrastructure (e.g. foundations and services) may also provide pathways. Surface water is also more likely to be captured by drainage before soaking into the ground.
- Further vertical migration into the underlying Glacial Till is significantly limited due to the predominantly low permeability nature of the underlying Glacial Till (i.e. a geological barrier). This is supported by the observed groundwater seepage within the south western section of the site, which indicates that the perched groundwater within the backfilled clay pits is relatively confined. Refer to the cross sections contained within Appendix N and Drawings LD10385-007 and LD10385-010 to 014.
- Lateral migration pathways through the ground to off-site receptors from the backfilled clay pit excavations are indicated to be very limited due to the surrounding low permeability Glacial Till (i.e. a geological barrier). Lateral migration through the ground within and between the various backfilled clay pits is anticipated to be variable due to the indicated extent and geometry of the various excavations and the variability encountered within the backfilled materials. Lateral migration at the base of the backfilled clay pit excavations is expected to predominate at the interface between the granular Made Ground and the underlying predominantly low permeability Glacial Till (i.e. a geological barrier). Refer to the cross sections contained within Appendix N and Drawings LD10385-006 to 007 and LD10385-010 to 014.
- Within the central and eastern areas of the site (area of the main clay pit excavations) there are a handful of exploratory hole positions where Made Ground directly overlies natural granular deposits or where only a very thin layer of clay is present. This indicates that vertical migration pathways are present in places to the underlying granular layers within the shallow Glacial Till. However, these

granular layers are indicated to have limited vertical and lateral connectivity and are separated from each other by a significant thickness of very low permeability, overconsolidated cohesive strata (i.e. a geological barrier). As such there is unlikely to be continuity between the shallow and deeper perched water within the Glacial Till. The perched and confined / isolated nature of the groundwater within the shallow Glacial Till are highlighted within the cross sections contained within Appendix N and Drawings LD10385-017 to LD10385-018.

- Shallow perched water strikes within Made Ground were encountered between 0.1m and 8.2m bgl with monitored elevations recorded between 85.18m and 75.49m AOD. Shallow perched groundwater strikes within the underlying natural superficial deposits were encountered between 1.0m and 15.0m bgl with monitored elevations recorded between 83.44m and 63.32m AOD. Analysis of groundwater levels within the perched groundwater within the Made Ground / landfill are variable but are generally indicated to be towards the deepest parts of the clay pit excavations as shown in Drawing LD10385-007 and Drawing LD10385-019. Groundwater flow within Glacial Till is also variable due to the lack of interconnectivity between the various sand and gravel layers as shown Drawing LD10385-020.
- Slightly confined conditions are indicated for the groundwater within the shallow natural superficial deposits, and this also suggests that these water bodies are confined. It is expected that these confined conditions would reduce the downward migration of some contaminants through groundwater.
- Interception of rainwater by the dense vegetation that is present at the site and the uptake of shallow perched water by roots and evaporation are also a mechanism by which the infiltration of rainwater / surface waters into the backfilled clay pit excavations is reduced.
- Limited vertical and lateral migration pathways may also exist via historic man-made features such as relic foundations, underground infrastructure / voids, excavations and buried services. However, the presence of these features is indicated to be limited from the various site investigations that have been undertaken.
- Lateral migration of perched groundwater beneath the site to the River Medlock Valley is considered unlikely due to the presence of significant thickness of low

permeability Glacial Till (i.e. a geological barrier) and the lack of connectivity that is indicated for the sand and gravel lenses.

Controlled Waters – Surface Water

16.4.3 The main pathway by which contaminants are likely to reach surface water receptors is through surface water run-off / overland flow as follows:

- The site and the surrounding topography generally falls to the south west and towards the site's south western corner.
- During development of the site, surface water run-off is likely to increase due to the removal of vegetation and earthworks. However, management of these surface waters would be required as part of the development of the site (i.e. via a CEMP or similar) and this should limit pathways to receptors.
- Following the development of the site it is envisaged that surface water pathways will be reduced as any waters will likely be captured within on-site drainage before they encounter any surface water receptors or soils.

Ground Gas and Vapour

16.4.4 With the exception of downward migration, the main ground gas pathways are similar to those lateral and vertical migration pathways envisaged for groundwater. However, the ground gas generation potential of the source is the main factor in the potential for the lateral migration of any ground gases and groundwater itself can sometimes facilitate lateral migration of dissolved ground gases. Ingress and accumulation then occurs once the ground gas or vapour has reached a valid receptor (e.g. a building). Inhalation is the main pathway for human health receptors.

16.4.5 Following development of the site, ground gas pathways are envisaged to be reduced due to the possible use of low permeability cover systems. Conversely built infrastructure (e.g. foundations and services) may also provide pathways.

Buildings / Infrastructure

16.4.6 Potential sources of on-site contamination and aggressive ground and groundwater have been identified that could have the ability to degrade concrete or water pipes which are likely to come into direct contact with the contaminated / aggressive Made Ground or groundwater. Ingress and accumulation of ground gases and vapours may also occur.

Flora / Fauna

16.4.7 The site is vegetated with other flora and fauna being present that have developed within potentially contaminated soils. Future vegetation may be planted at the site and may come into contact with contaminated soils or groundwater.

16.5 Qualitative Risk Assessment

16.5.1 A qualitative risk assessment has been undertaken for the contaminant linkages to identify any potentially unacceptable risks. The CIRIA document Contaminated Land Risk Assessment – a guide to good practice C552, 2001 defines the Consequence of Risk, Probability of Risk Being Realised and Risk Classification Definition. These definitions are provided in Appendix E and are used to provide a qualitative risk assessment for each identified source, pathway, receptor linkage.

16.5.2 The combined CSM and qualitative risk assessment for each identified source, pathway, receptor linkage can be found in Table 16.1.

Table 16.1: Combined CSM & Quantitative Environmental Risk Assessment

Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
Contamination in soil/shallow perched groundwater noted in the CSM originating from the following on-site sources: 1. Made Ground associated with site's former historic uses. 2. Site's former use as brickworks with clay extraction pits. 3. Site's former uses as historic	Human Health (inhalation, dermal contact and ingestion).	Future site users	Medium	Likely	Moderate (Low with mitigation)	The most sensitive receptor in this scenario would be a child. Hardstanding in the form of roads and pavements will be present across most of the site, reducing the potential for most pathways to be present. However, pathways could still be present in gardens and areas of soft landscaping. Remediation and mitigating measures will be required to protect future site users, and this would likely include clean cover systems within private gardens / areas of soft landscaping. Following remediation, the consequence of any risk being realised would be reduced.
		Current site users	Medium	Low	Low to Moderate	The site is currently densely vegetated, derelict and fenced / secure and only has infrequent use from trespassers. Fly tipped materials are present but pathways and long-term exposure are limited.
		Construction workers	Medium	Likely	Moderate (Low with mitigation)	Less sensitive receptor in this instance (adult). Increased risk to construction workers due to acute interaction with soils. Asbestos fibres have been recorded within soils above the threshold for human health and airborne fibres could be generated. No acute GAC exceedences noted. Risk to construction workers can be managed through the

Table 16.1: Combined CSM & Quantitative Environmental Risk Assessment

Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
and registered landfill.						use of appropriate and safe working procedures, the use of appropriate PPE and suitable mitigating measures to deal with asbestos fibres.
4. Former reservoir (possibly infilled)		Adjacent site users	Medium	High Likelihood	High (Low with mitigation)	The most sensitive receptor in this instance would be a child. Contaminated shallow perched groundwater has been observed seeping out of the ground and migrating to sensitive off-site receptors following a period of heavy rainfall. However, an impermeable bund and drainage channel has been installed to divert these waters back onto the site and away from off-site receptors. During development of the site contaminated soils and shallow perched groundwater will likely be exposed and the risk of migration to off-site receptors via windblown soils or surface water run-off would be increased. However, it is unlikely that contaminants from on-site would migrate off-site in large quantities or at the concentrations recorded on-site, so the consequence is reduced. Risks would be reduced by undertaking development works in accordance with a CEMP. Increase in hardstanding areas and reduced infiltration post development will reduce the risk of further seepages. Some form of leachate / shallow
5. Perched groundwaters within the made ground / landfill.						
6. Fly tipped materials & bund along the site's eastern boundary						

Table 16.1: Combined CSM & Quantitative Environmental Risk Assessment

Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
						perched groundwater mitigation may be required to prevent future groundwater seepage to off-site receptors.
	Controlled waters (migration of groundwater through the ground and surface water run-off/overland flow).	Superficial Secondary Undifferentiated Aquifer	Mild	Low	Low	The superficial Secondary Undifferentiated aquifer is not considered to be overly sensitive and comprises significant thickness of low permeability Glacial Till (i.e. a geological barrier). However, localised pathways do exist in places from the landfill to sand and gravel lenses within the till where these directly underlie the landfill and exceedences of contaminants have been recorded. However, the levels of contaminants observed within Made Ground were generally not reflected within shallow or deep natural deposits and the granular lenses are indicated to be discontinuous and not in continuity with other groundwater or surface water bodies, so the overall impact is indicated to be relatively localised and confined.
		Superficial Secondary A Aquifer	Medium	Unlikely	Low	The superficial Secondary A Aquifer encroaches into the north western section of the site and is likely be of limited extent. No evidence for significant natural granular deposits that would warrant a Secondary A Aquifer classification. Pathways are considered unlikely for the

Table 16.1: Combined CSM & Quantitative Environmental Risk Assessment

Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
						reasons outlined above for the Secondary Undifferentiated Aquifer.
		River Medlock	Medium	Unlikely	Low	The River Medlock is not overly sensitive (WFD Cycle 2 2019 Overall Classification: Moderate), and pathways are limited due to the distance to the receptors, the presence of predominantly low permeability Glacial Till (i.e. a geological barrier) between the site and the river and in some instance's barriers to surface water runoff/overland flow. While granular lenses are present within the Glacial Till, the ground model for the site indicates that these are isolated, and it is unlikely that any continuity is present over such a large distance.
	Buildings / Infrastructure (Direct contact)	Future and existing buildings and water pipes	Mild	Likely	Low to Moderate (Low with mitigation)	Elevated and widespread concentrations of aggressive contaminants (e.g. sulphates and PAH) are widespread and would have the ability to degrade concrete or water pipes. Mitigating measures could include concrete design to withstand chemical attack and barrier pipe/ ductile pipes for water supply pipes.
	Flora and Fauna	Existing vegetation and potential fauna	Minor	Likely	Low	The site is vegetated although recently tree feeling has been undertaken, with other flora and fauna being present that have developed within contaminated soils.

Table 16.1: Combined CSM & Quantitative Environmental Risk Assessment

Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
		on site and future vegetation				Future vegetation may be planted at the site and may come into contact with contaminated soils.
On-site ground gas sources and vapour sources including Made Ground / landfill, former infilled reservoir and contaminated groundwaters.	Buildings (gas / vapour migration, ingress and accumulation). Human Health (inhalation)	Future site users	Severe	Likely	High (Low with mitigation)	Significant thicknesses of Made Ground (up to 14m) have been identified within the historical landfill with abundant degradable constituents. A moderate ground gas generation potential is envisaged based on the age of the landfill and the recorded waste types. Elevated ground gas concentrations and flow rates have been recorded and the most recent monitoring visits to date are generally indicative of CS2 and a worst-case possible scenario of CS4. Recent data also indicates that there is a risk vapours could be generated from soils and groundwater and further work is required. Based on the most recent results, ground gas and vapour protection is envisaged (to be confirmed following a detailed vapour assessment) for new buildings on-site and this will mitigate the risk.
		Future on-site buildings	Severe	Likely	High (Low with mitigation)	
		Current site users	Mild	Unlikely	Very low	Current site users are infrequent (e.g. trespassers) and activities are undertaken in open atmosphere so the risk to current site users is very low.

Table 16.1: Combined CSM & Quantitative Environmental Risk Assessment

Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
		Adjacent site users	Severe	Unlikely	Low to Moderate (Low with mitigation)	Based on previous and more recent site investigations, pathways to off-site receptors are considered unlikely due to the natural clay deposits that are indicated along the site's boundaries. Possible pathways are indicated within the south easternmost corner of the site where historic excavations appear to have extended off-site. However, these are indicated to be relatively isolated from the main excavations that occurred on-site, and recent data indicates that only low gas concentrations have been recorded in this area. Mitigation measures could include gas venting trenches along site boundaries to reduce the risk.
		Adjacent buildings	Severe	Unlikely	Low to Moderate (Low with mitigation)	
Off-site historic and current sources as outlined in the CSM.	Inhalation, dermal contact and ingestion	Future site users	Medium	Low	Low to Moderate (Low with mitigation)	It is unlikely that soil bound contaminants from off-site (unless fully exposed) have made their way to site in large quantities. Most of the surrounding area is also developed so any significant sources of contamination are likely to have been removed or covered thereby breaking the pollutant pathway linkage.
		Current site users	Medium	Low	Low to Moderate (Low with mitigation)	

Table 16.1: Combined CSM & Quantitative Environmental Risk Assessment

Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
		Construction workers	Medium	Low	Low to Moderate (Low with mitigation)	See above for commentary.
	Migration of groundwater through the ground and surface water run-off/overland flow to those receptors beneath the site	Superficial Secondary A Aquifer	Medium	Unlikely	Low	In most cases migration of contaminants to the site via surface water / overland flow is unlikely due to the distance of the sources from the site, the presence of physical barriers and that interception by local drainage in developed areas is likely to occur. Migration of groundwater through the ground is unlikely due to the predominantly low permeability of the surrounding Glacial Till (i.e. a geological barrier). While outfalls to the canal may be present from off-site sources, continuity between the groundwater at the site and the Rochdale Canal is not indicated.
		Superficial Secondary Undifferentiated Aquifer	Mild	Unlikely	Very Low	
		River Medlock	Medium	Unlikely	Low	
	Direct contact	Existing and future buildings and water pipes	Mild	Unlikely	Very Low	See previous sections regarding the contaminative potential for off-site sources and the potential pathways for soils and groundwater that may be aggressive to buildings and water pipes.

Table 16.1: Combined CSM & Quantitative Environmental Risk Assessment

Table 16.1: Combined CSM & Quantitative Environmental Risk Assessment						
Source / Contaminant	Pathways	Receptors	Consequence of Risk Being Realised*1	Probability of Risk Being Realised*2	Risk Rating	Necessary Actions / Commentary
Other off-site ground gas and vapour sources including: 1. Potential areas of infilled land 2. Historic landfills 3. Cemetery	Gas migration, ingress, and accumulation	Future site users	Medium	Unlikely	Low (Very low with mitigation)	These sources are anticipated to have a low to moderate ground gas generation potential, so the consequence is reduced. However, pathways to the site are unlikely due to the predominantly low permeability of the surrounding Glacial Till. Gas concentrations recorded for those monitoring wells adjacent to the site’s south eastern boundary are relatively low and indicate that ground gas generation / migration from the infilled ground adjacent to the site’s south eastern boundary is of a limited nature. Ground gas protection is likely required for those on-site sources anyway so this will further reduce the risk from off-site sources.
		Current site users	Medium	Unlikely	Low (Very low with mitigation)	
		Existing and future buildings	Medium	Unlikely	Low (Very low with mitigation)	
Notes						
*1 Considers both the potentially severity of the hazard and the sensitivity of the receptor. Where applicable, the most sensitive receptor / hazard has been used for the overall assessment.						
*2 Considers both the presence of the hazard and the integrity of the pathway. Where applicable, the most likely hazard / pathways have been used for the overall assessment.						

17 GROUND ENGINEERING CONSIDERATIONS

17.1.1 It is understood that the site is to be redeveloped for a residential end use that also includes a school, but at this stage there is no finalised development plan. Following finalisation of any proposed development layouts, detailed design or structural loading information and any earthworks designs, this section may require detailed review to assess whether the recommendations made remain applicable or require re-assessment. These recommendations should not be considered in isolation without considering the report in full.

Design Stratigraphy

17.1.2 Highly variable Made Ground deposits have been encountered and are associated with the historical infilling of those former clay pit excavations that are recorded to have occupied most of the site. The depth of the Made Ground was found to vary significantly and has been recorded between 0.3m and 13.85m bgl (an indicative Made Ground contour plan is shown in Drawing LD10385-006), and is underlain by between 35m to 45m of predominantly cohesive / low permeability Glacial Till (an indicative Glacial Till thickness contour plan is shown in Drawing LD10385-007), which is in turn underlain by solid geology comprising weathered Sandstone of the Collyhurst Sandstone and Chester Formations (indicative rockhead contour plans are shown in Drawing LD10385-008 and 009).

Foundations

17.1.3 The Made Ground in its current state would not be suitable as a founding stratum without some form of ground improvement, due to its extremely variable nature and variable strength characteristics. For those areas where Made Ground can be fully excavated, recompacted and engineered without restriction, buildings could be founded on shallow reinforced foundations. However, for those areas where deeper Made Ground is to be left in-situ beneath the re-engineered Made ground, it is recommended that either deep trench reinforced foundations extending to natural strata or raft foundations are utilised. Larger structures with higher loadings such as the proposed school or multi-storey residential dwellings may require piling into the underlying Glacial Till. Following finalisation of the proposed development layout a foundation zoning plan should be produced to identify plot specific foundation requirements.

- 17.1.4 Where buildings require a piled foundation solution, specialist advice will be required to determine the most suitable pile types for the recorded ground conditions. Due to the presence of abundant large obstructions throughout the Made Ground, driven piles or Continuous Flight Auger (CFA) piles are unlikely to be suitable. Consideration will also need to be given to the minimisation of pile arisings originating from the Made Ground, as the regulators will likely consider this material to be waste and if it is to be retained on-site then it will need to meet a defined and pre-agreed end-of-waste criteria. Furthermore, given the presence of Made Ground and that ongoing or potential future consolidation could occur, it is essential that pile design allows for negative skin friction. Due to the presence of contaminated ground and groundwater within the former landfill, a piling risk assessment and subsequent mitigation may be required for a proposed piling solution on the basis that new pathway linkages may be created during pile construction.
- 17.1.5 Vibrostone / concrete columns or dynamic compaction may also be a suitable ground improvement technique for some parts of the site (exclusion zones will likely be required from neighbouring properties and the canal to protect them from vibration), and this may be adopted in combination with any material turnover that is undertaken. This combination may eliminate the requirement for raft or piled foundations in the areas where this can successfully be undertaken. However, this is subject to detailed inspection / advice from specialist ground improvement contractors as significant shallow perched waters are present that may require dewatering and consideration would also need to be given to the contamination that is present in soils and groundwater.
- 17.1.6 For those areas of the site where natural Glacial Till deposits are present at shallow depth (<2.5m bgl) it may be feasible to use traditional shallow foundations bearing into the Glacial Till. However, this is subject to careful design which ensures that total and differential settlements do not exceed serviceability limit states and ensures that the minimum ground cover to foundation formation level and foundation depths to suit the proximity / species of existing / recently felled trees are both maintained in accordance with current design standards and good engineering practice.
- 17.1.7 To minimise issues with potential differential settlement of the foundation structure, it is recommended that foundations are not constructed upon more than one stratum type and that new buildings do not straddle areas of improved and unimproved

ground or areas of buried highwalls. Where these areas cannot be avoided foundations should be either stepped / deepened to the same depth, alternative foundation solutions (e.g. piles) be adopted or the area of ground improvement is extended to include all areas where buildings are proposed. Any localised 'soft spot' areas encountered during the excavation for shallow foundations should also be removed and foundations extended down to suitable formation strata.

Floor Slabs

- 17.1.8 Due to the significant thicknesses of Made Ground across the site with areas where deeper Made Ground is likely to be left in-situ beneath re-engineered Made Ground, suspended floor slabs will likely be required to mitigate against settlement / differential settlement. This form of construction would also be beneficial for the ground gas protection measures that are indicated. However, this is also dependent on the finalised earthworks design, the type of foundation solution adopted for different areas of the site, and the other geotechnical factors outlined elsewhere in this report.

External Areas

- 17.1.9 The most likely sub-grade formations for external areas will be the excavated, recompacted and engineered Made Ground materials and to a lesser extent the very shallow natural Glacial Till. Based on the laboratory testing results undertaken for the cohesive Made Ground and shallow cohesive Glacial Till materials, frost susceptibility and the influence of trees will need to be considered when external designs are carried out.
- 17.1.10 Once site levels are known, validation testing should be undertaken to finalise the design for any external areas. For those areas of the site where deeper Made Ground is to be left in-situ beneath any re-engineered Made Ground there is a risk of ongoing or potential future long-term settlement and this will need to be considered in the remediation design and external designs. To limit settlements within those areas where deeper Made Ground is to be left in-situ beneath engineered Made Ground, reinforcement (e.g. geogrids), soil modification / stabilisation and / or ground improvement should be considered.
- 17.1.11 Modification / stabilisation or a non-volumetrically active capping layer may be required for those cohesive Made Ground and / or natural shallow cohesive Glacial

Till deposits that are indicated to be susceptible to frost and / or likely influenced by trees / shrubs. Further geotechnical testing may be required to confirm this.

- 17.1.12 All formations should be proof rolled prior to construction of external areas and this will aid in the detection of loose or soft pockets and allow appropriate measures to be taken. The formation should be inspected / validated by a competent geotechnical engineer.
- 17.1.13 In all instances it is recommended that advice and consultation with specialist ground works contractors be sought and further geotechnical testing and / or validation (e.g. Californian Bearing Ratio tests at formation level) will be required once site levels are known to finalise external designs.

Earthworks

- 17.1.14 Based on the existing site levels and the current proposed development plan, it is envisaged that some earthworks will be required for the proposed structures and / or external areas. At this preliminary stage, the formation levels for the site are not known, but it is anticipated that the materials excavated and potentially re-used as part of an earthworks exercise at the site are likely to comprise the shallow Made Ground materials and to a lesser extent the natural Glacial Till.
- 17.1.15 Results from the laboratory testing indicate that the Made Ground was often slightly dry or slightly wet of the optimum and, where cohesive, were generally of intermediate plasticity and medium shrinkage potential. There were also various anthropogenic constituents present within the shallow Made Ground and consequently, high levels of compaction may not be achievable unless modification / stabilisation and / or ground improvement of the soils is undertaken. Those large constituents that are indicated should be removed / regraded prior to engineering. It may be necessary to remove materials that have a high organic content, and / or high plasticity in order to achieve required levels of compaction in these materials.
- 17.1.16 While grading analyses indicate that the shallow cohesive superficial deposits may be suitable for use as general fill and in some case selected fill, results from the laboratory testing indicate that it was often slightly dry of the optimum and was generally of intermediate plasticity and low shrinkage potential. It may be necessary to remove materials that have a high organic content, and / or high plasticity in order to achieve required levels of compaction in these materials.

- 17.1.17 It may be feasible to stockpile concrete derived from the Made Ground and old foundations / surfacing which have been grubbed out. This material may be reused on site, once it has been crushed to a suitable size, provided that the material meet a defined and pre-agreed end-of-waste criteria.
- 17.1.18 In all instances, once formation levels are finalised specialist advice should be sought from specialist ground works contractors. Further geotechnical testing and validation will be required to ensure that the required levels of compaction have been achieved.

Total Settlements and Differential Settlements

- 17.1.19 For those areas where deeper Made Ground are to remain in-situ beneath engineered fill, settlements could exceed serviceability limit states and / or result in differential settlements in response to additional loads, degradation of waste materials leading to collapse and / or self-weight settlement etc. and these movements could exceed the serviceability limit states for residential housing and other structures. This will need to be taken into consideration for the chosen foundation or external designs.
- 17.1.20 Quantifying settlements of the Made Ground on site is inherently difficult due to the extreme variability of the material. The remediation design should consider future settlement performance. Following earthworks and remediation at the site, settlement testing (e.g. skip load tests or other forms of maintained load tests) should be undertaken to model total settlements and the time it would take for these settlements to occur, especially for those areas where shallow foundations are to be utilised in order to satisfy NHBC requirements. This would inform what mitigation measures would be required to deal with any unacceptable settlements.
- 17.1.21 For those areas where deeper Made Ground is to remain in-situ beneath engineered fill alternative foundation solutions may need to be adopted as outlined in the foundation's subsection. Alternatively, to limit settlements within these areas and to potentially allow for the use of shallow foundations, reinforcement (e.g. geogrids or geotextiles), soil modification / stabilisation and / or ground improvement of the shallow and deep Made Ground should be considered to mitigate against any ongoing or potential future settlements. Again, maintained load tests may be required to confirm the future settlement performance and in order to satisfy NHBC requirements.

Obstructions

- 17.1.22 Numerous large obstructions within the Made Ground and other relict infrastructure associated with the former brickwork's buildings were encountered during the site investigation. These features will likely require total or partial removal to facilitate development of the site. For any larger or deeper features that are to remain in-situ, it is recommended to undertake probing to identify if any further ground obstructions are present, which may impede the progress of the proposed foundation solutions. The results of such investigations will be used in the selection of foundations.

Buried Highwalls

- 17.1.23 Numerous buried highwalls to the former clay pit excavations are present beneath the site and the variation in the depth of the Made Ground could result in severe differential settlements if buildings are constructed across these areas. During earthworks it is recommended that exposed highwalls are surveyed and that the properties and geometry of the fill are further investigated so that exclusion zones where ground movements are likely to be unacceptably large can be delineated. Consideration should be given to the use of piled or raft foundation solutions in these areas as this would mitigate against any unacceptable movements and hence reduce the extent of any exclusion zones.

Excavations

- 17.1.24 Due to the high degree of variability encountered within the Made Ground, excavations should be supported or battered back to a stable angle to ensure adequate stability is achieved for the duration of any works. Any excavations that are to be left open or unsupervised will need to be secured. The temporary works design of the remediation contractor should also reduce the risk of instability to any other surrounding works and safeguard the stability of such land.
- 17.1.25 Any excavations requiring entry by site personnel should be fully supported for reasons of safety and the main works Contractor shall satisfy themselves at all times of the suitability and stability of excavated strata and adopt appropriate shoring techniques, where appropriate in accordance with the Confined Spaces Regulations.
- 17.1.26 Excavations within the Made Ground and natural superficial strata present across the site should be readily achievable using conventional mechanical backhoe excavators. Occasionally hard digging conditions may be encountered where obstructions are

present within the Made Ground Deposits and in this instance larger capacity excavators and pneumatic / hydraulic breaking equipment may be necessary.

Groundwater

- 17.1.27 Shallow perched groundwaters were frequently encountered within Made Ground during the construction of exploratory holes at the site and during groundwater monitoring visits. A temporary groundwater seepage at the surface was also noted along the sites southern boundary following a period of heavy rainfall. Groundwater levels can vary seasonally or following periods of prolonged wet or dry weather and levels higher or lower than those measured may be present during construction. The groundwater level may also change following any changes to site levels.
- 17.1.28 Due to the presence of shallow perched groundwaters, there will likely be a requirement for localised temporary works in the form of dewatering / barriers during excavation of any service trenches, mass excavations or excavations that are undertaken as part of any earthworks exercise at the site. There are also environmental and possible permitting considerations associated with the management of these shallow perched groundwaters and these are detailed further in Section 19. Groundwater treatment may be required prior to discharge or removal from site.
- 17.1.29 If groundwater is encountered during excavation, degradation of the formation may occur. The formation should therefore be adequately protected from seepages and protected from adverse weather conditions. The earthworks design should ensure that temporary works site drainage is allowed for. If the formation layer becomes wet resulting in loosening of the surface materials, then excavation may have to be taken deeper in order to find a suitable bearing layer.
- 17.1.30 Sub-artesian groundwater conditions are indicated within the deeper groundwaters and will need to be considered for any deep piled foundations as any strata where these conditions are encountered could be subject to hydraulic pressures.

Collapse Compression

- 17.1.31 Made Ground / Fill materials deposited in a low-density state in the dry can, at a later date, become inundated with water, which can result in collapse compression / inundation settlement. Such settlements may be significant and exceed development serviceability limits if mitigation measures are not undertaken. Areas of colliery spoil

material have been identified within the north eastern section of the site and these types of materials can be particularly susceptible to collapse compression.

- 17.1.32 Trial pit excavations within the colliery spoil noted distinct angled layering within this stratum that is indicative of end tipped materials that have likely been placed without any systematic compaction. While corrected SPT N-Values indicate that the suspected colliery spoil materials are of medium density, there were a number of very coarse constituents (e.g. cobbles and boulders of weak siltstone) that could have exaggerated the results.
- 17.1.33 While no water strikes were generally encountered within this stratum, it was noted to be damp throughout with moisture contents being recorded between 7.1 and 21% (on average 13.6%), which is indicative of partial saturation. Groundwater monitoring undertaken by Celtic in 2007 from two monitoring wells (BH5 and BH12) screened within this stratum recorded groundwater from this base of this stratum only at depths of between 4.99m and 7.1m bgl (between 76.21m and 71.12m AOD).
- 17.1.34 Six laboratory compaction tests have been completed on the suspected colliery spoil and a comparison of the results with recorded moisture contents indicates that the materials were generally dry of their optimum moisture contents indicating that there is a potential for collapse compression to occur.
- 17.1.35 Two soakaway tests were undertaken within the Colliery Spoil, with dimensions of the pit monitored before and after the test to assess any collapse caused by the addition of water. 1000 litres of water were added to SA05 within the Colliery Spoil and this initially drained within 12 minutes. After the inundation test, the depth of the trial pit was 100mm deeper than prior to the test. An identical test was undertaken in SA02, with the water completely draining in 90 seconds and the base of the pit 70mm deeper after completion of the test.
- 17.1.36 Based on the findings it is considered that there is a low to moderate risk of collapse compression within the Colliery Spoil. Results suggest that there are areas where moisture contents are lower than optimum resulting in the potential for collapse compression to occur. The inundation testing and laboratory compaction tests have provided evidence that collapse compression may occur because of water inundation.
- 17.1.37 It would be prudent to investigate the risk of collapse compression further for any colliery spoil materials that are to remain in-situ once earthworks are completed in

these areas. For those areas where suspected colliery spoil is excavated and recompacted, the risk of collapse compression will be significantly reduced.

- 17.1.38 A similar risk from collapse compression / inundation settlement is envisaged for those other areas of the site where susceptible fill materials are present. As such, the remediation design should consider the future settlement performance of the wider remediated site in regard to collapse compression / inundation settlement, as well as any other potential types of settlement.

Combustion

- 17.1.39 Calorific value (CV) is commonly used for assessing combustibility of Colliery Spoil. It is generally accepted that samples with a CV of 10 MJ/kg or greater are almost certainly combustible, whilst samples with a CV of 2 MJ/kg or less are unlikely to be combustible. Samples with a CV of 7 MJ/kg or greater are considered to be at risk from smouldering.
- 17.1.40 Six samples of colliery spoil material were tested for calorific value. The results ranged from <2.0 – 9.0 MJ/kg at depths of between 0.3m and 5.4m bgl.
- 17.1.41 Materials with a calorific value >7 MJ/kg should be kept a minimum of 1m away from any potential sources of ignition (sub-station, services etc.) and when used in areas of private gardens or soft landscaping that a 1m thick layer of inert material is present to prevent accidental ignition.
- 17.1.42 Any colliery spoil excavated during development of the site with a calorific value >7 MJ/kg should not be left exposed for long periods of time to minimise the risk of combustion. Covering any stockpiles with suitable cohesive material will prevent any oxygen getting to the coal and minimise the combustion risk.
- 17.1.43 Further calorific value testing is recommended during earthworks where Colliery Spoil is used as fill material, so that the material placed in the upper 1m, or within 1m of a potential ignition source does not exceed 7 MJ/kg. The same applies to those materials that are to be stockpiled at the site. The remediation design should consider the potential combustibility of any fill materials and ensure that such risks are adequately mitigated by design (e.g. selection of fills, reduction in permeability of compacted fills etc).

Concrete Assessment

- 17.1.44 A suite of chemical tests were undertaken in Accordance with BRE Special Digest 1: 2005 - Concrete in Aggressive Ground in order to specify the concrete class required at the site. Results from both the WA 2020 and 2022, along with the Celtic 2007 investigations have been considered in this assessment (this includes specific geochemical testing and those results obtained from the environmental testing).
- 17.1.45 The suspected colliery spoil has the potential for pyrite to be present, so consideration has been given to the total potential sulfate content to account for the potential for oxidation of pyrite following ground disturbance.
- 17.1.46 A summary of the Design Concrete Class (DS) and the Aggressive Chemical Environment (ACEC) for each soil type is presented in Table 17.1:

Table 17.1: Summary of Design Concrete Class		
Soil Type	Design Concrete Class	ACEC Class (mobile groundwater)
Made Ground – Suspected Colliery Spoil	DS-4	AC-5
Made Ground – Suspected Combustion Waste	DS-2	AC-2
Made Ground – Suspected Construction and Demolition Waste	DS-2	AC-2
Made Ground – Suspected Household Waste	DS-2	AC-2
Granular Made Ground	DS-2	AC-2
Cohesive Made Ground	DS-2	AC-3Z
Topsoil Fill	DS1	AC-2Z
All Made Ground	DS-2	AC-2
Glacial Till	DS1	AC-1

- 17.1.47 Due to the high degree of variability encountered across the site and the potential for various Made Ground types to be intermixed a worst-case Design Sulphate Class (DS) of “DS-2” and an Aggressive Chemical Environment for Concrete (ACEC) of “AC-3Z” has

been determined for the Made Ground. The exceptions being for those suspected colliery spoil materials were “DS-4” and “AC-5” is indicated due to the potential for pyrite to be present. For the natural strata at the site the assessment for natural ground locations has been undertaken and “DS-1” and “AC-1” is indicated.

Soakaways

- 17.1.48 Four soakaway tests were carried out in general accordance with BRE Digest 3652 “Soakaway Design”. The locations of the soakaways are shown on Drawing LD10385-003, and the logs are within Appendix F. Where the water level did not fall to 25% effective depth, the test was not considered suitable for calculation of an infiltration rate, and this was the case for both of the tests undertaken. Calculated infiltration rates for each successful test are summarised in the table below:

Table 17.2: Summary of Soakaway Testing			
Location	Stratum	Infiltration Rate	Remarks
SA01	Cohesive Glacial Till	n/a	Groundwater level remained constant for two hours
SA03		n/a	Seepage in pit during excavation. Water level increased slightly during two-hour test
SA02	Colliery Spoil	1.01E-02	-
SA05 x2		1.21E-04 & 2.07E-04	Two tests undertaken

- 17.1.49 Testing indicates that traditional soakaways will not provide a suitable drainage solution for the discharge of surface water run-off within the Cohesive Glacial Till at the site. Furthermore, given the significant thicknesses of Made Ground encountered across the site, the recorded levels of contamination, the shallow perched groundwater issues and the risk associated with collapse compression, soakaway construction is not considered suitable.

Slag Expansion

- 17.1.50 Six emery expansion tests were undertaken on the suspected slag materials to assess the degree of expansion following subjection to increasing temperatures. Changes in height of between 0.22 – 1.92mm (on average 1.16mm) were noted. No significant heat sources are envisaged for the proposed development so the risk of slag expansion due to heat is thought to be low.

- 17.1.51 Slag can also expand following saturation due to hydration. However, as most of the materials were either below the water table or partially saturated to some extent the risk from expansion is thought to be low.
- 17.1.52 Further testing should be undertaken during earthworks if the suspected combustion waste materials, particularly those above the water table or indicated to be relatively dry, are to be used as engineered fill.
- 17.1.53 Consideration should be given to the stockpiling of any excavated slag to expose the material to moisture from natural precipitation and / or application of water by spraying so that hydration and associated expansion takes place prior to use of the material. Up to 18 months may be needed to hydrate any potentially expansive oxides.

Trafficability

- 17.1.54 During the various stages of site investigation works undertaken by WA ground conditions at the site were generally noted to be wet, soft and compressible and this resulted in significant delays due to trafficability issues.
- 17.1.55 Trafficability at the site on surface materials and / or on any excavated shallow Made Ground may need to be considered, particularly during wet weather and this could necessitate stabilisation of the soils or the use of track mats during the development of the site. The remediation contractor should factor such trafficability issues into their design, method of works and programme.

18 GEOTECHNICAL RISK REGISTER

18.1 Introduction

18.1.1 This section presents the Geotechnical Risk Register for the site, together with details of other construction related risks known at this time. The risks have been evaluated using the risk evaluation matrix suggested in Part 2 of HD22/08 “Managing Geotechnical Risk” which is reproduced in Table 18.1:

Table 18.1: Risk Evaluation Matrix				
Probability	Impact		Risk (R = P X I)	Response to Risk
Very Likely (5)	Very High (5)	Potential to halt project or potential for major claim or similar	17 to 25	Unacceptable: act now to prevent
Likely (4)	High (4)	Significant delay on overall project or major impact on cost	13 to 16	Unacceptable: act now to prevent
Probable (3)	Medium (3)	Major delay on this task, but significant impact on overall project unlikely or Significant impact on cost	9 to 12	Early attention required
Unlikely (2)	Low (2)	Minor delay on this task, but significant impact on overall project unlikely or minor impact on cost	5 to 8	Regular attention required
Negligible (1)	Very Low (1)	No significant impact on task or project or negligible impact on cost	1 to 4	Monitor

18.1.2 The geotechnical risk register is presented in the Table 19.2. The purpose of the risk register is to highlight the potential risks, and consequences of those risks, together with measures to be taken to mitigate the risks. It is envisaged that the geotechnical risk register becomes a “live” document which is reviewed and revised throughout the development of the site, as the risks become better understood, or when additional risks are identified by further works or during remediation of the site, or site later site development.

Table 18.2: Geotechnical Risk Register

Reference	Identified Geotechnical Hazard/Risk	Cause	Risk Before Control			Consequence	General Control Measures	Residual Risk		
			P	I	R			P	I	R
1	Total and differential Settlements	The site is a historical landfill with significant thickness of Made Ground with varying proportions of waste materials that may settle in response to additional loads, degradation of waste materials, self-weight settlement etc. Natural cohesive soils of very low to high compressibility (generally medium compressibility) indicated.	4	4	16	Settlement of the ground and damage to overlying buildings, externals, pipes or services by differential settlement. Negative friction can occur on piles installed through a compressible layer due to consolidation.	Settlement calculations, mini zone load tests and / or monitoring to quantify risk. Avoid large differential loadings of ground. Piled foundations or rafts for structures. Reinforcement or soil stabilisation / ground improvement of shallow soils for external areas and services. Service and external designs to accommodate ongoing or potential future settlement. Settlement of deeper fill materials likely to be ongoing or to occur in the future. Deep ground improvement (e.g. dynamic compaction may be an option). Long-term maintenance of external areas and services may be required.	3	2	6

Table 18.2: Geotechnical Risk Register

Reference	Identified Geotechnical Hazard/Risk	Cause	Risk Before Control			Consequence	General Control Measures	Residual Risk		
			P	I	R			P	I	R
2	Unforeseen or highly variable ground conditions	Ground conditions encountered different from those encountered during the ground investigation. Inherent variability due to the site being a historical landfill and high degree of variability indicated from site investigation.	4	4	16	Problematic for foundation, floor slab and external design and earthworks if ground conditions change over short distances. Cost and programme implications.	Various control measures as discussed in the sections below.	1	4	4
3	Exposed site surface becoming soft causing trafficability problems	Excess rainfall, vegetation removal, grubbing of concrete bases and site strip exposing variable and susceptible soils, shallow perched and deeper groundwaters, standing water and frequent trafficking. Significant delays due to trafficability experienced during the most recent stage of site investigations.	4	4	16	Vehicles becoming struck and areas of the site being inaccessible, causing delays and additional costs.	Avoid exposure of soft material if possible. Consider specialist plant, track matting or surface stabilisation / ground improvement of soils.	2	3	6

Table 18.2: Geotechnical Risk Register

Reference	Identified Geotechnical Hazard/Risk	Cause	Risk Before Control			Consequence	General Control Measures	Residual Risk		
			P	I	R			P	I	R
4	Groundwater	Shallow perched groundwaters frequently encountered within Made Ground. High water table indicated with groundwater seepage at the surface following a period of heavy rainfall. Deeper groundwater within granular layers within Glacial soils. Slight artesian conditions noted for groundwater encountered within bedrock and deeper Glacial soils.	4	3	12	Potential for water ingress into open excavations that may result in instability and collapse. Softening of sub-grade material. Reduced bearing capacity for some types of foundations. Sub artesian groundwater may cause issues for deep piled foundations. Groundwater levels may vary seasonally and change following any changes to site levels.	Groundwater control measures during excavations (e.g. dewatering / barriers). Drainage and foundation designs that consider groundwater conditions. Groundwater monitoring. During development of the site control / management of surface waters and shallow perched groundwaters will naturally be required.	2	2	4
5	Collapse Compression	Susceptible materials (e.g. loose partially saturated fill including colliery spoil) prone to water inundation if left in-situ.	3	3	9	Collapse due to increased loads and / or more commonly the addition of water causing damage to structures, externals and services by sudden or differential settlements.	Assessment via wetting / loading tests. Rafts or piled foundations for structures, ground improvement techniques for externals and services. Where practicable, excavation, recompaction as engineered fill. Avoid large amounts of water entering the ground via soakaways	1	3	3

Table 18.2: Geotechnical Risk Register

Reference	Identified Geotechnical Hazard/Risk	Cause	Risk Before Control			Consequence	General Control Measures	Residual Risk		
			P	I	R			P	I	R
6	UXO	The site is located within a moderate risk bombing area with several bomb strikes within the surrounding area and nearby strategic military targets.	3	3	9	UXO or munitions encountered in excavations or at depth.	UXO risk assessment to be undertaken prior to mass earthworks / remedial works / development to re-quantify the risk. Mitigation as determined by risk assessment.	1	3	3
7	Bulking	Overconsolidated Glacial materials and colliery spoil are likely to be susceptible to bulking or an increase in volume upon excavation. Slag within the suspected combustion wastes could expand in certain conditions.	3	3	9	Bulking could have implications for any cut and fill balance that may be required and if material is planned for re-use. Bulking will also influence haulage operations, especially where material will need to be sent off-site.	Determination and adoption of bulking factor for incorporation into any civil engineering designs.	1	3	3

Table 18.2: Geotechnical Risk Register

Reference	Identified Geotechnical Hazard/Risk	Cause	Risk Before Control			Consequence	General Control Measures	Residual Risk		
			P	I	R			P	I	R
8	Excavatability and obstructions	Numerous very coarse constituents within Made Ground impeding excavations progression of piled foundations. Further obstructions associated with relict foundations and underground infrastructure in the areas of the former brickworks buildings.	4	2	8	Delays caused by breaking out obstructions. Significant obstructions may affect subsequent design and construction by hindering excavations and / or obstructing foundations. Obstructions may contain voids or be filled with hazardous substances.	Larger capacity excavators and pneumatic / hydraulic breaking equipment to deal with obstructions. Probing for piled foundations or mass excavation works for other foundation types.	1	2	2
9	Aggressive Ground	Concentrations of sulphate and other contaminations noted in soils and groundwater that would be harmful to concrete and services. Potential for pyrite to be present within colliery spoil.	4	2	8	Damage to building materials (e.g. foundations, external areas, aggregates, and services) via chemical attack or corrosion	Design concrete to withstand aggressive ground. Results indicate a design sulphate class of DS-2 and AC-3Z may be appropriate. The exceptions being for those suspected colliery spoil materials were "DS-4" and "AC-5" is indicated due to the potential for pyrite to be present. For the natural strata "DS-1" and "AC-1" is indicated.	1	2	2

Table 18.2: Geotechnical Risk Register

Reference	Identified Geotechnical Hazard/Risk	Cause	Risk Before Control			Consequence	General Control Measures	Residual Risk		
			P	I	R			P	I	R
10	Instability of excavations	Highly variable, loose, or soft compressible soils at shallow depth associated with Made Ground infill material and granular layers within Glacial Till.	3	2	6	Failure / instability of excavations. Stability of land surrounding site.	Temporary supports or battering of side slopes. Dewatering or groundwater barriers. Earthworks design and construction sequences and temporary works drainage to mitigate risks.	1	2	2
11	Combustibility	Some of the Made Ground materials at the site (e.g. colliery spoil or combustion waste) are indicated to be susceptible to combustion.	2	3	6	Combustion or smouldering of materials	Stockpiles should be protected to prevent ignition and any susceptible material used as engineered fill may need to be placed beneath a 1m thick inert layer in garden areas / areas of soft landscaping to prevent accidental ignition. Further calorific value testing should be undertaken if these materials are to be used as engineered fill. Remediation design to remove risk of future combustion via fill selection during engineering and the formation of low permeability engineered soils.	1	3	3

Table 18.2: Geotechnical Risk Register

Reference	Identified Geotechnical Hazard/Risk	Cause	Risk Before Control			Consequence	General Control Measures	Residual Risk		
			P	I	R			P	I	R
12	Faulting	A geological fault is conjectured to cross the westernmost section of the site; although not proven during site investigation works. However, foundations are not envisaged to extend to within influencing distance of the fault.	2	2	4	Highly weathered, altered, or fractured rock within the zone of influence of the fault that impacts on foundation design. Differing ground conditions either side of the fault. Ground gas and / or water emissions.	Generally not applicable as foundations to rockhead are not envisaged. Otherwise, non-percussive piling techniques and / or foundation designs to consider ground conditions if foundations are to extend to rockhead.	1	2	2
13	Expansive Soils (Shrink / Swell) including Frost Heave	Cohesive soils of low to intermediate (generally low) shrinkage potential and very low to moderate (generally very low) volume change potential indicated. Site was previously densely vegetated with various types of mature trees, and these have since been removed. Trees may be retained along site boundaries and new trees planted as part of the proposed development.	2	2	4	Shrink / swell of ground potentially damaging building foundations, externals, pipes, or services by differential movements.	Consideration of deepening foundations where near to trees or former tree locations. Foundations in excess of 1m depth to counter the effects of frost heave. Removal of unsuitable materials and replacement with engineered fill for external areas. Reinforcement or soil stabilisation / ground improvement. Do not plant or remove trees near to buildings without specialist advice.	1	2	2

Table 18.2: Geotechnical Risk Register

Reference	Identified Geotechnical Hazard/Risk	Cause	Risk Before Control			Consequence	General Control Measures	Residual Risk		
			P	I	R			P	I	R
14	Services	Unrecorded services may be present at the site.	1	2	2	Service strike	Obtain service plans prior to the start of works. All site work to be undertaken using appropriate methods of utility protection precautions.	1	2	2
15	Rock Weathering	Weathered rockhead profile identified, likely exacerbated by faulting at the site. However, foundations are not envisaged to extend to bedrock.	1	1	1	Weathered zone with variable geotechnical properties that can be problematic for foundation design.	Generally not applicable as foundations to rockhead are not envisaged. Otherwise, avoidance of weathered zone with foundations being taken to more competent rock or founded within competent overlying strata.	1	1	1
16	Variable Rockhead	Depth to bedrock increases to the south west. The depth to bedrock has likely been influenced by the faulting that is present at the site. Consequently, a high degree of variability is envisaged. However, foundations are not envisaged to extend to bedrock.	1	1	1	Problematic for foundation design if foundations need to be taken to rockhead (not envisaged). Deeper foundations that could increase cost.	Generally not applicable as foundations to rockhead are not envisaged. Otherwise, locate buildings that require foundations to rockhead in those areas where less variability is present. Alternative foundations solutions may be possible for some structures.	1	1	1

19 CONCLUSIONS AND RECOMMENDATIONS

19.1 Contamination – Human Health

19.1.1 Laboratory results were analysed using the CLEA methodology to assess the risk to human health for a residential with plant uptake land use scenario. A range of widespread to isolated exceedances of the screening values were recorded in soils for a range of determinands that are typical of a historical landfill. This included metals (arsenic, lead, nickel, beryllium, chromium VI, cadmium, copper and zinc), PAH's, TPH's, total cyanide, PCB's, SVOC / VOC's, BTEX and PFAS. Asbestos was identified in 26 out of 129 No. samples with quantifiable concentrations recorded between <0.001 and 5.11%.

Future Site Users

19.1.2 Remedial works / mitigation will be required to prepare a site of this nature for residential development and to reduce the risks from those contaminant concentrations considered to represent an unacceptable risk to identified receptors and to provide an overall site betterment. While some of the mitigation is envisaged to be provided by the proposed development itself (i.e. external hardstanding areas and building cover breaking most of the SPR linkages) and the adoption of clean cover systems for private gardens and areas of public open space; a Detailed Quantitative Risk Assessment (DQRA) will be required to further quantify the risks to human health and to provide sufficient information to undertake an Options Appraisal and to develop a Detailed Remediation Strategy for the site.

19.1.3 The final thickness and composition of any clean cover system, the inclusion of any hardstanding areas as pathway breaks and the reporting outlined above, will all need to be agreed with the regulatory authorities prior to remedial / development works commencing on-site.

Construction Workers

19.1.4 Construction workers are envisaged to be at increased risk as they are likely to have acute interaction with contaminated soils and asbestos fibres that have been identified within the Made Ground. It is envisaged that the risks can be managed through the use of appropriate health and safety measures, practices and procedures, the use of appropriate PPE and suitable mitigating measures to deal with asbestos

fibres as outlined below. Following mitigation, the risks to construction workers is considered to be low.

Asbestos in Soils

- 19.1.5 Due to the low to high concentrations of asbestos fibres that have been recorded within the Made Ground at the site, it is recommended that groundworks at the site are undertaken in accordance with an Asbestos Management Plan (AMP) to ensure compliance with the Control of Asbestos Regulations 2012 (CAR 2012) to protect construction workers and members of the public from exposure to asbestos fibres. The groundworks on site should be designed and planned to minimise the exposure of workers / members of the public to contaminated soil and to minimise potential generation of airborne fibres with appropriate environmental controls established by the contractors working on the site. This should also be considered in the Health and Safety plan under the CDM Regulations.
- 19.1.6 It is also recommended that a watching brief for asbestos containing material is maintained during groundworks across the site, particularly within the suspected construction and demolition type waste that are present within the central sections of the site. If any unrecorded asbestos is visually identified during the groundworks, all works within the vicinity should cease and further advice should be sought, as additional testing, mitigation or remedial measures may be required.

Adjacent Site Users

- 19.1.7 Due to the sensitivity of the adjacent site users (e.g. primary school and residential properties with gardens), since contaminated shallow perched groundwaters have historically been observed seeping out of the site and migrating off-site, and that contaminated soils and groundwaters could be mobilised during the development of the site, mitigation measures will need to be undertaken to reduce the risk to off-site receptors.
- 19.1.8 The greatest risks are envisaged as part of the remedial / construction works, but it is anticipated that the risks can be reduced to acceptable levels by undertaking the works in accordance with an appropriate Construction and Environment Management Plan (CEMP) with appropriate environmental controls established by the contractors working on the site. Furthermore, the remedial works themselves would be removing any unacceptable risk associated with contamination at the site and would provide

overall site betterment. Post remediation / development of the site further betterment is envisaged due to the breakage of any unacceptable source-pathway-receptor linkages.

- 19.1.9 The long-term condition of the site will also need to prevent perched shallow groundwater and / or groundwater seepages from impacting off-site receptors. This is discussed further below in the groundwater flooding subsection.

Vapours

- 19.1.10 Soil and groundwater vapours could pose a risk to those identified receptors and at this early stage it is envisaged that passive vapour protection measures in new buildings, which is line with third party assessments, and / or some form of source reduction may be required. Further DQRA will be required in line with current guidance to specify the precise requirements for vapour protection and / or confirm if remediation is necessary. The final choice for mitigation will be in conjunction with specialist remediation contractors and will be subject to agreement with relevant regulators.
- 19.1.11 Depending on the outcome of the vapour assessment from the DQRA, there may be a requirement for vapour monitoring in line with BS8576. To allow for a more representative / pragmatic assessment to be undertaken, additional shallow monitoring wells could be installed post remediation with subsequent vapour monitoring being undertaken.

19.2 Contamination – Controlled Waters

- 19.2.1 Exceedances in screening values within perched groundwater have been recorded for metals, cyanide, sulphate, TPH, PAH, phenol, PFOS, PFOA and benzene with the most widespread and elevated exceedances present within perched groundwaters within the Made Ground. Similar exceedances have also been recorded within soil leachate for some of these contaminants indicating that soil leachate may be contributing to some extent to those concentrations of contaminants recorded within perched groundwaters.

Groundwaters

- 19.2.2 The ground model for the site indicates that the perched groundwaters within the Made Ground are largely contained by the underlying natural Glacial Clays (i.e. a geological barrier). While pathways to perched groundwaters within immediately

underlying granular lenses within the Secondary Undifferentiated Aquifer are present in places, and exceedences have been recorded, these granular layers are indicated to be discontinuous and not in continuity with other sensitive groundwaters or surface water bodies. Furthermore, multiple lines of evidence exist to demonstrate the lack of a source-pathway-receptor linkage from the site to the bedrock Principal or Secondary B Aquifers (see Section 16); most notably that they have been proven to both be overlain by substantial thicknesses (between 35m and 45m thick) of predominantly low permeability Glacial Till (i.e. a geological barrier).

19.2.3 Consequently, it is considered highly unlikely that continuity exists with the bedrock Principal or Secondary B Aquifers and exceedences recorded within soils and perched groundwaters within the Made Ground and isolated perched groundwaters with the Secondary Undifferentiated Aquifer, are not considered to represent an ongoing or potential future significant risk to these deep groundwaters. As such, viable linkages to the Principal and Secondary B Aquifers have been removed from the CSM and subject to agreement with the regulators, do not need to be considered further.

19.2.4 Some form of dewatering and groundwater treatment will be required for those shallow perched groundwaters within Made Ground that are likely to be encountered during earthworks / remediation and that will require discharge from the site. Early liaison with the relevant regulatory authorities and utility providers is recommended to establish any permitting and / or discharge requirements that would need to be met. This will also provide betterment to the site by removing contaminant load during the works.

Surface Waters

19.2.5 Continuity between the Rochdale Canal and those perched groundwaters at the site are not indicated to be present based on the multiple lines of evidence as outlined in Section 16. While limited surface water run-off into the canal could currently be occurring in places, the potential for significant leaching to occur is considered to be very low to negligible due to the limited amount of time these waters would have to percolate through the soils before entering the canal. Infiltration and interception by vegetation are also more likely to occur. Furthermore, baseline concentrations for some contaminants within the canal are indicated to be elevated independent of any influence from the site indicating that the site does not appear to be having a significant adverse impact upon water quality in the Rochdale Canal and, as such,

contaminant linkages to the Canal have been discounted from the CSM and, subject to agreement with the regulators, do not need to be considered further.

19.2.6 The greatest risks to surface waters receptors are envisaged as part of the remedial / construction works, but it is anticipated that the risks can be reduced to acceptable levels by undertaking the works in accordance with an appropriate Construction and Environment Management Plan (CEMP) with appropriate environmental controls established by the contractors working on the site. Furthermore, the remedial works themselves would be removing any unacceptable risk associated with contamination at the site and would provide overall site betterment.

19.2.7 The risk posed to the River Medlock is indicated to be low as pathways are limited due to the distance to the receptor, the presence of predominantly low permeability Glacial Till (i.e. a geological barrier) between the site and the river, barriers to surface water runoff / overland flow and capture by urban drainage. While granular lenses are present within the Glacial Till, the ground model for the site indicates that these are isolated, and it is unlikely that any horizontal continuity is present over such a large distance. While the river may be fed from the sandstone beneath the site, there are no viable pathways to the sandstone from the site. Due to the distance to the river, significant attenuation and dilution is also likely to occur. As such, the river does not need to be considered further; subject to agreement with the regulators.

Groundwater Flooding

19.2.8 A temporary seepage of perched groundwaters from within the Made Ground was historically noted at the site following a period of heavy rainfall. This has been mitigated in the short term by a third-party and this included the installation of a temporary impermeable bund along the impacted part of the site's southern boundary with a small drainage ditch to divert the groundwaters back onto the site and away from off-site receptors.

19.2.9 During development any future seepage / shallow perched groundwaters would be managed via mitigation that would naturally be required as part of a development of this nature. This would be implemented via an appropriate Construction and Environment Management Plan (CEMP) with appropriate environmental controls established by the contractors working on the site.

- 19.2.10 Following remediation and development of the site, the risk of groundwater flooding / seepage will be significantly reduced due to a c. 70% increase in hardstanding areas, the capture of surface waters by drainage and the possible use of low permeability cover systems for private gardens and areas of POS; all of which would reduce infiltration.
- 19.2.11 However, further groundwater seepage could still occur due to leachate generation etc. and as such there may be a requirement for the ongoing or potential future management / mitigation of these shallow perched groundwaters. While the risk is considered to be very low, hydrogeological modelling may be required to understand the potential for future seepages to occur and / or the remediation contractor would need to satisfy themselves that the remediation strategy / works effectively eliminates the potential for any future seepages to occur. If the risk of groundwater seepage cannot be eliminated, either at the design stage, or as the remedial works progress, then appropriate mitigation may be required to avoid potentially contaminated water being encountered by future site users at the surface. If required, subsequent discussions should be undertaken with specialist contractors and / or the relevant utility providers to determine the most effective way to manage this in the long term. Early liaison with the relevant regulatory authorities is also recommended to establish any permitting requirements.
- 19.2.12 In all instances, care will need to be taken to ensure that no new pathways are created to receptors, that the schemes are sufficiently robust, agreement is reached with the regulators and that the relevant permits, if required, are obtained.

Requirement for Controlled Waters DQRA

- 19.2.13 Given the above, the multiple lines of evidence outlined elsewhere in the report, the fact that the remaining receptors are not overly sensitive, and pathways are limited, the requirement for a DQRA for controlled water is not considered necessary. However, this is subject to any permitting requirements and / or agreement with the regulators. Early liaison with the regulatory authorities is recommended to establish any further requirements.
- 19.2.14 Regardless of the approach required, it is considered that protection and betterment of the groundwater and surface waters can be achieved through the remedial works and the construction of the proposed development due to increased hardstanding areas and / or any surface water run-off being captured by drainage. This would

reduce infiltration of rainwater into the near surface soils and correspondingly any associated leaching and migration of potential contaminants into the groundwater or surface waters will be reduced. Furthermore, as part of the remedial works some dewatering of excavations etc. is envisaged and some treatment of shallow perched groundwaters would be required to enable for discharge from the site, resulting in an overall betterment.

19.3 **Materials Management**

- 19.3.1 The site is a recorded landfill and the regulators state that materials that have been deposited under a waste management licence or environmental permit retain their waste classification. If the landfill site materials are excavated, in order for the material to be retained in any form, it must meet a defined and pre-agreed end-of-waste criteria or be undertaken using a bespoke deposit for recovery permit. If the material does not meet the required end-of-waste criteria or the recovery criteria, then any re-placement must be done under contemporary waste and environmental legislation i.e. it is likely to require another type of environmental permit.
- 19.3.2 In this instance a bespoke deposit for recovery permit is considered to be appropriate for the site; subject to agreement with the regulators. A waste recovery plan will need to be completed that demonstrates that the waste recovery test has been met and this information will need to be provided to the regulators before proceeding with the deposit for recovery permit application.
- 19.3.3 There are some areas of the site that have been proven by the site investigation works to lie outside of the recorded extent of the former clay pit excavations (subsequently landfilled) and where only limited thickness of Made Ground have been encountered (<0.50m). While the entire site boundary is recorded as landfill, it may be possible to reuse site won materials from the areas outside of the former clay pit excavations in accordance with the Definition of Waste Code of Practice (DoWCoP) or similar and an accompanying Materials Management Plan (MMP). This would enable for the reuse of this excavated material without it being classified as waste and, together with an agreed remediation strategy, demonstrate that the re-used material does not pose a risk to future site users or controlled waters. The MMP should be produced and agreed with relevant qualified persons and a declaration made (and receipt received) prior to work commencing. Early engagement and agreement with the regulatory authorities will be required to ascertain if this is an option.

- 19.3.4 Care will need to be taken during earthworks that are undertaken at the site to avoid unnecessarily excavating materials that could be classified as waste. In the event that any material is required to be removed from site to landfill, it is recommended that the chemical results obtained and the results from any further necessary testing are analysed to tentatively divide the materials at the site into hazardous and non-hazardous waste classifications in accordance with the relevant regulations, which include, but are not limited to Duty of Care, the Landfill Regulations, the Hazardous Waste Regulations and Publication WM3.

19.4 **Ground Gas and Radon**

- 19.4.1 The ground gas risk assessments indicates that the current site should be classified as Characteristic Situation 2 and that ground gas protection measures would be required for new buildings. Protection measures are likely to comprise a gas / vapour / organic contamination resistant membrane and passive subfloor dispersal layer.
- 19.4.2 When further information about the form of the proposed residential structures is available and if a significant number of structures are found to conform to the model low rise housing type for the NHBC Traffic Light System assessment, then it may be prudent to undertake a separate assessment for those structures where this would be applicable, as the scope of the ground gas protection measures could be reduced.
- 19.4.3 If significant surcharging of the site is to be undertaken as part of the remedial works or the development of the site, that could result in increased ground gas generation, or if impermeable cover systems are used that could result in the build-up of gas, then additional ground gas monitoring may be required at the edges of such features to further quantify the risk.
- 19.4.4 An initial assessment for radon gas has been carried out. The assessment indicates that the site is located within an area where no radon protection measures are required.

19.5 **Possible Free Phase Contamination / Free Product**

- 19.6 Frequent groundwater level monitoring was undertaken using a product / water interface probe in areas where visual and olfactory evidence of contamination has been observed in exploratory holes, where OIP “blips” were recorded and where exceedences of the soil saturation limits have been noted. No NAPL or free product

was detected with the interface probe nor was any visual evidence recorded during development, purging and sampling of perched groundwaters.

19.7 Unrecorded Contamination

19.7.1 It should be noted that the site was a landfill, and a high degree of variability is envisaged, and previously unrecorded contamination may be present. A protocol should be implemented to allow groundworkers to act appropriately upon encountering or suspecting the presence of previously unidentified ground contamination so that specialist advice can be sought and the possible requirement for additional remedial works can be identified.

19.7.2 A mound covering an area of approximately 950m² is present within the eastern section of the site. It is unknown at this stage if any contamination and / or asbestos is present within or beneath this mound, as investigation of this feature was beyond the scope of these works, due to its integrity having to be maintained to prevent unauthorised vehicular access to the site from Mitchell Street. During the site investigation works some of the original exploratory hole positions also had to be altered slightly because areas were inaccessible, largely due to the way the concurrent vegetation clearance works were being undertaken by a third party.

19.7.3 Consequently, further unrecorded contamination may be present and as a result a live “hotspot protocol” should be implemented that would allow for any unrecorded or problematic ground to be further investigated, assessed and the remediation strategy updated accordingly as the remediation works progress (subject to approval by the regulators).

19.8 Detailed Remediation Strategy and Verification Reporting

19.8.1 A detailed remediation strategy will be required for the site and will ultimately need to consider the above noted uncertainties. The exact requirements of the remedial strategy are also dependent on the completion of a DQRA and Options Appraisal that includes feedback from the Client’s appointed remediation contractor. This information will be used to inform the mitigation and / or remediation that is required on site to reduce the identified risks and will feed into the final remediation strategy submitted to the Local Authority for approval.

19.8.2 The Detailed Remediation Strategy shall set out the overall objectives and outline methodologies to be used to undertake the mitigation / remediation and will outline

criteria that the remediation should meet in order to demonstrate that risks have been suitably reduced and describe the verification and validation requirements for mitigation and remediation works.

- 19.8.3 Subsequent verification and validation reporting will also be required to demonstrate to the regulatory authorities that the Detailed Remediation Strategy and associated plans have been followed and the remedial targets met.

19.9 Water Supply Pipes

- 19.9.1 Consideration should be given to the risks posed to any drinking water pipes and underlying utility connections that may be present and / or are constructed within, or come into contact with, the soils or shallow perched waters that have been identified at the site, as aggressive contaminants with the ability to permeate the materials and affect water supply are widespread. Appropriate assessment of subsurface ground services should be undertaken utilising the associated regulator documentation. It should be noted that the requirement for further chemical testing to meet these requirements may be required. Clean service corridors with mitigation that prevents creating preferential pathways are also recommended.

- 19.9.2 Depending on the how the development works are to be phased, there may be a requirement for these assessments to be undertaken prior to the completion of remedial works. This should be confirmed with the relevant contractors and / or regulatory authorities prior to works commencing at the site.

19.10 Decommissioning of Monitoring Wells

- 19.10.1 As part of the remedial works at the site, those monitoring wells that have been installed at the site should be decommissioned, as they may deteriorate and pose an ongoing or potential future risk to the Principal Aquifer and / or those other controlled waters receptors identified. Decommissioning should be undertaken in line with the Environment Agencies 'Good practice for decommissioning redundant boreholes and wells' (October 2012) to ensure that groundwater pollution does not occur.

19.11 Foundation Works Risk Assessment

- 19.11.1 Risk assessment and subsequent mitigation will also be required for some forms of foundation (e.g. piles) on the basis that new pathways / contaminant linkages to deeper groundwaters may be created. If the risk assessment or mitigation measures

are not deemed to be adequate by the EA an alternative foundation solutions may need to be considered.

- 19.11.2 Consideration should also be given to the possibility for some form of foundations (e.g. piles) to act as vertical vents for potentially hazardous ground gases and vapours. Consequently, the use of a propriety system that does not permit vertical venting may be required. However, this is subject to detailed inspection / advice from specialist ground improvement / piling contractors.

19.12 **Invasive Species**

- 19.12.1 Japanese knotweed is known to be present at the site, though its full extent has not been delineated. If it has not been recently undertaken, it is recommended that a full Japanese knotweed survey is completed at the site to determine its current extent on the site and those areas / soils that could be impacted. The survey should include other invasive species such as Giant Hogweed and Himalayan Balsam to confirm if these species are present or not.
- 19.12.2 A legislatively compliant Invasive Non-Native Species Management Plan covering, in particular Japanese knotweed, as well as other species, together with suitable monitoring, validation and management of the remedial works themselves, will be required to deal with the Japanese knotweed and associated infested soils that are present at the site. Consideration will need to be given to the impacts of dealing with the Japanese knotweed and how this could impact on the remedial / development programme for the site.

19.13 **Geotechnical**

- 19.13.1 It is understood that the site is to be redeveloped for a residential end use that also includes a school. Following finalisation of any proposed development layouts, detailed design or structural loading information and any earthworks designs / specifications, these recommendations and conclusions may require detailed review to assess whether they remain applicable or require re-assessment. These recommendations should not be considered in isolation without considering the reporting in full.

19.14 Foundations

- 19.14.1 The Made Ground in its current state would not be suitable as a founding stratum without some form of ground improvement, due to its extremely variable nature and variable strength characteristics. For those areas where Made Ground can be fully excavated, recompacted and engineered without restriction or where competent shallow Glacial Till (<2.5m bgl) is present; buildings could be founded on shallow reinforced foundations. However, for those areas where deeper Made Ground is to be left in-situ beneath the re-engineered Made Ground, it is recommended that either deep trench reinforced foundations or raft foundations are utilised. Larger structures with higher loadings such as the proposed school or multi-storey residential dwellings may require piling into the underlying Glacial Till.
- 19.14.2 Vibrostone / concrete columns or dynamic compaction may also be a suitable ground improvement technique for some parts of the site, and this may be adopted in combination with any material turnover that is undertaken. This combination may eliminate the requirement for raft or piled foundations in the areas where this can successfully be undertaken.
- 19.14.3 Numerous buried highwalls to the former clay pit excavations are present beneath the site and the variation in the depth of the Made Ground could result in severe differential settlements if buildings are constructed across these areas. Consideration should be given to the use of piled or raft foundation solutions in these areas as this would mitigate against any unacceptable movements and hence reduce the extent of any exclusion zones.

19.15 Floor Slabs

- 19.15.1 Due to the significant thicknesses of Made Ground across the site, with areas where deeper Made Ground is likely to be left in-situ beneath re-engineered Made Ground, suspended floor slabs will likely be required to mitigate against settlement / differential settlement.

19.16 External Areas

- 19.16.1 The most likely sub-grade formations for external areas will be the excavated, recompacted and engineered Made Ground and to a lesser extent the very shallow natural Glacial Till.

19.16.2 Once site levels are known, validation testing should be undertaken to finalise the designs for any external areas. To limit settlements within the areas where deeper Made Ground is to be left in-situ beneath engineered Made Ground, reinforcement (e.g. geogrids), soil modification / stabilisation and / or ground improvement should be considered.

19.16.3 Modification / stabilisation or a non-volumetrically active capping layer may be required for those cohesive Made Ground and / or cohesive Glacial Till deposits that are indicated to be susceptible to frost and / or likely influenced by trees / shrubs. Once final site levels and make up are known, further geotechnical testing should be undertaken to confirm this.

19.17 Earthworks

19.17.1 Earthworks will be required across the site for the proposed structures and external areas and the materials excavated and potentially re-used are likely to comprise the shallow Made Ground materials and to a lesser extent the natural Glacial Till; provided they comply with the acceptability criteria for earthworks as defined by the Highways Agency Manual of Contract for Highways Work, Volume 1: Specification for Highway Works, Series 600, Earthworks (SHW) and that the excavated materials have met defined and pre-agreed end-of-waste criteria. In areas of fill beneath proposed structures, fills should be selected in accordance with the above and compacted using an appropriate end product compaction specification. An appropriate level of compaction and frequency and method of testing will need to be selected.

19.17.2 It is envisaged that high levels of compaction will not be achievable unless modification / stabilisation and / or ground improvement of the soils is undertaken. It may be necessary to remove materials that have a high organic content, and / or high plasticity in order to achieve required levels of compaction.

19.18 Excavations

19.18.1 Excavations should be supported or battered back to a stable angle to ensure adequate stability is achieved for the duration of any works. Any excavations that are to be left open or unsupervised will need to be secured. The temporary works design of the remediation contractor should also reduce the risk of instability to any other surrounding works and safeguard the stability of such land.

19.19 Groundwater

19.19.1 There will likely be a requirement for localised temporary works in the form of dewatering / barriers during excavation of any service trenches, mass excavations or excavations that are undertaken as part of any earthworks exercise at the site. There are also environmental considerations associated with the management of these shallow perched groundwaters and these are detailed further above.

19.20 Collapse Compression

19.20.1 Areas of fill material (e.g. colliery spoil) have been identified across the site and there is a low to moderate risk of collapse compression for those susceptible materials that are to be left in-situ. It would be prudent to investigate the risk of collapse compression further for any such materials that are to remain in-situ once earthworks are completed in these areas. For those areas where the fill materials are to be excavated and recompacted, the risk of collapse compression will be significantly reduced / eliminated.

19.21 Combustion

19.21.1 Those colliery spoil materials identified at the site are indicated to be susceptible to combustion. Materials with a calorific value >7 MJ/kg should be kept a minimum of 1m away from any potential sources of ignition and should not be left exposed for long periods of time to minimise the risk of combustion. When used in areas of private gardens or soft landscaping a 1m thick layer of inert material should be present to prevent accidental ignition.

19.21.2 Further calorific value testing is recommended during earthworks where colliery spoil is used as fill material, so that the material placed in the upper 1 m, or within 1m of a potential ignition source does not exceed 7 MJ/kg. The same applies to those materials that are to be stockpiled at the site.

19.22 Concrete Assessment

19.22.1 Due to the high degree of variability encountered across the site and the potential for various Made Ground types to be intermixed a worst-case Design Sulphate Class (DS) of "DS-2" and an Aggressive Chemical Environment for Concrete (ACEC) of "AC-3Z" has been determined for the Made Ground. The exceptions being for those suspected colliery spoil materials where "DS-4" and "AC-5" is indicated due to the potential for

pyrite to be present. For the natural strata at the site the assessment for natural ground locations has been undertaken and “DS-1” and “AC-1” is indicated.

19.23 Soakaways

19.23.1 Given the significant thicknesses of Made Ground encountered across the site, the recorded levels of contamination, the shallow perched groundwater issues and that are risk associated with collapse compression, soakaway construction is not considered suitable for the site. Soakaways in those areas where natural Glacial Till is present at shallow are also not considered to be feasible.

19.24 Slag Expansion

19.24.1 Laboratory testing indicates that the risk from the expansion of slag is thought to be low. However, further testing should be undertaken during earthworks if the suspected combustion waste materials, particularly those above the water table or indicated to be relatively dry, are to be used as engineered fill.

19.25 Total Settlements

19.25.1 Following earthworks and remediation at the site, settlement testing (e.g. skip load or other maintained load tests) should be undertaken to model total settlements and the time it would take for these settlements to occur, especially for those areas where shallow foundations are to be utilised in order to satisfy NHBC requirements. This would inform what mitigation measures would be required to deal with any unacceptable settlements.

19.25.2 For those areas where deeper Made Ground is to remain in-situ beneath engineered fill, alternative foundation solutions may need to be adopted. Alternatively, to limit settlements within these areas and to potentially allow for the use of shallow foundations, reinforcement (e.g. geogrids), soil modification / stabilisation and / or ground improvement of the shallow and deep Made Ground should be considered to mitigate against any ongoing or potential future settlements. Maintained load testing may also be required in these areas to confirm the remediation and foundation design and to satisfy NHBC requirements.

19.26 Trafficability

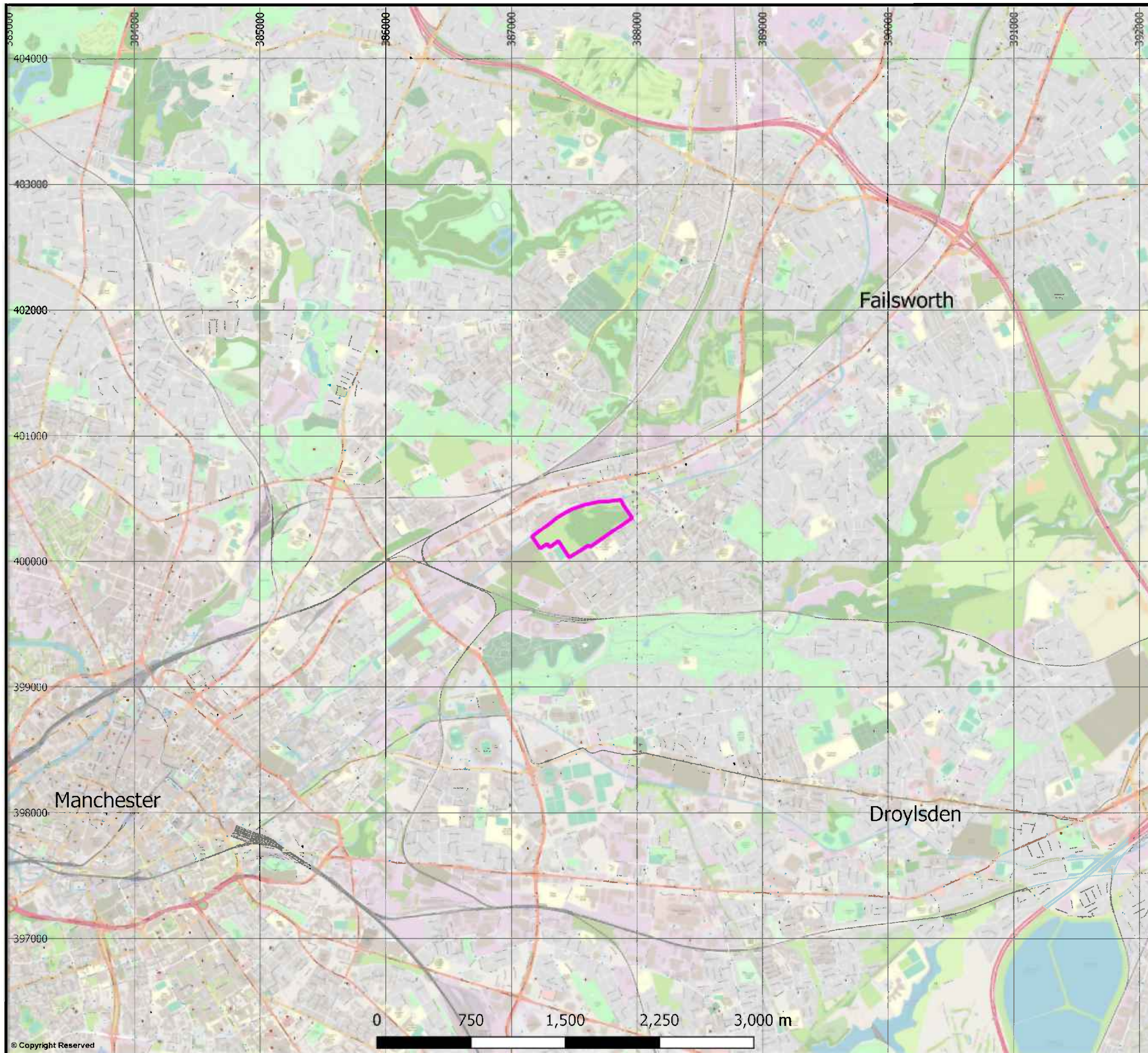
19.26.1 Trafficability at the site on surface materials and / or on any excavated shallow Made Ground will need to be considered by the remediation contractor, particularly during

wet weather and this could necessitate stabilisation of the soils or the use of track matts during the development of the site.

19.27 UXO

- 19.27.1 The previous UXO Detailed Risk Assessment that was carried out for the site in 2020 was based on the proposed site investigation works and future bulk excavations of parts of the site. The report states that a reassessment will be required for the bulk earthworks that would need to be undertaken as part of the development of the site. The remediation of the site should be carried out in accordance with the recommendations given in the revised UXO risk assessment.

DRAWINGS



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Site Boundary



Notes

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REV	DETAILS	DATE	DRN	CHD	APP'D

CLIENT	NUVU DEVELOPMENTS LTD
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PROJECT	TEN ACRES LANE
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DRAWING TITLE	SITE LOCATION PLAN
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DRG No	LD10385-001	REV	
DRG SIZE	A3	SCALE	1:30,000
		DATE	25/08/22
DRAWN BY	JC	CHECKED BY	VC
		APPROVED BY	AR



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PROJECT
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DRAWING TITLE
SITE LOCATION PLAN - AERIAL

DRG No	LD10385-002	REV
DRG SIZE	A3	SCALE
		1:5,000
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Site Boundary

Exploratory Hole Positions 2022

- WA Rotary Boreholes 2022
- WA Cable Percussion Boreholes 2022
- WA Trial Pits 2022
- WA Windowless Sample Holes 2022

Previous Exploratory Hole Positions

- Celtic Rotary Boreholes 2007
- Celtic Cable Percussion Boreholes 2007
- Celtic Trial Pits 2007
- Celtic Windowless Sample Holes 2007
- WA Cable Percussion Boreholes 2019
- WA Trial Pits 2019
- WA Windowless Sample Holes 2019
- WA Rotary Boreholes 2020
- WA Cable Percussion Boreholes 2020
- WA Trial Pits 2020
- WA Windowless Sample Holes 2020
- WA Cone Penetration Test Locations 2021

Notes

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PROJECT	TEN ACRES LANE
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DRAWING TITLE	EXPLORATORY HOLE LOCATION PLAN
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DRG No	LD10385-003	REV	A
DRG SIZE	A3	SCALE	1:2,750
		DATE	25/08/22
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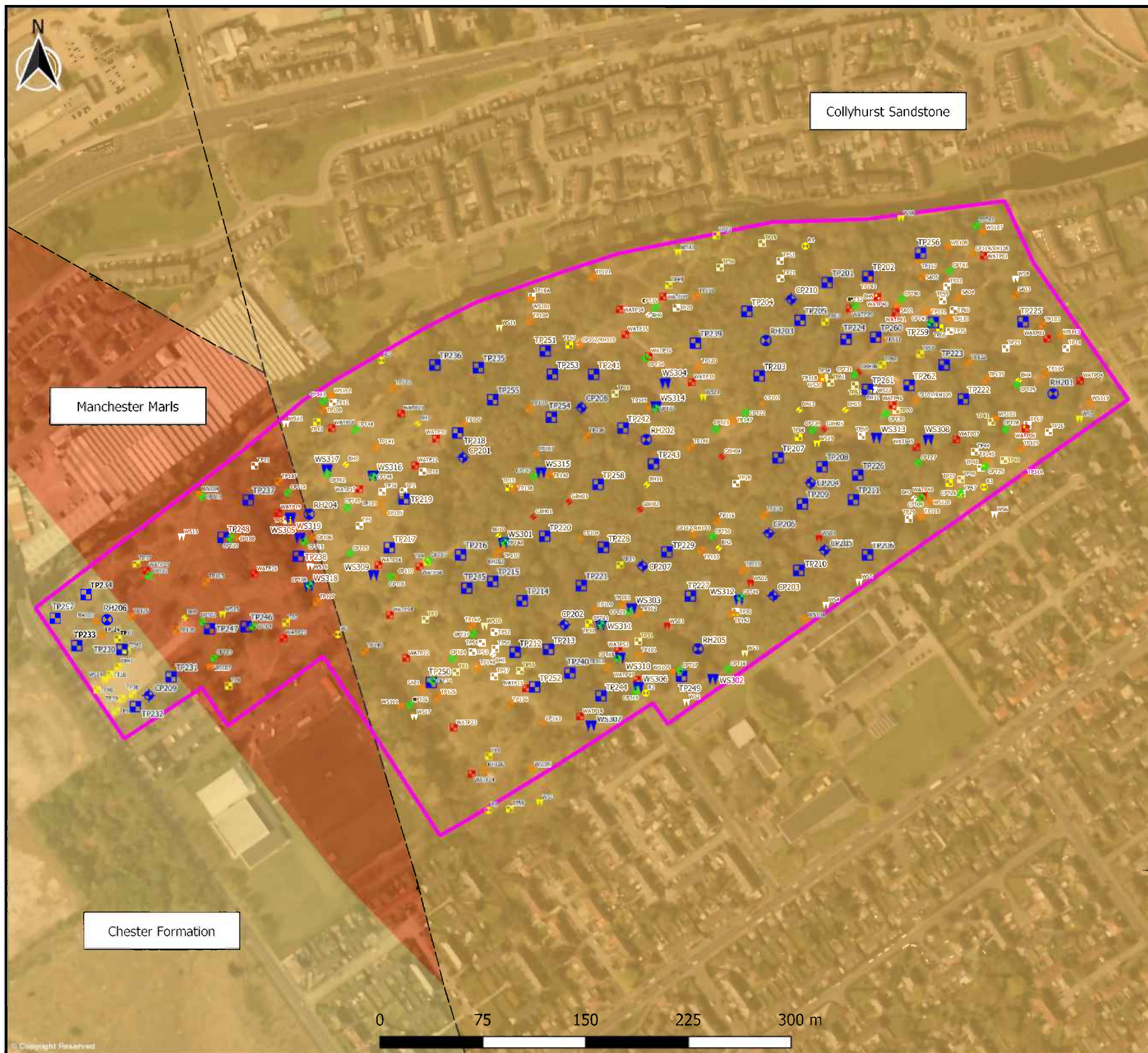
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- Site Boundary
- Collyhurst Sandstone Formation
- Manchester Marls Formation
- Chester Formation
- Conjectured Fault

Exploratory Hole Positions 2022

- WA Rotary Boreholes 2022
- WA Cable Percussion Boreholes 2022
- WA Trial Pits 2022
- WA Windowless Sample Holes 2022

Previous Exploratory Hole Positions

- Celtic Rotary Boreholes 2007
- Celtic Cable Percussion Boreholes 2007
- Celtic Trial Pits 2007
- Celtic Windowless Sample Holes 2007
- WA Cable Percussion Boreholes 2019
- WA Trial Pits 2019
- WA Windowless Sample Holes 2019
- WA Rotary Boreholes 2020
- WA Cable Percussion Boreholes 2020
- WA Trial Pits 2020
- WA Windowless Sample Holes 2020
- WA Cone Penetration Test Locations 2021

Notes

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REVISION	DETAILS	DATE	DRN	CHKD	APPD

CLIENT
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PROJECT
TEN ACRES LANE

DRAWING TITLE
GEOLOGICAL SITE FEATURES PLAN - SOLID GEOLOGY

DRG No	LD10385-004	REV	B
DRG SIZE	A3	SCALE	1:2,750
		DATE	23/09/2022
DRAWN BY	JC	CHECKED BY	VC
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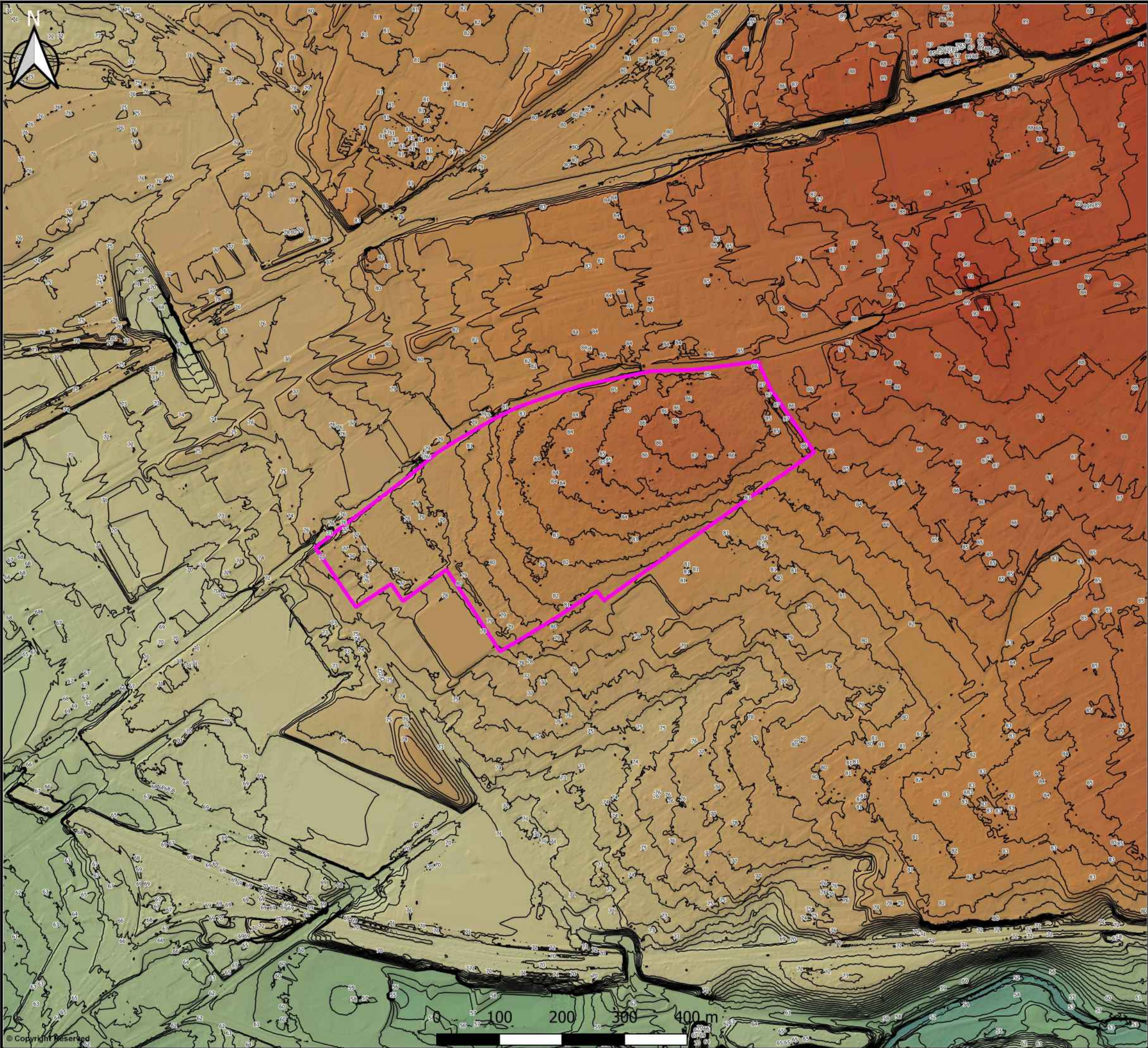
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Site Boundary

Elevation in Metres Above Ordnance Datum

- 43m
- 56m
- 70m
- 83m
- 96m

Notes

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PROJECT	TEN ACRES LANE
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DRAWING TITLE	SHADED RELIEF MAP
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DRG No.	LD10385-005	REV
DRG SIZE	A3	SCALE
		1:6,500
		DATE
		25/08/2022
DRAWN BY	JC	CHECKED BY
		VC
		APPROVED BY
		AR



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DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Indicative Extent of Clay Pit Excavations from Historical Maps
- Made Ground Thickness mbgl
 - 0.0 - 1.0
 - 1.0 - 2.0
 - 2.0 - 3.0
 - 3.0 - 4.0
 - 4.0 - 4.9
 - 4.9 - 5.9
 - 5.9 - 6.9
 - 6.9 - 7.9
 - 7.9 - 8.9
 - 8.9 - 9.9
 - 9.9 - 10.9
 - 10.9 - 11.9
 - 11.9 - 12.9
 - 12.9 - 13.8

Notes

mbgl = Metres below ground level
See Drawing LD10385-003A for the exploratory hole legend. Only exploratory holes used for the contour are shown. Contours are indicative only and have been interpolated between those exploratory holes where the full depth of Made Ground has been proved. Due to the highly complex geometry of the historic clay pit excavations this contour should be used with caution. This contour / drawing also contains information from third party boreholes and no reliance can be provided for this data. We cannot be liable for any more with third party data.
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PROJECT	TEN ACRES LANE				
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DRAWING TITLE	INDICATIVE MADE GROUND THICKNESS CONTOUR PLAN				
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DRG No	LD10385-006		REV		
DRG SIZE	A3	SCALE	1:2,750	DATE	25/08/2022
DRAWN BY	JC	CHECKED BY	VC	APPROVED BY	AR



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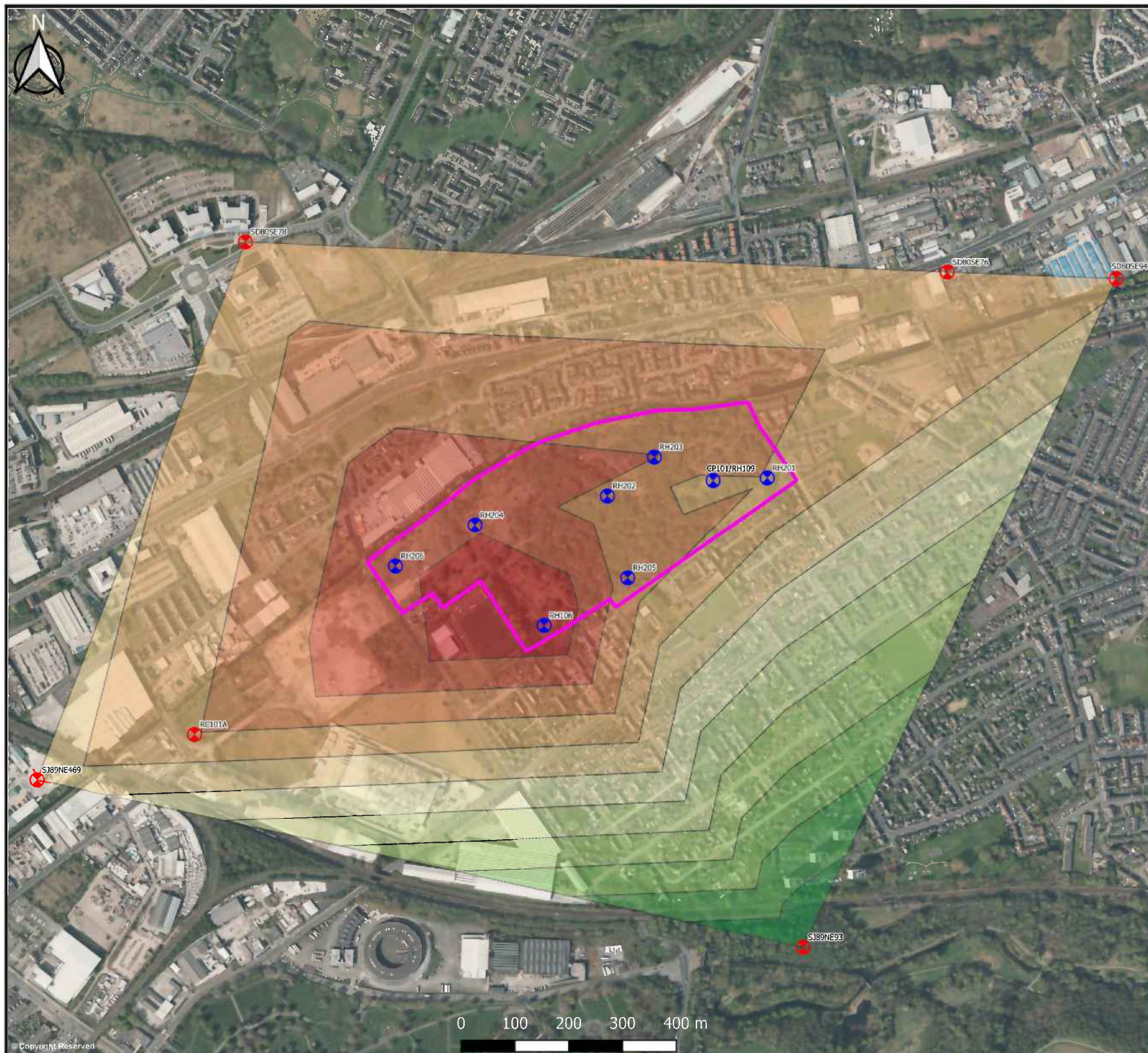
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DO NOT SCALE FROM THIS DRAWING

Legend

Site Boundary

Boreholes Proving Glacial Till Thickness

● WA Boreholes

● Third Party Boreholes

Glacial Till Thickness Contour

- 12.2 - 15.1m
- 15.1 - 18.1m
- 18.1 - 21.0m
- 21.0 - 23.9m
- 23.9 - 26.9m
- 26.9 - 29.8m
- 29.8 - 32.8m
- 32.8 - 35.7m
- 35.7 - 38.6m
- 38.6 - 41.6m
- 41.6 - 44.5m

Notes

Contours are indicative only and have been interpolated between those exploratory holes where the till thickness of the Glacial Till has been proven. There are numerous other boreholes on and off site that are indicative of Glacial Till thickness, but were terminated before the thickness was proven and hence are not shown on this plan. Please refer to the 3D model screenshot shown in Drawing LD10385-010 to 014 and cross sections. This contour drawing also contains information from third party boreholes and no reliance can be placed on this data. WA cannot be liable for any errors within the third party data.

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CLIENT
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PROJECT
TEN ACRES LANE

DRAWING TITLE
INDICATIVE GLACIAL TILL THICKNESS CONTOUR PLAN

DRG No	LD10385-007	REV	A
DRG SIZE	A3	SCALE	1:7,000
		DATE	23/09/2022
DRAWN BY	JC	CHECKED BY	VC
		APPROVED BY	AR



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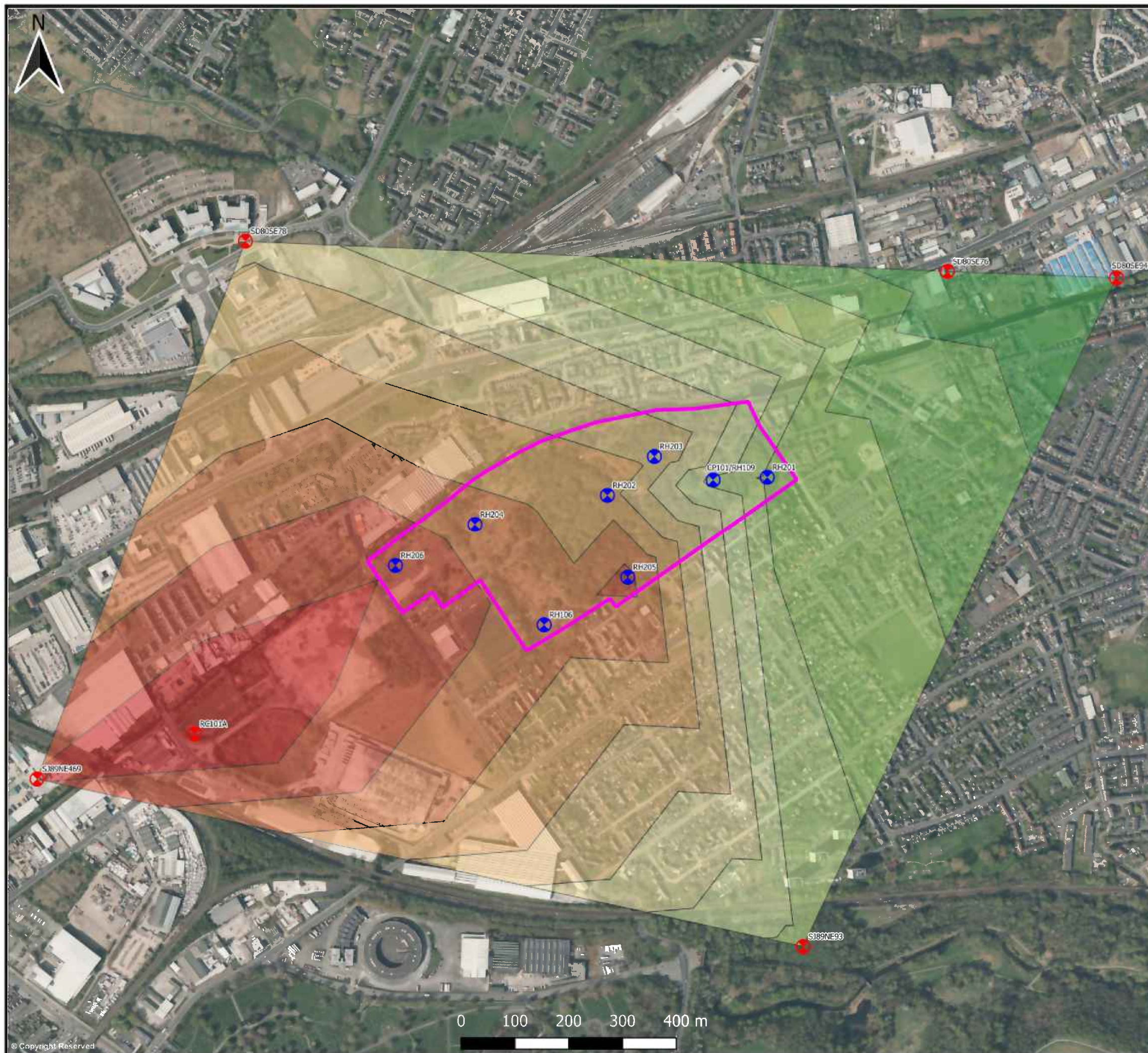
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N:\LD\LD10385 - Ten Acres Further SI Works\03 - Design\QGIS\Output\Drawings 2022



DO NOT SCALE FROM THIS DRAWING

Legend

Site Boundary

Conjectured Fault

Boreholes Proving Rockhead

WA Boreholes Proving Rock

Third Party Boreholes Proving Rock

Indicative Rockhead Contour mAO

29.5 - 31.7

31.7 - 33.9

33.9 - 36.1

36.1 - 38.4

38.4 - 40.6

40.6 - 42.8

42.8 - 45.0

45.0 - 47.2

47.2 - 49.4

49.4 - 51.7

51.7 - 53.9

Notes

mAO = metres above ordnance datum

Drawing is for illustrative purposes only and is an interpolation between points where the depth to rockhead is indicated. Due to the facting that is present on-site the contours should be used with caution. The contour drawing also contains information from third party boreholes and no reliance can be placed on this data. WA cannot be liable for any errors within the third party data.

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CLIENT

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PROJECT

TEN ACRES LANE

DRAWING TITLE

INDICATIVE ROCKHEAD CONTOUR PLAN
mAO

DRG No	LD10385-008	REV	A
DRG SIZE	A3	SCALE	1:7,000
		DATE	23/09/2022
DRAWN BY	JC	CHECKED BY	VC
		APPROVED BY	AR



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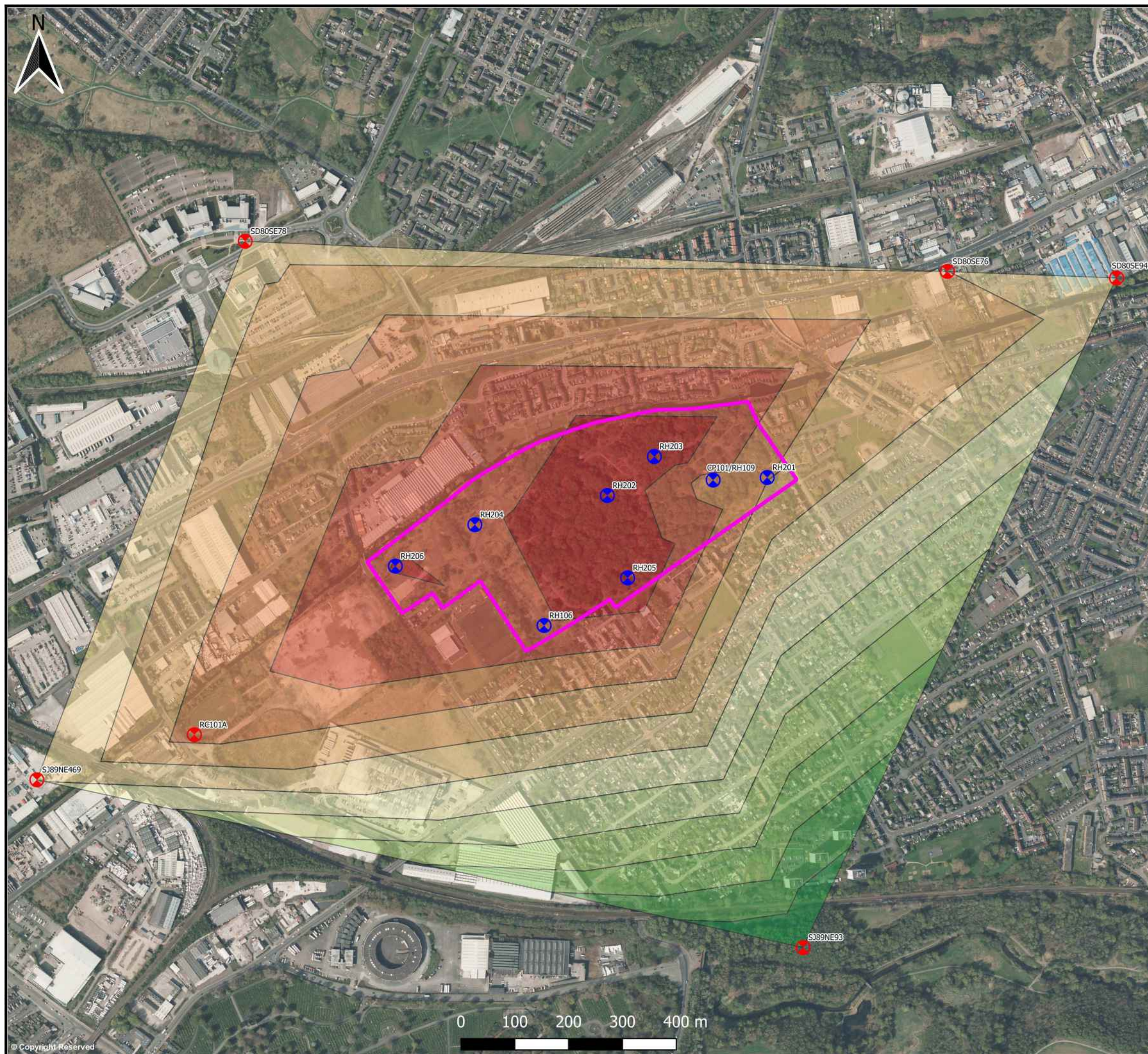
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DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Conjectured Fault
- Boreholes Proving Rockhead**
 - WA Boreholes Proving Rock
 - Third Party Boreholes Proving Rock
- Indicative Rockhead Contour mbgl**

- 12.2 - 15.5
- 15.5 - 18.7
- 18.7 - 22.0
- 22.0 - 25.2
- 25.2 - 28.5
- 28.5 - 31.8
- 31.8 - 35.0
- 35.0 - 38.3
- 38.3 - 41.6
- 41.6 - 44.8
- 44.8 - 48.1

Notes

mbgl = metres below ground level
Drawing is for illustrative purposes only and is an interpolation between points where the depth to rockhead is indicated. Due to the faulting that is present on-site the contours should be used with caution. The contour / drawing also contains information from third party boreholes and no reliance can be provided for this data. We cannot be liable for any errors within the third party data.
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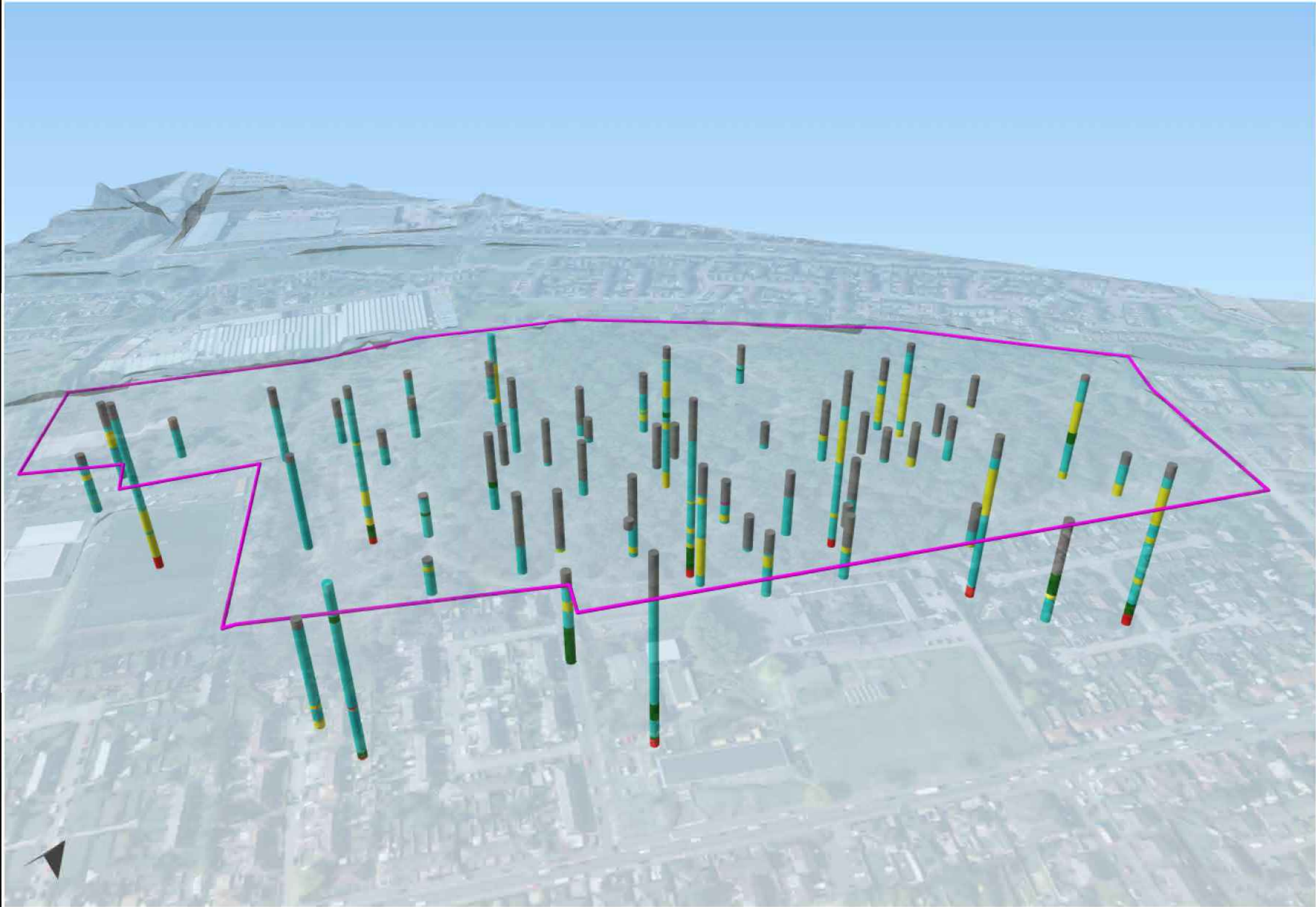
DRAWING TITLE
**INDICATIVE ROCKHEAD CONTOUR PLAN
MBGL**

DRG No. LD10385-009		REV A
DRG SIZE A3	SCALE 1:7,000	DATE 23/09/2022
DRAWN BY JC	CHECKED BY VC	APPROVED BY AR

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DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Made Ground
- Cohesive Glacial Till (Clay)
- Cohesive Glacial Till (Silts)
- Granular Glacial Till (Sands)
- Granular Glacial Till (Gravels & Cobbles)
- Bedrock

Notes

Drawing is for illustrative purposes only and the strata have been simplified and only shows cable percussion or rotary boreholes. Please refer to the exploratory hole logs for further detailed information.
The model also contains information from third party boreholes and no reliance can be provided for this data. Where data from third parties has been used, WA cannot be liable for any errors within the third party data. LIDAR Composite DTM - 1m: © Environment Agency copyright and/or database right 2022. All rights reserved. Open Government License.
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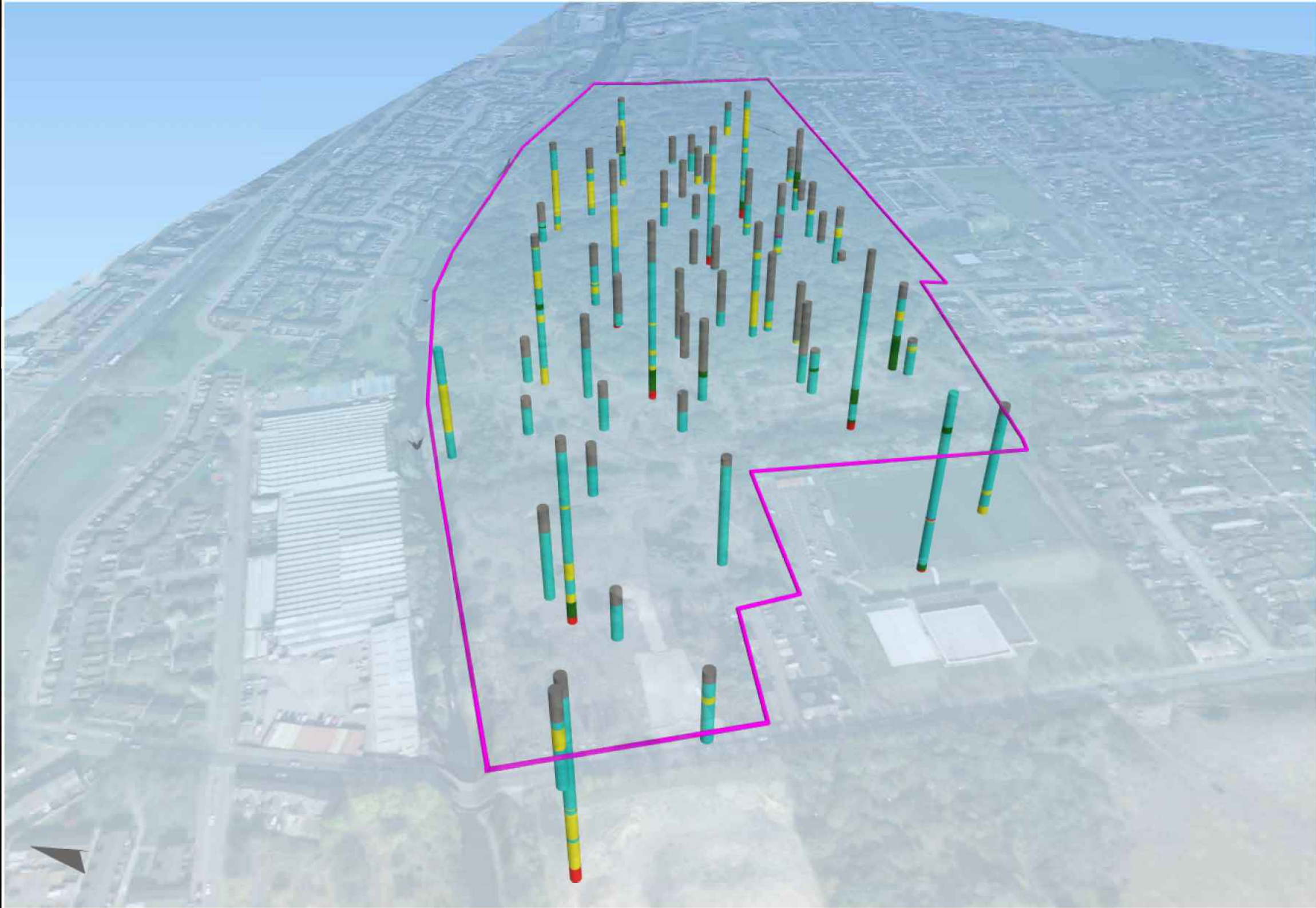
PROJECT	TEN ACRES LANE
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DRAWING TITLE	SIMPLIFIED 3D MODEL BOREHOLES VIEW LOOKING NORTH
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DRG No.	LD10385-010	REV
DRG SIZE	A3	SCALE
		DATE
DRAWN BY	JC	CHECKED BY
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DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Made Ground
- Cohesive Glacial Till (Clay)
- Cohesive Glacial Till (Silts)
- Granular Glacial Till (Sands)
- Granular Glacial Till (Gravels & Cobbles)
- Bedrock

Notes

Drawing is for illustrative purposes only and the strata have been simplified and only shows cable percussion or rotary boreholes. Please refer to the exploratory hole logs for further detailed information.
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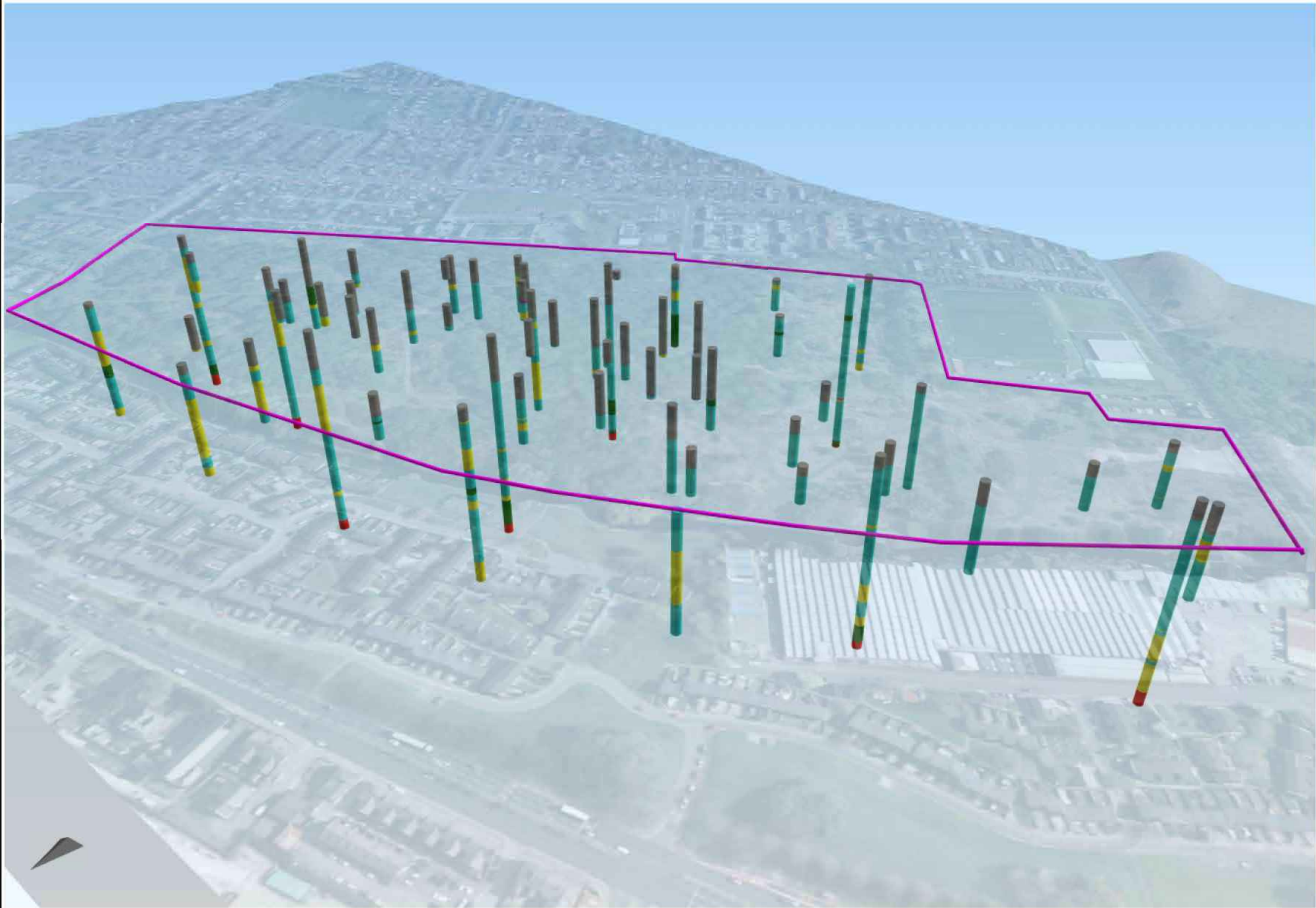
PROJECT	TEN ACRES LANE
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DRAWING TITLE	SIMPLIFIED 3D MODEL BOREHOLES VIEW LOOKING EAST
---------------	--

DRG No.	LD10385-011	REV	
DRG SIZE	A3	SCALE	1:100
		DATE	08/07/2022
DRAWN BY	JC	CHECKED BY	VC
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DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Made Ground
- Cohesive Glacial Till (Clay)
- Cohesive Glacial Till (Silts)
- Granular Glacial Till (Sands)
- Granular Glacial Till (Gravels & Cobbles)
- Bedrock

Notes

Drawing is for illustrative purposes only and the strata have been simplified and only shows cable percussion or rotary boreholes. Please refer to the exploratory hole logs for further detailed information.
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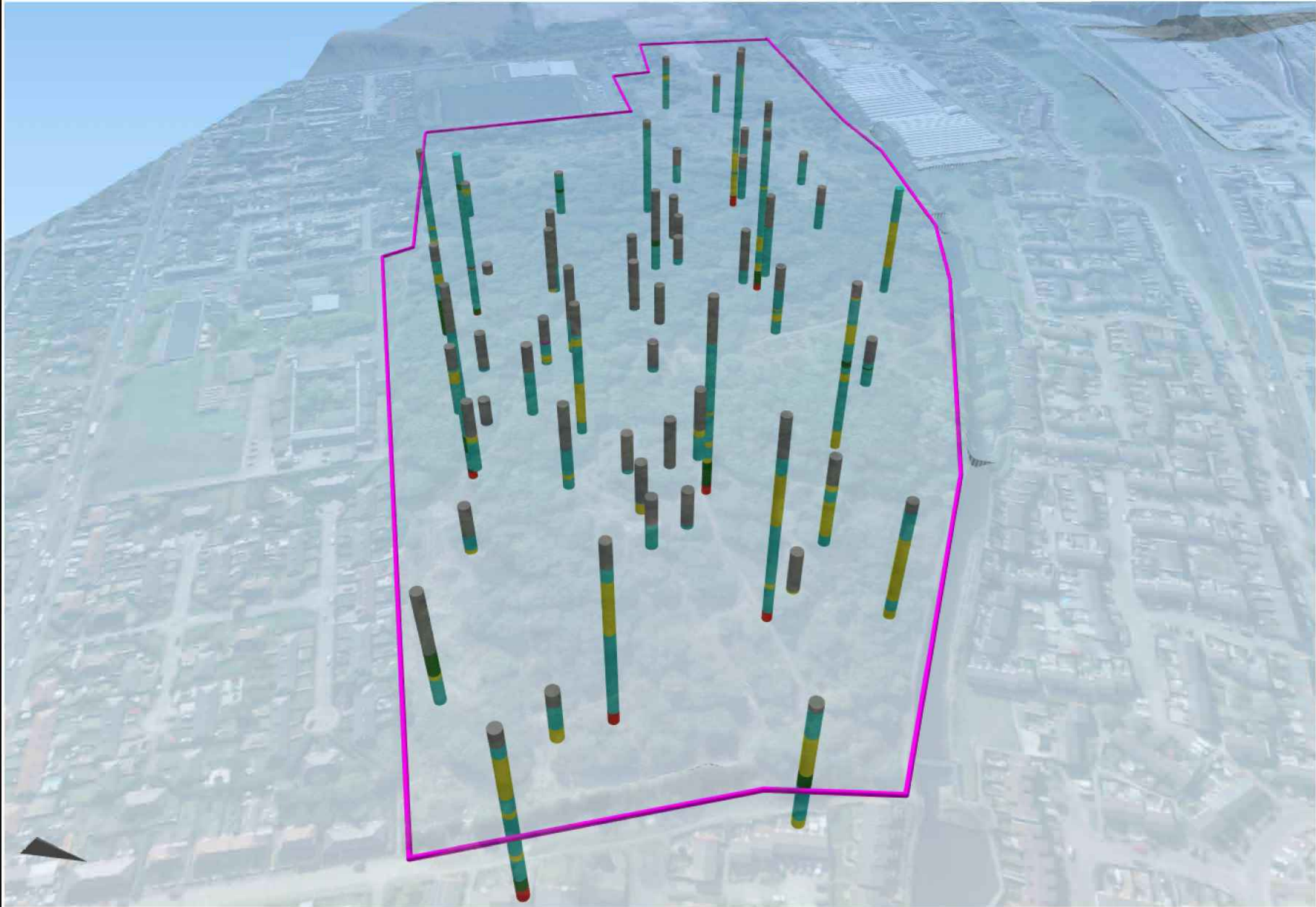
PROJECT	TEN ACRES LANE
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DRAWING TITLE	SIMPLIFIED 3D MODEL BOREHOLES VIEW LOOKING SOUTH EAST
---------------	--

DRG No.	LD10385-012	REV
DRG SIZE	A3	SCALE
		DATE
DRAWN BY	JC	CHECKED BY
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DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Made Ground
- Cohesive Glacial Till (Clay)
- Cohesive Glacial Till (Silts)
- Granular Glacial Till (Sands)
- Granular Glacial Till (Gravels & Cobbles)
- Bedrock

Notes

Drawing is for illustrative purposes only and the strata have been simplified and only shows cable percussion or rotary boreholes. Please refer to the exploratory hole logs for further detailed information.
The model also contains information from third party boreholes and no reliance can be provided for this data. Where data from third parties has been used, WA cannot be liable for any errors within the third party data. LIDAR Composite DTM - 1m: © Environment Agency copyright and/or database right 2022. All rights reserved. Open Government License.
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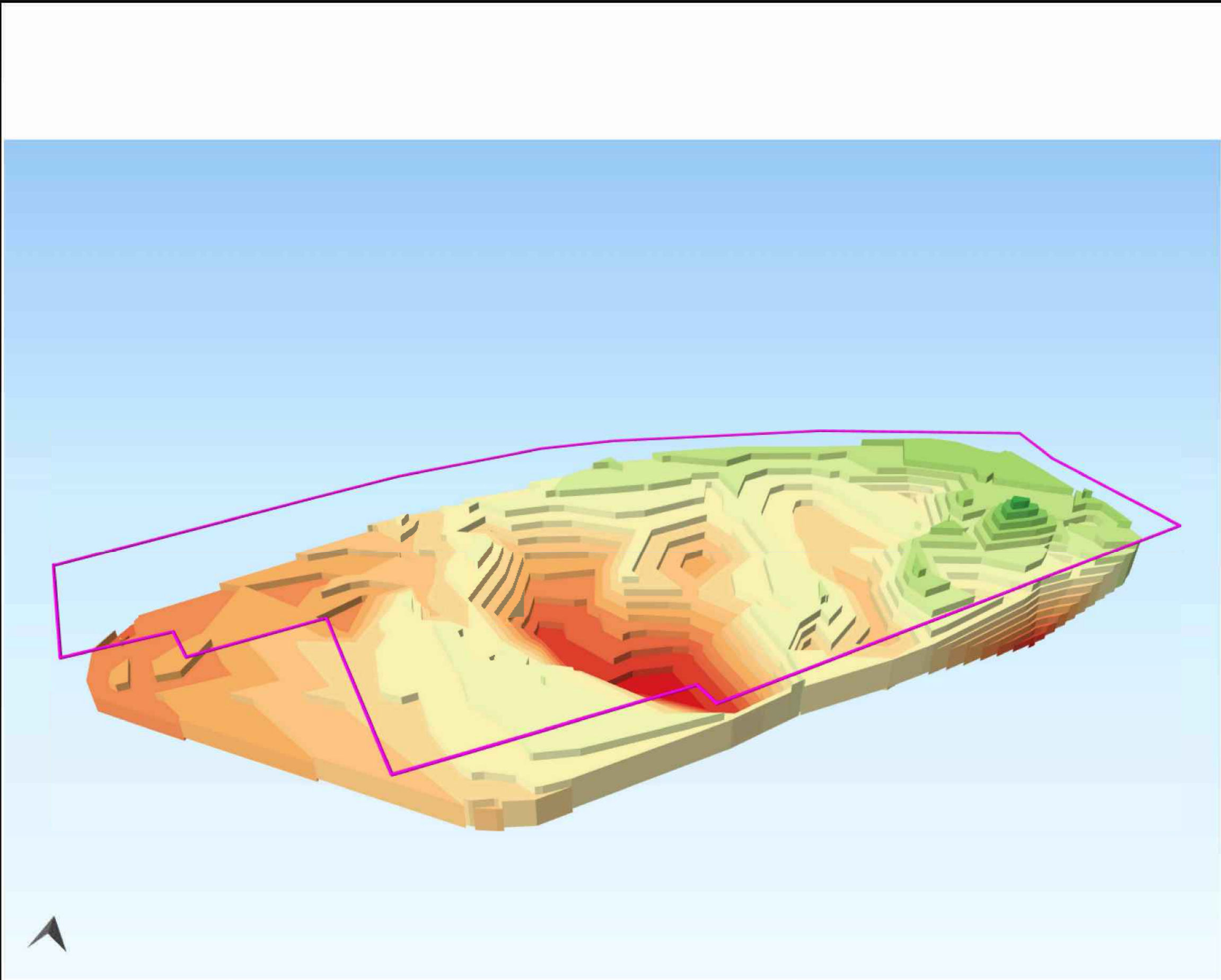
PROJECT	TEN ACRES LANE
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DRAWING TITLE	SIMPLIFIED 3D MODEL BOREHOLES VIEW LOOKING WEST
---------------	--

DRG No.	LD10385-013	REV
DRG SIZE	A3	SCALE
		DATE
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DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Made Ground Contour mAOD
- 68.8 - 70.1
 - 70.1 - 71.5
 - 71.5 - 72.9
 - 72.9 - 74.2
 - 74.2 - 75.6
 - 75.6 - 77.0
 - 77.0 - 78.3
 - 78.3 - 79.7
 - 79.7 - 81.1
 - 81.1 - 82.4
 - 82.4 - 83.8
 - 83.8 - 85.2
 - 85.2 - 86.5
 - 86.5 - 87.9
 - 87.9 - 89.3

Notes

mAOD = metres above ordnance datum.

Contours are indicative only and have been interpolated between those exploratory holes where the full depth of Made Ground has been proved. Due to the likely complex geometry of the historic clay pit excavations the contours should be used with caution. The contour / drawing also contains information from third party boreholes and no reliance can be provided for this data. WA cannot be liable for any errors within the third party data.

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PROJECT	TEN ACRES LANE
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DRAWING TITLE	3D MODEL VIEW MADE GROUND CONTOUR
---------------	-----------------------------------

DRG No.	LD10385-014	REV
DRG SIZE	A3	SCALE
		DATE
DRAWN BY	JC	CHECKED BY
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DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Conjectured Fault
- ⊗ WA Boreholes With Response Zones In Bedrock

Groundwater Contour Bedrock mAO

- 54.4 - 54.6
- 54.6 - 54.8
- 54.8 - 55.0
- 55.0 - 55.2
- 55.2 - 55.5
- 55.5 - 55.7
- 55.7 - 55.9
- 55.9 - 56.1
- 56.1 - 56.3
- 56.3 - 56.5
- 56.5 - 56.7

Notes

Contours are indicative only and have been interpolated between monitoring wells with the average groundwater level being used from the visits to date. Due to the faulting that is present at the site the contours shown should be used with caution.
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CLIENT	NUVU DEVELOPMENTS LTD
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PROJECT	TEN ACRES LANE
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DRAWING TITLE	INDICATIVE GROUNDWATER FLOW CONTOUR WITHIN BEDROCK
---------------	---

DRG No	LD10385-015	REV	
DRG SIZE	A3	SCALE	1:2,750
		DATE	08/07/2022
DRAWN BY	JC	CHECKED BY	VC
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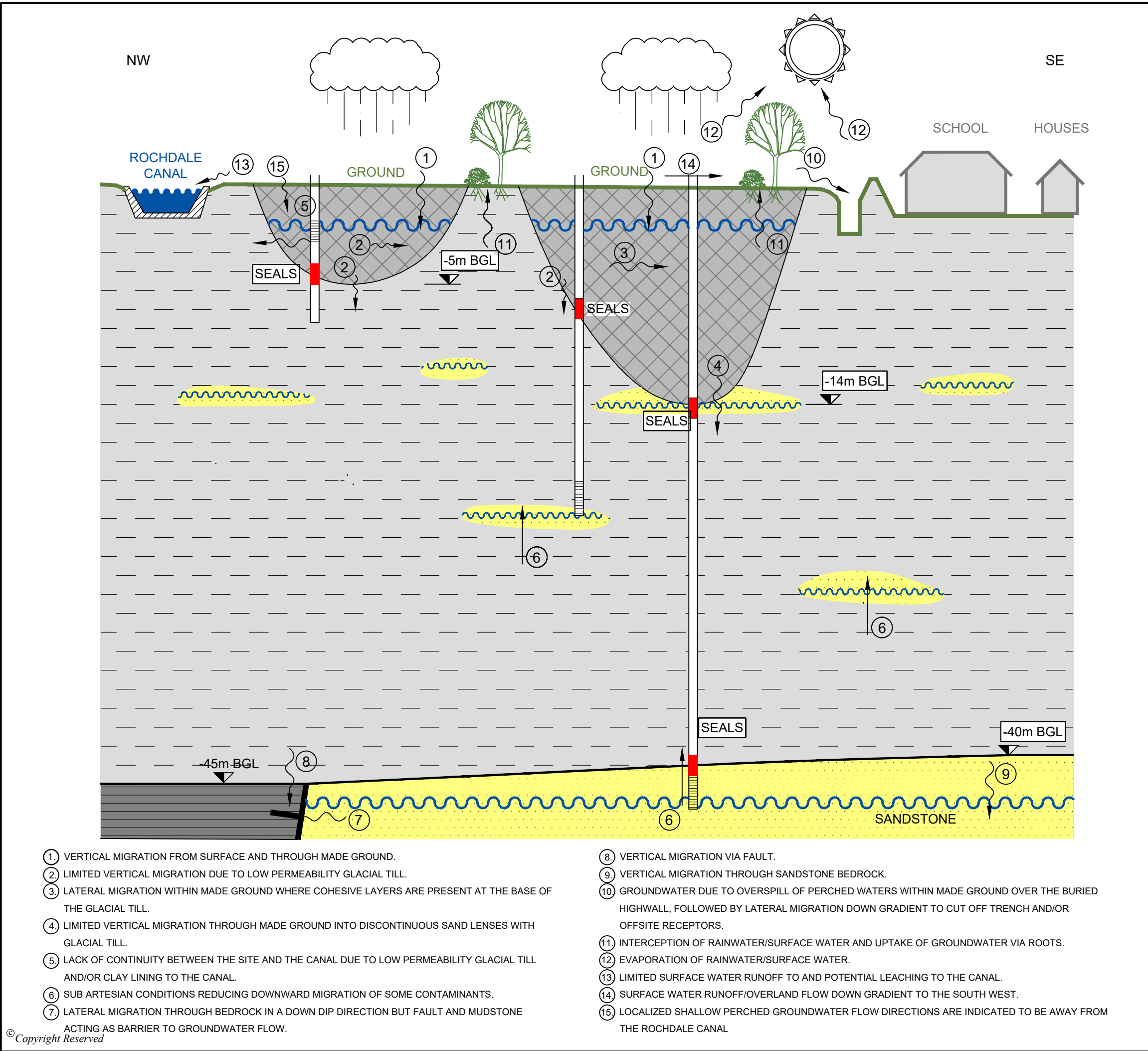
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KEY

MADE GROUND

CLAY

MUDSTONE

SAND LENSES

SANDSTONE

WATER

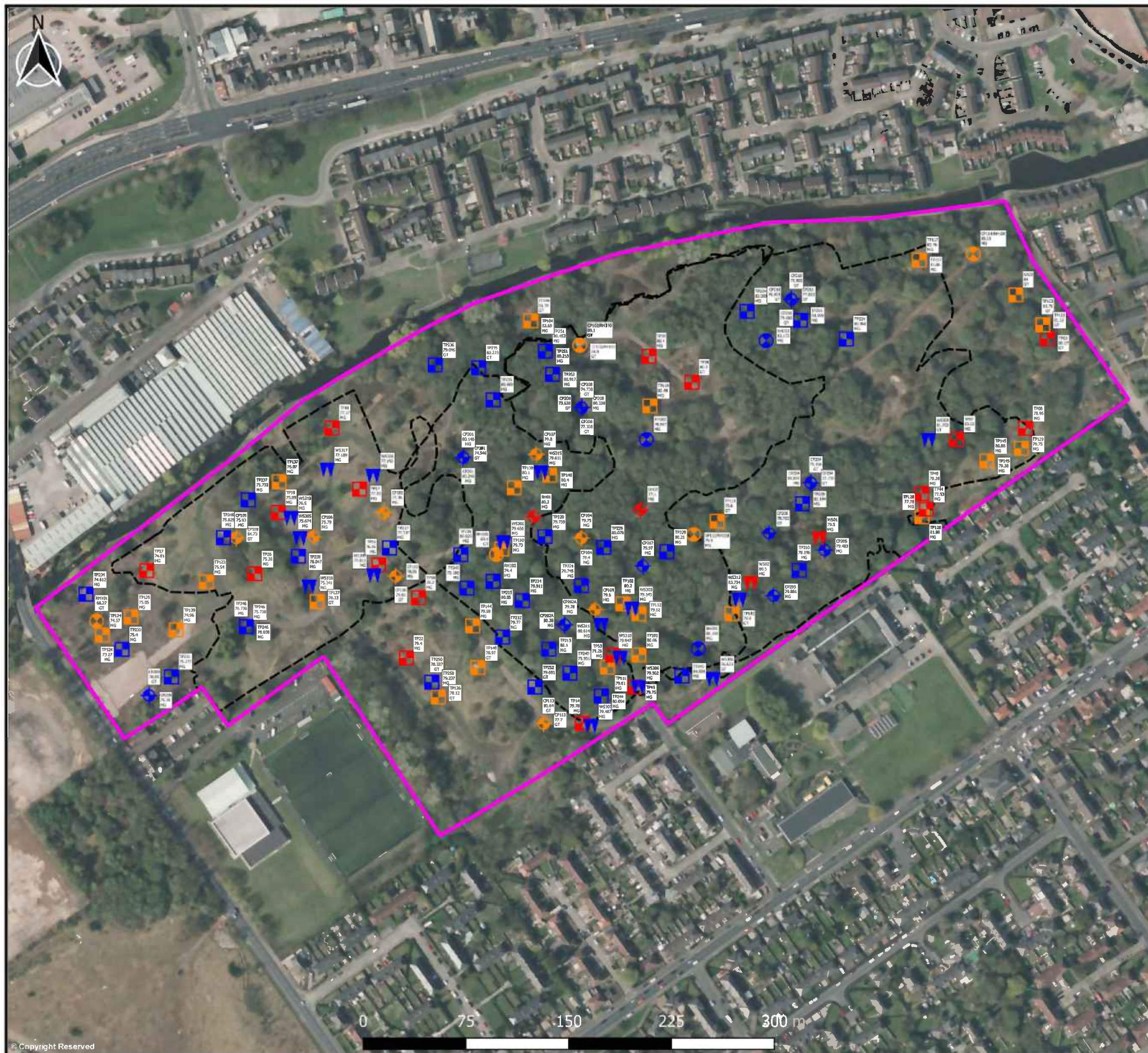
CLAY CAPPING

BOREHOLE LOCATION

DATUM - BELOW GROUND LEVEL (BGL)

FAULT WITH TICK SHOWING DOWN
THROW DIRECTION TO SW

NOTE: DRAWING IS FOR ILLUSTRATIVE
PURPOSES ONLY AND IS NOT TO SCALE



DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Recorded Extent of Clay Pit Excavations from Historical Maps
- Groundwater Strike 2022
- WA Rotary Boreholes 2022
- WA Cable Percussion Boreholes 2022
- WA Windowless Sample Hole 2022
- WA Trial Pits 2022
- WA Rotary Boreholes 2020
- WA Cable Percussion Boreholes 2020
- WA Trial Pits 2020
- WA Cable Percussion Boreholes 2019
- WA Windowless Sample Holes 2019
- WA Trial Pits 2019

Notes

WA = Wardell Armstrong
mAOD = Metres Above Ordnance Datum
Exploratory Hole Labels = Location, Water Strike in mAOD and Strata.
LIDAR Labels = mAOD
MG = Made Ground
GT = Glacial Till

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REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED

CLIENT	NUVU DEVELOPMENTS LTD
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PROJECT	TEN ACRES LANE
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DRAWING TITLE	GROUNDWATER STRIKE ELEVATIONS mAOD
---------------	---------------------------------------

DRG No	LD10385-017	REV	
DRG SIZE	A3	SCALE	1:2,750
DRAWN BY	JC	CHECKED BY	VC
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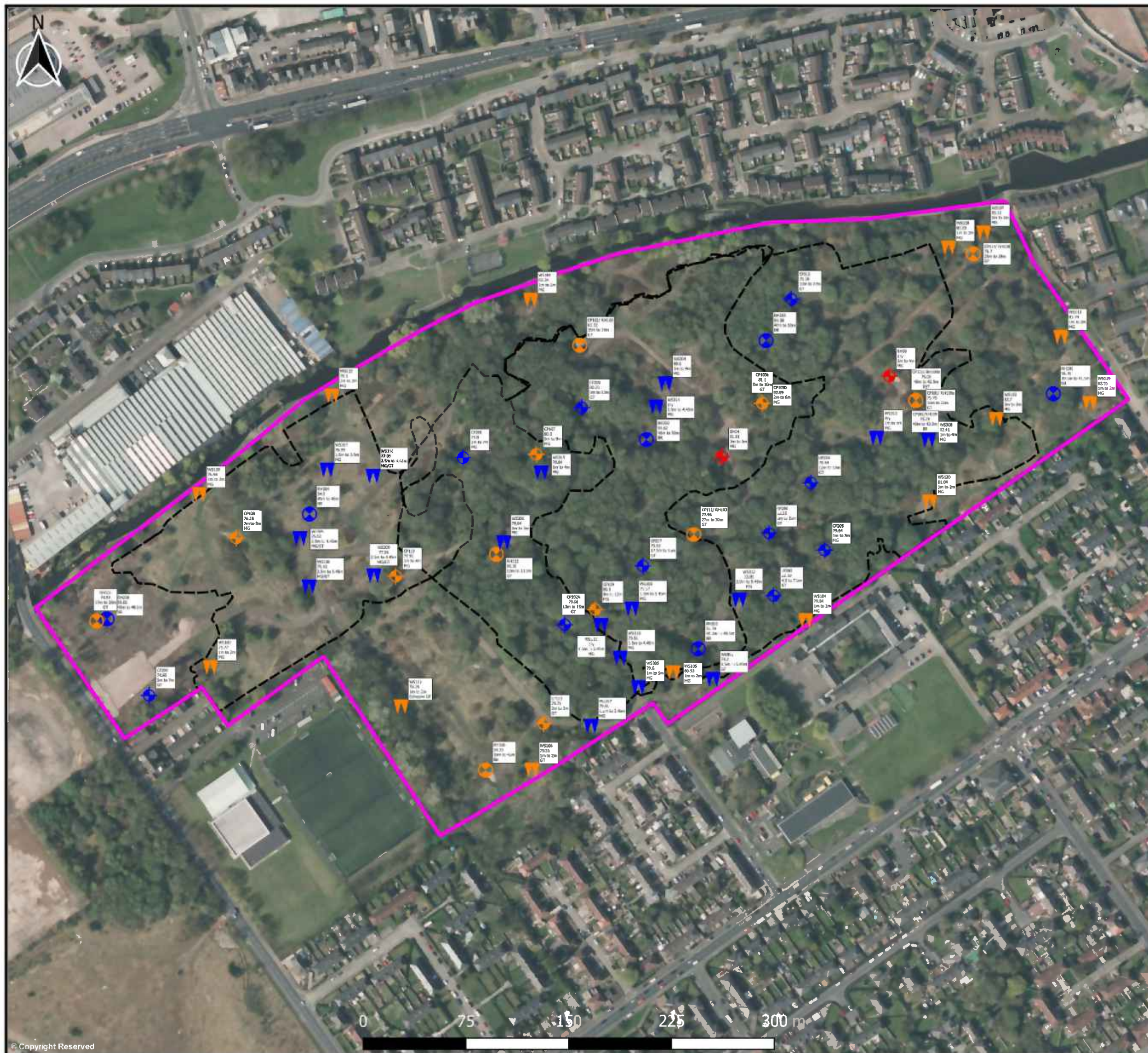
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DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Recorded Extent of Clay Pit Excavations
- Exploratory Hole Locations

Notes

WA = Wardell Armstrong
mAO D = Metres Above Ordnance Datum

Exploratory Hole Labels = Location, Water Strike in mAO D, Reponse Zone and Strata.

MG = Made Ground
GT = Glacial Till
BR = Bedrock

Reported value is the average groundwater monitoring elevation per borehole. For those boreholes that were monitored between November 2020 and July 2022, seasonal variations have been noted, and reference should be made to the accompanying report (ref: LD10385-RPT-001).
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PREPARED BY	DETAILS	DATE	DRN	CHD	CHP

CLIENT	NUVU DEVELOPMENTS LTD
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PROJECT	TEN ACRES LANE
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DRAWING TITLE	GROUNDWATER MONITORING ELEVATIONS mAO D
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DRG No	LD10385-018	REV	
DRG SIZE	A3	SCALE	1:2,750
		DATE	29/08/22
DRAWN BY	JC	CHECKED BY	VC
		APPROVED BY	AR



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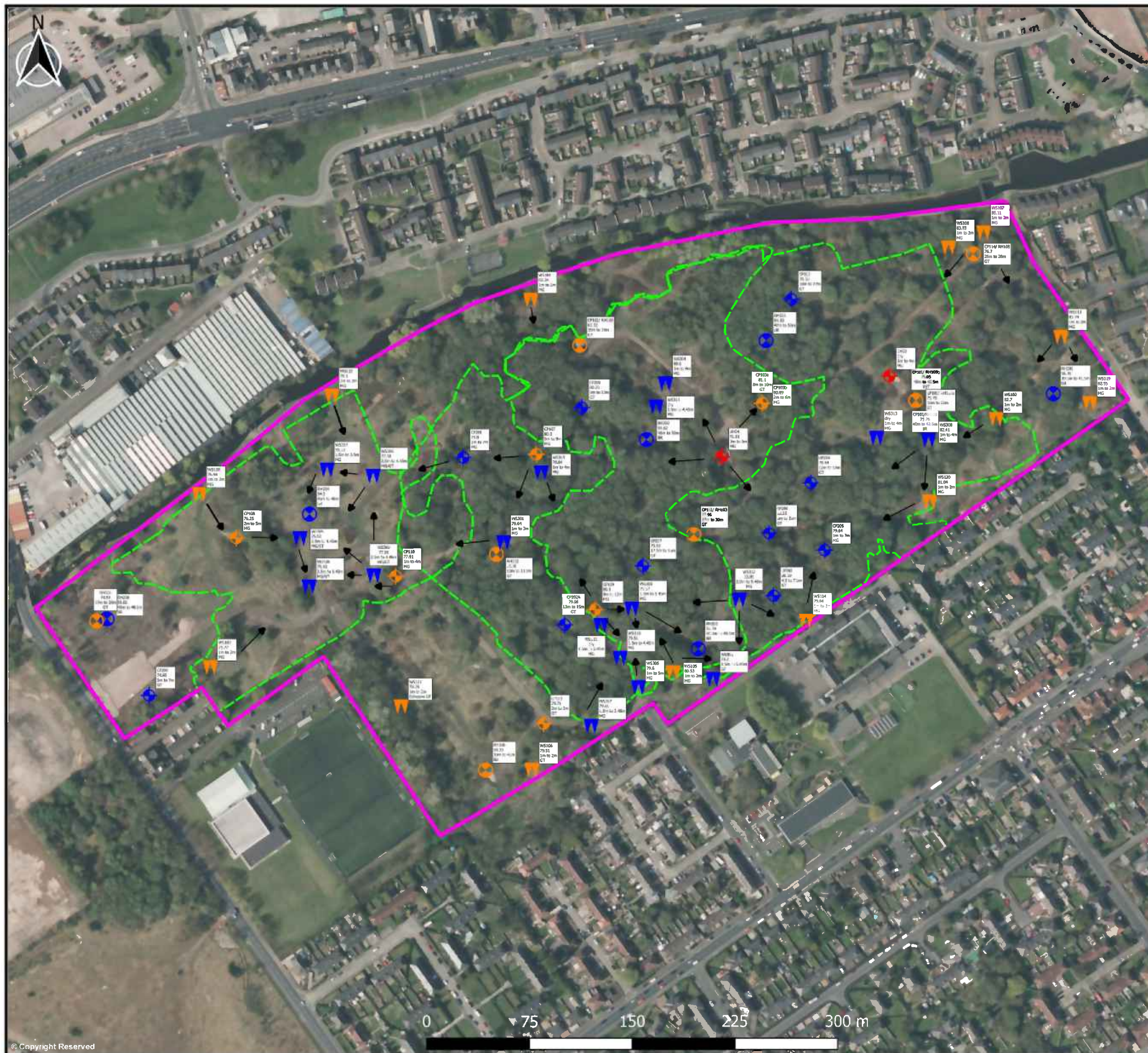
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DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Recorded Extent of Clay Pit Excavations
- Indicative Groundwater Flow Direction

Groundwater Elevations Monitoring Updated

- WA Rotary Boreholes 2022
- WA Cable Percussion Boreholes 2022
- WA Windowless Sample Holes 2022
- WA Rotary Boreholes 2020
- WA Cable Percussion Boreholes 2020
- WA Windowless Sample Holes 2020
- WA Boreholes 2019

Notes

WA = Wardell Armstrong
mAO = Metres Above Ordnance Datum

Exploratory Hole Labels = Location, Water Strike in mAO, Response Zone and Strata.

MG = Made Ground
GT = Glacial Till
BR = Bedrock

This drawing is for illustrative purposes only and is based on the average monitoring levels recorded from each borehole. For those boreholes that were monitored between November 2020 and July 2022, seasonal variations have been noted and reference should be made to the accompanying report (LD10385-RPT-001). LIDAR Composite DTM - 1m: © Environment Agency copyright and/or database right 2022. All rights reserved. Open Government License. BING imagery reproduced under license. Boundaries are indicative. Aerial imagery shown for context purposes only.

PREPARED BY	DETAILS	DATE	DRN	CHKD	APPD

CLIENT	NUVU DEVELOPMENTS LTD
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PROJECT	TEN ACRES LANE
---------	----------------

DRAWING TITLE	INDICATIVE GROUNDWATER FLOW DIRECTION IN PERCHED WATERS WITHIN MADE GROUND
---------------	--

DRG No	LD10385-019	REV	
DRG SIZE	A3	SCALE	1:2,750
		DATE	29/08/22
DRAWN BY	JC	CHECKED BY	VC
		APPROVED BY	AR



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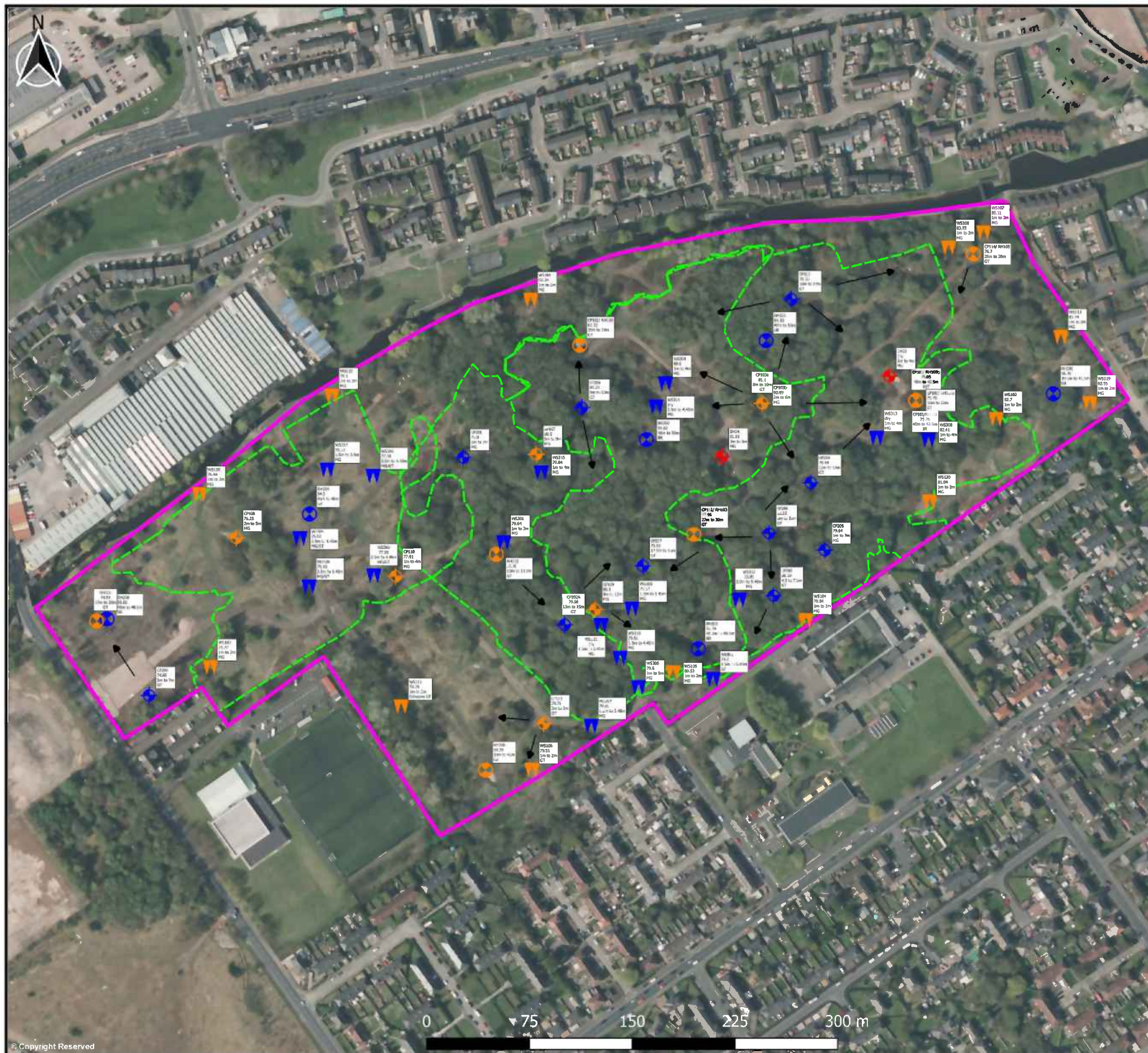
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DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Recorded Extent of Clay Pit Excavations
- Indicative Groundwater Flow Direction

Groundwater Elevations Monitoring Updated

- WA Rotary Boreholes 2022
- WA Cable Percussion Boreholes 2022
- WA Windowless Sample Holes 2022
- WA Rotary Boreholes 2020
- WA Cable Percussion Boreholes 2020
- WA Windowless Sample Holes 2020
- WA Boreholes 2019

Notes

WA = Wardell Armstrong
mAO = Metres Above Ordnance Datum

Exploratory Hole Labels = Location, Water Strike in mAO, Response Zone and Strata.

MG = Made Ground
GT = Glacial Till
BR = Bedrock

This drawing is for illustrative purposes only and is based on the average monitoring levels recorded from each borehole. For those boreholes that were monitored between November 2020 and July 2022, seasonal variations have been noted and reference should be made to the accompanying report (LD10385-RPT-001).
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REV	DESCRIPTION	DATE	DRN	CHKD	APPD

CLIENT	NUVU DEVELOPMENTS LTD
--------	-----------------------

PROJECT	TEN ACRES LANE
---------	----------------

DRAWING TITLE	INDICATIVE GROUNDWATER FLOW DIRECTION IN PERCHED WATERS WITHIN GLACIAL TILL
---------------	---

DRG No	LD10385-020	REV	
DRG SIZE	A3	SCALE	1:2,750
DATE	29/08/22	APPROVED BY	AR



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DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Recorded Extent of Clay Pit Excavations
- Areas of Largely Suspected Combustion Waste
- Areas of Largely Suspected Construction & Demolition Waste
- Areas of Largely Suspected Combustion Waste >1m Thick
- Areas of Largely Suspected Colliery Spoil
- Areas of Suspected Household Waste
- Significant Areas of Largely Unknown Ground Conditions

Notes

Please refer to Drawing LD10385-003A for the exploratory hole legend. Areas outlined are indicative and are for illustrative purposes only. Only predominant Made Ground types are indicated. Vertical extent is not represented. Suspected household waste materials are centred on the areas in which they were encountered and are not indicative of the lateral and vertical extent. Actual ground conditions may vary between exploratory hole locations due to the inherent variability that would be expected within a historical landfill of this nature. BING imagery reproduced under license. Boundaries are indicative. Aerial imagery shown for context purposes only.

REVISION	DETAILS	DATE	DRN	CHKD	APP'D
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CLIENT
NUVU DEVELOPMENTS LTD

PROJECT
TEN ACRES LANE

DRAWING TITLE
INDICATIVE MADE GROUND TYPES

DRG No.	LD10385-021	REV
DRG SIZE	A3	SCALE
		1:2,750
		DATE
		29/08/22
DRAWN BY	JC	CHECKED BY
		VC
		APPROVED BY
		AR



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DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Approximate Area of Groundwater Seepage 2020
- Recorded Extent of Clay Pit Excavations

Notes

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REVISION	DETAILS	DATE	DRN	CHKD	APPD

CLIENT	NUVU DEVELOPMENTS LTD
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PROJECT	TEN ACRES LANE
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DRAWING TITLE	INDICATIVE AREA OF GROUNDWATER SEEPAGE
---------------	--

DRG No	LD10385-022	REV	
DRG SIZE	A3	SCALE	1:2,750
		DATE	29/08/22
DRAWN BY	JC	CHECKED BY	VC
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N:\LD\LD10385 - Ten Acres Further SI Works\03 - Design\QGIS\Output\Drawings 2022



DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Recorded Extent of Clay Pit Excavations
- WA Cone Penetration Test (CPT) Locations 2021
- CPT Location - No Blip
- CPT Location - Notable Blips

Notes

WA = Wardell Armstrong

"Blips" = Denotes locations where fluorescence has been induced by fuel polycyclic aromatic hydrocarbons (PAHs) during the push of the ultraviolet probe.

Drawing is for illustrative purposes only and areas highlighted are indicative only. Depths of "blips" are not indicated and reference should be made to the results contained within Appendix Q of the report. BING imagery reproduced under license. Boundaries are indicative. Aerial imagery shown for context purposes only.

REVISION	DETAILS	DATE	DRN	CHKD	APP'D
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CLIENT	NUVU DEVELOPMENTS LTD
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PROJECT	TEN ACRES LANE
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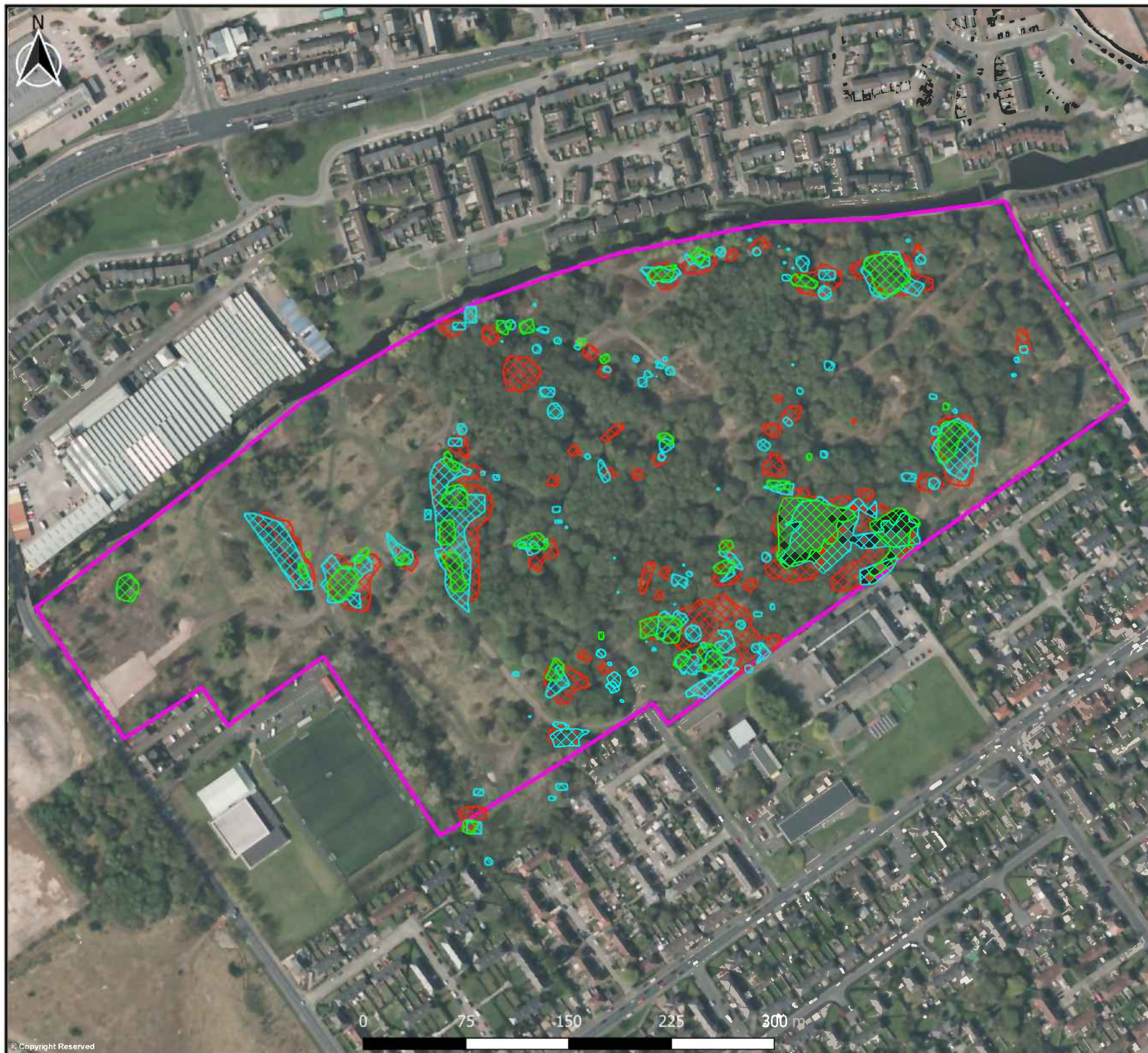
DRAWING TITLE	OPTICAL IMAGE PROFILE (OIP) "BLIPS"
---------------	--

DRG No.	LD10385-024	REV
DRG SIZE	A3	SCALE
		1:2,750
		DATE
		06/09/22
DRAWN BY	JC	CHECKED BY
		VC
		APPROVED BY
		AR

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DO NOT SCALE FROM THIS DRAWING

Legend

- Site Boundary
- Japanese Knotweed Extents Surveyed 2007
- Japanese Knotweed Extents Surveyed 2010
- Japanese Knotweed Extents Surveyed 2021

Notes

Drawing is for illustrative purposes only and has been produced via georeferencing techniques. Consequently, areas highlighted are indicative only. The drawing also contains third party data and no reliance can be provided for this data. WA cannot be liable for any errors within third party data. BING imagery reproduced under license. Boundaries are indicative. Aerial imagery shown for context purposes only.

PREPARED BY	DETAILS	DATE	DRN	CHKD	APPD

CLIENT	NUVU DEVELOPMENTS LTD
--------	-----------------------

PROJECT	TEN ACRES LANE
---------	----------------

DRAWING TITLE	JAPANESE KNOTWEED OVERLAY PLAN
---------------	--------------------------------

DRG No	LD10385-025	REV	
DRG SIZE	A3	SCALE	1:2,750
		DATE	09/09/22
DRAWN BY	JC	CHECKED BY	VC
		APPROVED BY	AR



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APPENDIX A

Standard Terms and Conditions and Limitations to Report

STANDARD TERMS AND CONDITIONS AND LIMITATIONS TO REPORT

General

This Report is provided for the stated purpose and for the sole use of the client in accordance with the Terms and Conditions of Appointment under which the services were performed. The Report is confidential to the client and no other warranty, expressed or implied, is made as to the professional advice included in the Report or any other services provided by Wardell Armstrong LLP. This Report may not be disclosed by the Client nor relied upon by any other party without the prior and express written agreement of Wardell Armstrong LLP.

Wardell Armstrong LLP disclaim any undertaking or obligation to advise any person of any change in any matter affecting the Report which may come or be brought to Wardell Armstrong LLP's attention after the date of the Report.

Where any site observations have been carried out, these have been restricted to a level of detail required to meet the stated objectives of the services. The results from any site observations made may vary and further confirmatory work should be made after the issuance of this Report. Wardell Armstrong LLP does not guarantee or warrant any estimates or projections contained in this Report.

The findings and recommendations are considered to be valid and appropriate at the time of preparation and for the specific purpose or purposes intended. Wardell Armstrong LLP will not be liable if any findings are used by third parties, without written agreement of the company, or if an interpretation is made and action taken without further consultation.

The conclusions and recommendations contained in this Report provide an overview and guidance only and should not be specifically relied upon without considering the context of the reporting fully. They are also based upon information provided by others including details supplied by the client and/or professional advisors on the assumption that all relevant information from whom it has been requested and/or supplied is accurate. Information so provided and/or supplied has not been verified independently by Wardell Armstrong LLP, unless otherwise stated in the Report.

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- For any purpose or project other than for which it was commissioned, and
- By any third party with whom an agreement has not been executed.

Desk Study

The methodology adopted and the sources of information used by Wardell Armstrong LLP in providing the services are outlined in this Report. The work described in this Report is based on the conditions and information as stated at the date the Report was completed. The scope of this Report and the services are accordingly limited by these circumstances. The findings outlined in the Report together with any opinions expressed and recommendations made are considered to be valid and appropriate at the time of preparation and for the specific purpose or purposes intended.

Wardell Armstrong LLP disclaim any undertaking or obligation to advise any person of any change in any matter affecting the Report which may come or be brought to Wardell Armstrong LLP's attention after the date of the Report. Unless otherwise stated in this Report, the assessments made assume that the sites and facilities will continue to be used for their current purpose without significant changes.

The report does not constitute or contain a valuation nor is it a full rigorous environmental audit. In this instance the report is prepared for a proposed residential land use that will also incorporate a new school and playing fields and includes a review of past investigations, environmental reports and relevant correspondence supplied for review.

A site walkover survey has been completed and while reasonable effort has been made to obtain an overview of the site conditions, no attempt has been made to enter areas of the site that are unsafe or present a risk to health and safety, are locked, barricaded, overgrown, or the location of the area has not been made known or accessible. The walkover survey does not constitute an asbestos, archaeological or ecological survey and not all areas of the site may have been visited or made available for inspection.

The opinions given in this report have been based on finite data and are relevant only to the purpose for which the report was commissioned.

The information reviewed should not be considered exhaustive and has been accepted in good faith as providing true and representative data indicative of site conditions. Should additional information become available which may affect the opinions expressed in this report, Wardell Armstrong LLP, reserves the right to review such information and, if warranted, to modify the opinions accordingly.

It should be noted that any risks identified in a Phase 1 report are perceived risks based on the information reviewed; actual risks can only be assessed following a physical investigation of the site.

Site Investigation

The findings within this report are based on those light percussion boreholes, rotary open and cored boreholes, windowless sampling holes, trial pits and soakaways. The results from this site assessment

are indicative of the ground conditions encountered at the positions the boreholes were drilled and/or where the trial pits were excavated and only represent a fraction of the site. Whilst reasonable inferences have been made between the site investigation locations, ground conditions for a site of this nature are inherently variable and their physical/chemical conditions can only be inferred between investigation locations. Localised conditions may vary, and the opinions expressed are for guidance only.

It should be noted that some of the proposed site investigation locations could not be drilled because of access restrictions or due to the presence of Japanese Knotweed.

The number of sampling points, methods of sampling and testing do not preclude the existence of other more variable ground conditions and/or “hotspots” of contamination elsewhere on the site where physical and/or chemical concentrations may be higher than those encountered. Contamination may vary spatially and temporally. The absence of certain ground, contamination or groundwater conditions at the positions tested is not a guarantee that such conditions do not exist anywhere across the site or could exist at these locations at a later date.

Observations made in respect of soil gas and/or groundwater conditions are based on monitoring work carried out over a relatively short period of time. It should be noted the gas and/or groundwater levels will vary due to seasonal, tidal and/or weather-related effects. These effects may not be reflected fully in relation to the monitoring works carried out to date.

The scope of the investigation was selected on the basis of the Client’s general development proposals and may be inappropriate to any other form of development or scheme that may be considered at the site in the future.

There may be exceptional ground conditions elsewhere on the site which may not have been encountered during this phase of investigation that have not been considered as part of this report.

The risk assessment(s) and opinion(s) provided are based on current guidance; no liability can be accepted for the retrospective effects of any future changes or amendments that may be relevant in the future.

APPENDIX B

Landmark Envirocheck Reports and Maps

Historical Mapping Legends

Ordnance Survey County Series 1:10,560

	Gravel Pit		Sand Pit		Other Pits
	Quarry		Shingle		Orchard
	Osiers		Reeds		Marsh
	Mixed Wood		Deciduous		Brushwood
	Fir		Furze		Rough Pasture
	Arrow denotes flow of water		Trigonometrical Station		
	Site of Antiquities		Bench Mark		
	Pump, Guide Post, Signal Post		Well, Spring, Boundary Post		
	Surface Level				
	Sketched Contour		Instrumental Contour		
	Main Roads		Minor Roads		
	Sunken Road		Raised Road		
	Road over Railway		Railway over River		
	Railway over Road		Level Crossing		
	Road over River or Canal		Road over Stream		
	Road over Stream				
	County Boundary (Geographical)				
	County & Civil Parish Boundary				
	Administrative County & Civil Parish Boundary				
	County Borough Boundary (England)				
	County Burgh Boundary (Scotland)				
	Rural District Boundary				
	Civil Parish Boundary				

Ordnance Survey Plan 1:10,000

	Chalk Pit, Clay Pit or Quarry		Gravel Pit
	Sand Pit		Disused Pit or Quarry
	Refuse or Slag Heap		Lake, Loch or Pond
	Dunes		Boulders
	Coniferous Trees		Non-Coniferous Trees
	Orchard		Scrub
	Bracken		Heath
	Marsh		Reeds
	Building		Glasshouse
	Sloping Masonry		Pylon
	Cutting		Embankment
	Road Under		Road Over
	Level Crossing		Foot Bridge
	Standard Gauge Multiple Track		Standard Gauge Single Track
	Siding, Tramway or Mineral Line		Narrow Gauge
	Geographical County		Administrative County, County Borough or County of City
	Municipal Borough, Urban or Rural District, Burgh or District Council		Borough, Burgh or County Constituency
	Civil Parish		
	Boundary Post or Stone		Police Station
	Church		Post Office
	Club House		Public Convenience
	Fire Engine Station		Public House
	Foot Bridge		Signal Box
	Fountain		Spring
	Guide Post		Telephone Call Box
	Mile Post		Telephone Call Post
	Mile Stone		Well

1:10,000 Raster Mapping

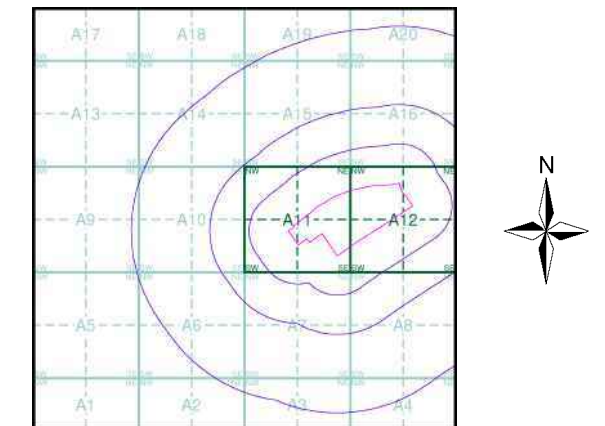
	Gravel Pit		Refuse tip or slag heap
	Rock		Rock (scattered)
	Boulders		Boulders (scattered)
	Shingle		Mud
	Sand		Sand Pit
	Slopes		Top of cliff
	General detail		Underground detail
	Overhead detail		Narrow gauge railway
	Multi-track railway		Single track railway
	County boundary (England only)		Civil, parish or community boundary
	District, Unitary, Metropolitan, London Borough boundary		Constituency boundary
	Area of wooded vegetation		Non-coniferous trees
	Non-coniferous trees (scattered)		Coniferous trees
	Coniferous trees (scattered)		Positioned tree
	Orchard		Coppice or Osiers
	Rough Grassland		Heath
	Scrub		Marsh, Salt Marsh or Reeds
	Water feature		Flow arrows
	Mean high water (springs)		Mean low water (springs)
	Telephone line (where shown)		Electricity transmission line (with poles)
	Bench mark (where shown)		Triangulation station
	Point feature (e.g. Guide Post or Mile Stone)		Pylon, flare stack or lighting tower
	Site of (antiquity)		Glasshouse
	General Building		Important Building



Historical Mapping & Photography included:

Mapping Type	Scale	Date	Pg
Lancashire And Furness	1:10,560	1848	3
Cheshire	1:10,560	1882	4
Lancashire And Furness	1:10,560	1894	5
Cheshire	1:10,560	1899	6
Lancashire And Furness	1:10,560	1909 - 1910	7
Cheshire	1:10,560	1911	8
Lancashire And Furness	1:10,560	1923	9
Lancashire And Furness	1:10,560	1932 - 1933	10
Cheshire	1:10,560	1938	11
Lancashire And Furness	1:10,560	1938	12
Ordnance Survey Plan	1:10,000	1956	13
Ordnance Survey Plan	1:10,000	1966 - 1968	14
Manchester	1:25,000	1975	15
Ordnance Survey Plan	1:10,000	1978	16
Ordnance Survey Plan	1:10,000	1981 - 1982	17
Ordnance Survey Plan	1:10,000	1987	18
Ordnance Survey Plan	1:10,000	1990 - 1993	19
10K Raster Mapping	1:10,000	1999	20
10K Raster Mapping	1:10,000	2006	21
VectorMap Local	1:10,000	2020	22

Historical Map - Slice A



Order Details

Order Number: 267713911_1_1
 Customer Ref: Ten Acres
 National Grid Reference: 387320, 400240
 Slice: A
 Site Area (Ha): 18.51
 Search Buffer (m): 1000

Site Details

Site at 387600, 400310

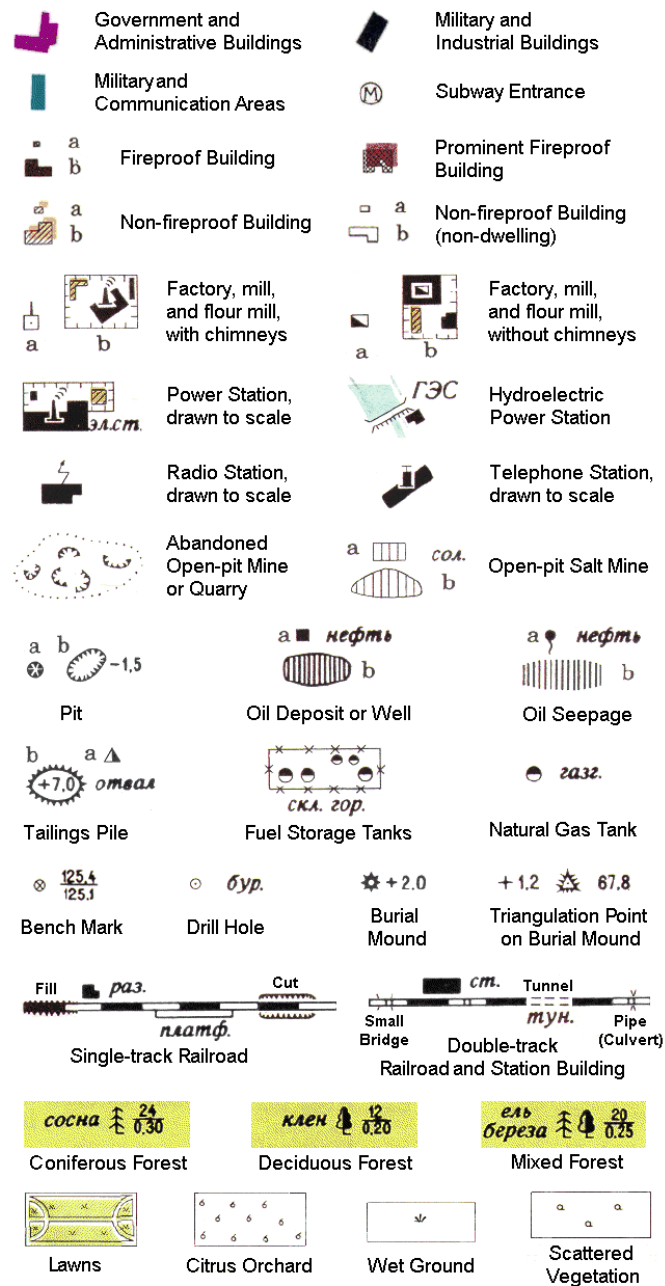


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Russian Military Mapping Legends

1:5,000 and 1:10,000 mapping

a. Not drawn to scale b. Drawn to scale



243.8 Values for prominent elevations

186.0 Numbers for spot elevations, depth soundings, contour lines, etc.

0.2 Velocity of the current, width of river bed, depth of river

180/12 Fractional terms: length and capacity of bridges; depth of fords and condition of the river bottom; height of forest and the diameter of trees

Russian Alphabet (For reference and phonetic interpretation of map text)

А а (A) З з (Z) П п (P) Ч ч (CH)

Б б (B) И и (I) Р р (R) Ш ш (SH)

В в (V) Й й (Y) С с (S) Щ щ (SHCH)

Г г (G) К к (K) Т т (T) Ъ ъ (-)

Д д (D) Л л (L) У у (U) Ы ы (Y)

Е е (E) М м (M) Ф ф (F) Ь ь (')

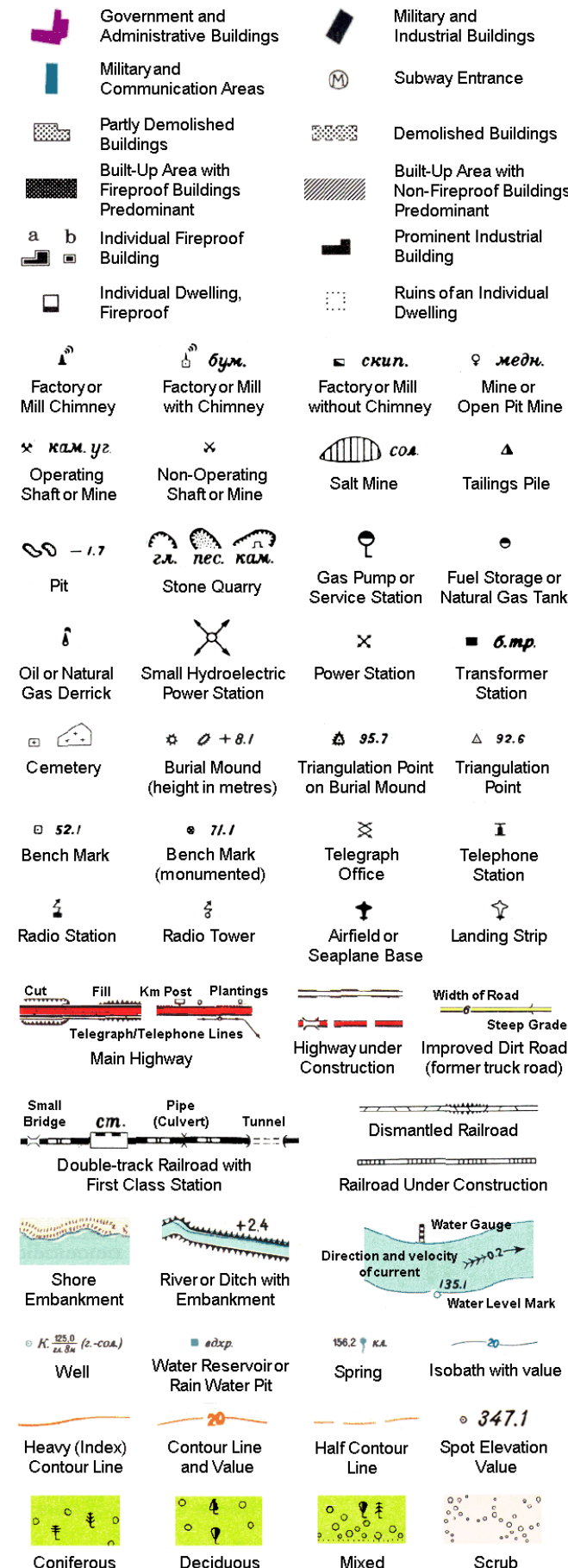
Ё ё (YO) Н н (N) Х х (KH) Э э (E)

Ж ж (ZH) О о (O) Ц ц (TS) Ю ю (YU or IU)

Я я (YA or IA)

1:25,000 mapping

a. Not drawn to scale b. Drawn to scale



Key to Numbers on Mapping

SD80_Manchester

No.	Description
24	Depot (Railway)
75	Factory (Locomotives And Railway Carriage Repairs)
136	Foundry (Cast Iron)
233	Factory (Textiles)

SJ89_Manchester

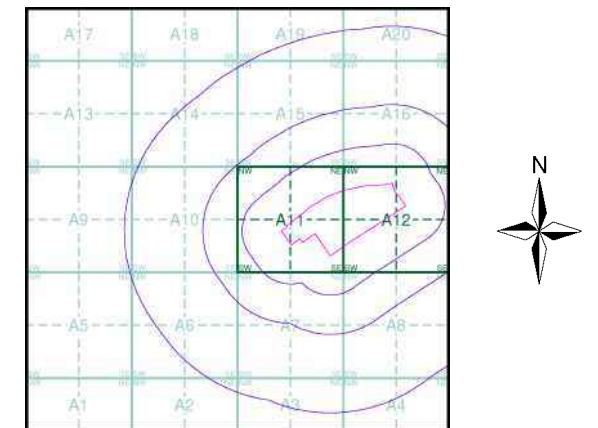
No.	Description
61	Factory (Gas)
83	Factory (Machinery)



Historical Mapping & Photography included:

Mapping Type	Scale	Date	Pg
Lancashire And Furness	1:10,560	1848	3
Cheshire	1:10,560	1882	4
Lancashire And Furness	1:10,560	1894	5
Cheshire	1:10,560	1899	6
Lancashire And Furness	1:10,560	1909 - 1910	7
Cheshire	1:10,560	1911	8
Lancashire And Furness	1:10,560	1923	9
Lancashire And Furness	1:10,560	1932 - 1933	10
Cheshire	1:10,560	1938	11
Lancashire And Furness	1:10,560	1938	12
Ordnance Survey Plan	1:10,000	1956	13
Ordnance Survey Plan	1:10,000	1966 - 1968	14
Manchester	1:25,000	1975	15
Ordnance Survey Plan	1:10,000	1978	16
Ordnance Survey Plan	1:10,000	1981 - 1982	17
Ordnance Survey Plan	1:10,000	1987	18
Ordnance Survey Plan	1:10,000	1990 - 1993	19
10K Raster Mapping	1:10,000	1999	20
10K Raster Mapping	1:10,000	2006	21
VectorMap Local	1:10,000	2020	22

Russian Map - Slice A



Order Details

Order Number: 267713911_1_1

Customer Ref: Ten Acres

National Grid Reference: 387320, 400240

Slice: A

Site Area (Ha): 18.51

Search Buffer (m): 1000

Site Details

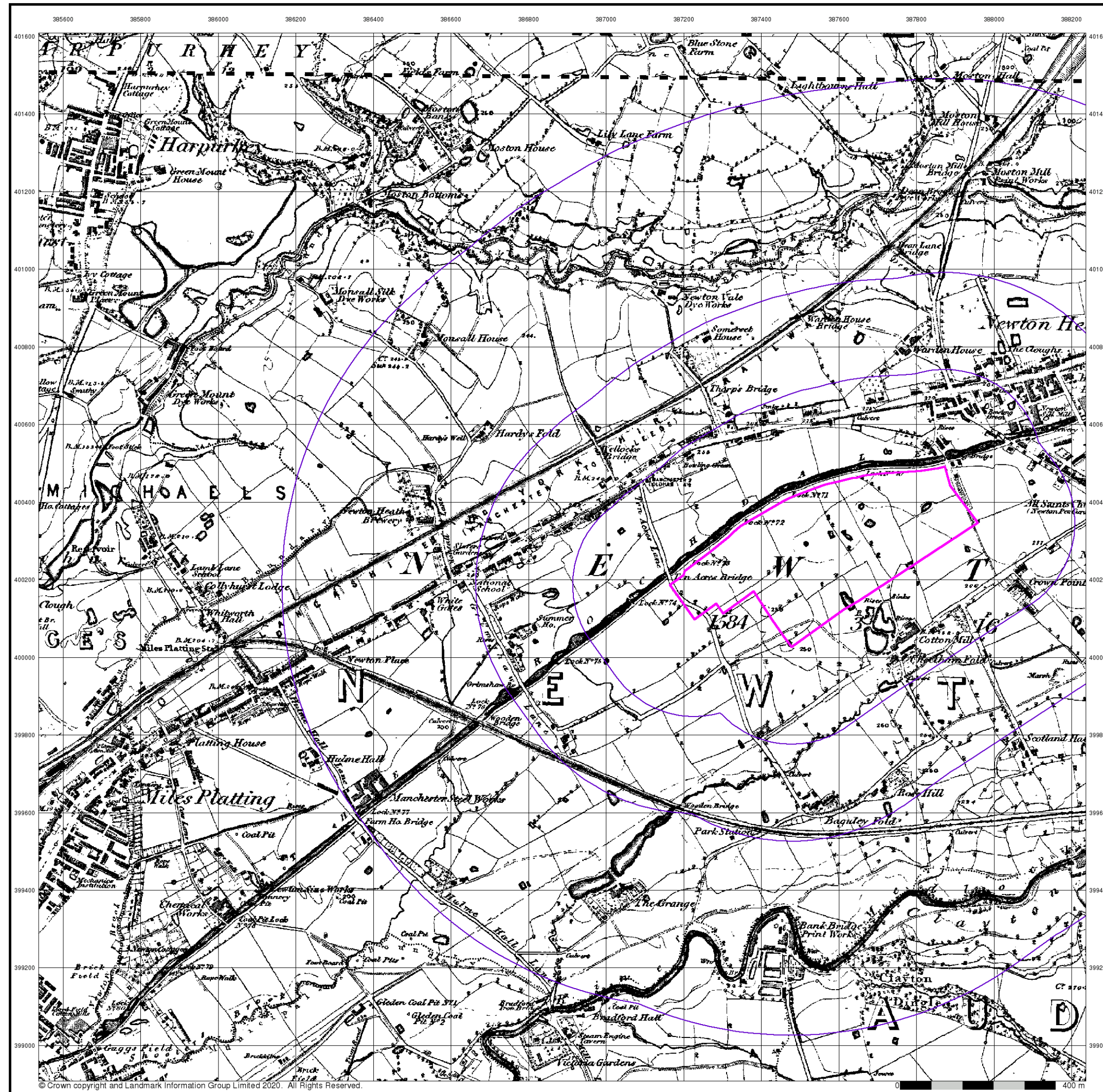
Site at 387600, 400310



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Lancashire And Furness

Published 1848

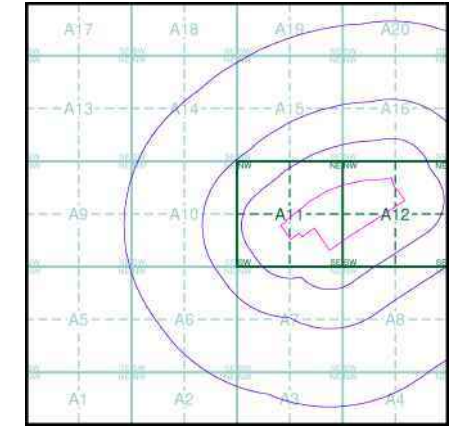
Source map scale - 1:10,560

The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840's. In 1854 the 1:2,500 scale was adopted for mapping urban areas; these maps were used to update the 1:10,560 maps. The published date given therefore is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas. In the late 1940's, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

Map Name(s) and Date(s)

09600	1848	1:10,560
10400	1848	1:10,560

Historical Map - Slice A



Order Details

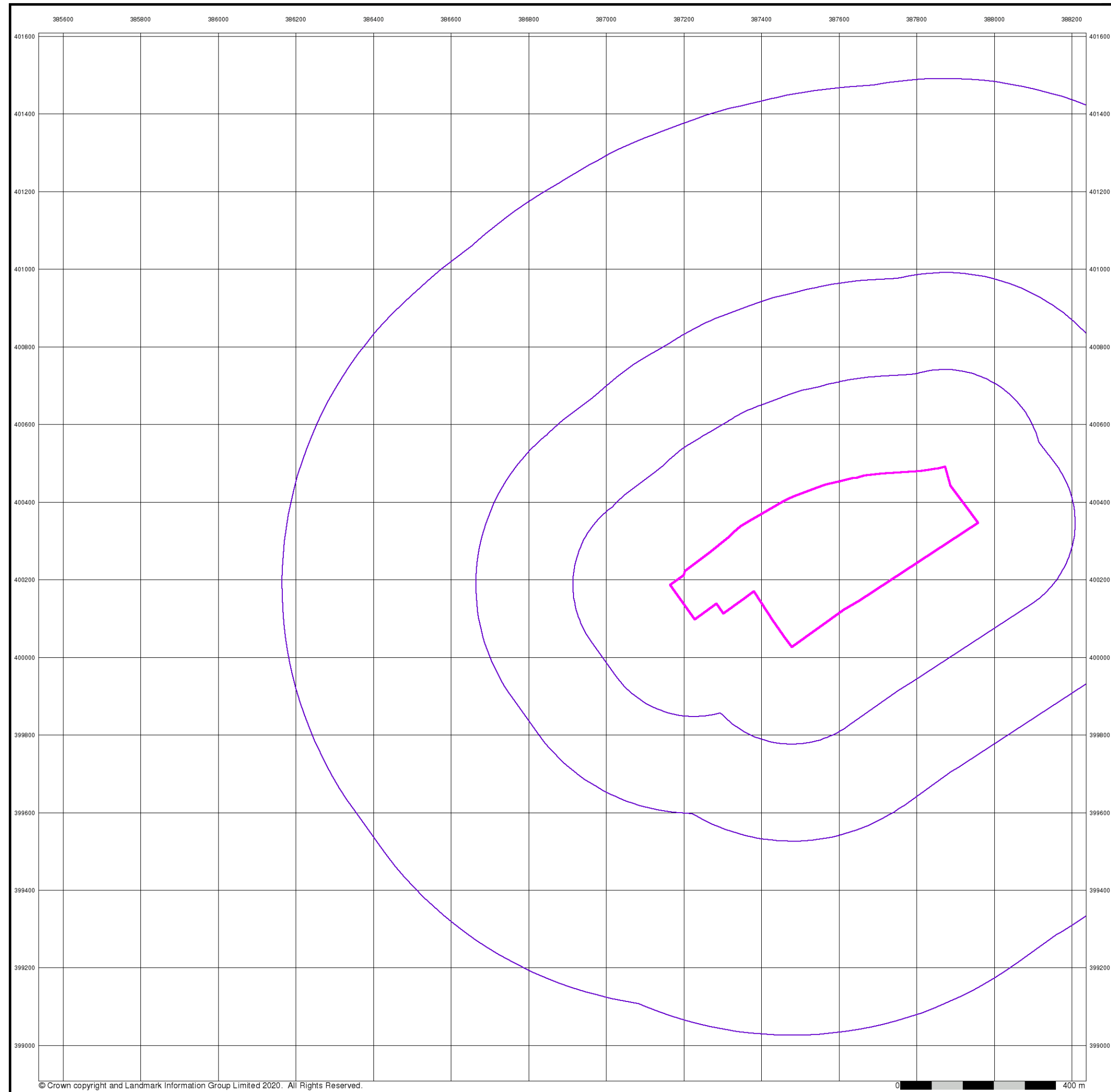
Order Number:	267713911_1_1
Customer Ref:	Ten Acres
National Grid Reference:	387320, 400240
Slice:	A
Site Area (Ha):	18.51
Search Buffer (m):	1000

Site Details

Site at 387600, 400310



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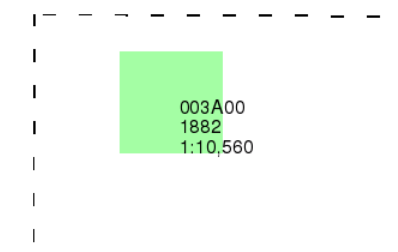
Cheshire

Published 1882

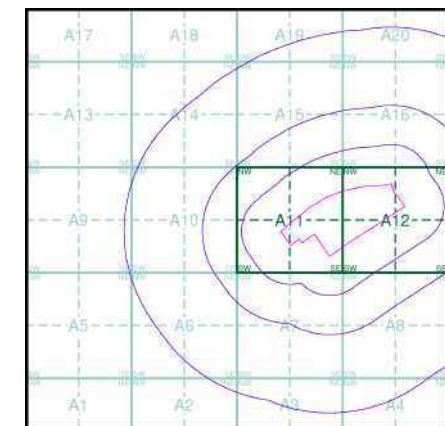
Source map scale - 1:10,560

The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840's. In 1854 the 1:2,500 scale was adopted for mapping urban areas; these maps were used to update the 1:10,560 maps. The published date given therefore is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas. In the late 1940's, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

Map Name(s) and Date(s)



Historical Map - Slice A



Order Details

Order Number: 267713911_1_1
Customer Ref: Ten Acres
National Grid Reference: 387320, 400240
Slice: A
Site Area (Ha): 18.51
Search Buffer (m): 1000

Site Details

Site at 387600, 400310



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