Next Generation Engineering Consultancy Services

Remediation Strategy Report for Proposed Biohub, Greenheys Business Centre, Pencroft Way, Manchester Science Park, M15 6JJ

Project No: NX534



Client

Next Generation Engineering Consultancy Services

DOCUMENT VERIFICATION

Report Reference: **NX534** **Issue:** Final **Date:** **18.09.2023**

Written by: Matthew Tomkinson
Senior Geoenvironmental Engineer
(For and on Behalf of NX Consulting Ltd)

Written & Approved by: Mark Newton
Director
(For and on Behalf of NX Consulting Ltd)

Revision History

Revision	Date	Description	Reviewed by	Approved by
Issue	September 2023	Final		

Issued By:

NX Consulting Limited
Station House,
Altrincham,
Cheshire,
WA14 1EP

Contact: Mark Newton
Telephone: 0161 9040187
Email: marknewton@nxconsulting.org.uk

©NX Consulting Limited

EXECUTIVE SUMMARY

NX Consulting Limited has been commissioned by Bruntwood Sci-Tech Ltd (The Client) to produce a remediation strategy on the land at Greenheys Business Centre, Manchester Science Park, Pencroft Way, Manchester M15 6JJ.

It is understood that the proposed scheme includes the construction of a 7-storey building comprising up to 17,249sq. m (GIA) commercial floorspace across 6 occupiable floors (Use Class E), plus plant level above; in addition to associated cycle parking, hard and soft landscaping, access and servicing and other associated works. The proposed site layout is presented in Appendix A.

The proposals comprise two phases, comprising:

- Phase 1: Construction compound and removal of trees (no below ground works);
- Phase 2: Greenheys Building and associated landscaping and access.

As Phase 1 will be returned to a cleared site following construction, only Phase 2 is relevant for the purpose of this assessment.

The NX Consulting carried out Phase I Desk Study and Phase II Geoenvironmental Assessment in April & May 2023.

During the site investigation works, groundwater testing within the superficial drift deposits between 1.80m and 3.0m bgl, highlighted Total Petroleum Hydrocarbons (C10 – C35) concentrations of up to 350mg/l were recorded in exploratory boreholes within WS08, 17a, 18a, 20 & 22 above UKDWS and EQS guideline values. A detailed quantitative risk assessment (DQRA) & piling risk assessment was carried out, by NX, in September 2023. Both reports should be read in conjunction with this document.

Remedial target concentrations have been developed for localised hydrocarbon contamination identified in soil and groundwater. No soil targets are exceeded by site concentrations. Groundwater targets are exceeded for TPH aromatic fractions C_{10} to C_{12} and C_{12} to C_{16}. However predicted concentrations down hydraulic gradient have not been realised and this suggests plume migration may be more restricted than modelled data initially suggests.

The development works will be conducted in two phases, with the enabling works carried out by East Coast Construction Limited, and the main contractor (Wilmott Dixon) being responsible for provision of gas protection measures, specialist barrier pipework, importation of landscaped soils and clean cover systems.

The initial enabling works will be carried out by East Coast Construction between the October 2023 and January 2024.

A piling risk assessment has been carried out to establish the most suitable choice of pile to reduce migration pathways for potential soil and groundwater contamination into the underlying aquifer. Piling method statement should consider appropriate and necessary PPE to reduce exposure to ground contamination and include a toolbox talk to ensure drilling contractors are aware of ground conditions before any works commence.

The works will be involve a 'best sustainable approach' to remediation of potential contamination; involving a minimal approach with respect to the removal and disposal of contaminated materials from site.

Minimum volumes of material will be moved around the site, limiting site workers and neighbours to dust, noise and visual intrusion. Minimum material will be taken off site thus conserving landfill space locally and minimising lorry movements onto local roads from the site.

Unsuitable materials, that cannot be reused on site, will require removal from site to suitably licensed waste management facility.

Up to 450m3 of hydrocarbon contaminated soils are anticipated to be removed as part of the enabling works. The DQRA modelling has shown that if it can be confidently confirmed that upgradient groundwater is not impacted and the source has been removed, or no longer exists;

©NX Consulting Limited

or the source is upgradient and off site, active remediation of groundwater is unlikely to be required. None the less, the contractor should allow for all requirements in relation to disposal of pumped water and free product. This should include the removal of any free product present on groundwater via skimming or other method to a point of no discernible sheen may be required; along with subsequent appropriate disposal/treatment of any unrecorded free product and water arisings. However, it must be stressed that this may change, as a results of findings of the site turnover. An engineer from NX should be in attendance during the enabling works to record the findings and take verification sampling as required.

Once the enabling works are completed, recorded and potentially unrecorded contaminants will be isolated beneath buildings and areas of hardstanding, direct contact with recorded and potentially unrecorded contamination will remain a potentially viable pathway in landscaping and P.O.S Area scenario.

Within landscaping and P.O.S. areas, the proposed remediation or mitigation will comprise the following:

- Excavation & removal from site of granular and cohesive Made Ground from areas where future site levels are to be reduced.
- Placement of clean cover soil system within of soft landscaping, public open spaces or commercial gardens; where site levels are to be raised.
- Removal and replacement with clean cover systems within soft landscaping, public open spaces or commercial gardens where site levels are to be more or less unchanged.

The depths of material to be removed or the thickness of a soil barrier shall comprise the following:

- Within areas of soft landscaping a minimum 600mm of clean cover / removal & replacement of Made Grounds should be assumed.
- Within areas of areas of public open space to be grassed; a minimum 600mm of clean cover / removal & replacement of made ground should be assumed.
- A hard to dig layer or geotextile (designed to reduce infiltration) will be required within the cover system platform. If a geotextile is adopted then drainage should be introduced within the cover system layer to prevent waterlogged conditions within landscaped and P.O.S areas.

Imported subsoil/topsoil materials will require chemical validation to demonstrate that they are suitable for a commercial end use and taken to depths sufficient to provide a sufficient cover system for all proposed materials used which are capable to support root growth. The depth of cover should also be consistent with the needs of the landscaped architects planting requirements.

For purposes of off-site disposal Waste Acceptance Criteria (WAC) testing is recommended on all made ground soils prior to discharge to a suitably licensed facility. Preliminary assessment indicates the majority of site soils are likely to be classified as Non-Hazardous. Areas of hazardous waste soils should be anticipated where hydrocarbon contamination has been recorded.

Construction workers should take appropriate health and safety measures when dealing with potential asbestos and hydrocarbon containing soils. General guidance on the protection of workers who may be exposed to asbestos containing materials is provided in the Health and Safety Executive (HSE) document "Asbestos: The Licensed Contractors Guide". Alternatively, further testing of Made Ground materials could be conducted to provide a higher degree of confidence and negate the need for measures recommended in the above document.

New services and infrastructure should be kept as shallow as possible to avoid the need for dewatering. An approach to mitigate contaminant migration into service trenches where these pass through any residual areas of organic contamination, should be included in the CEMP. All areas of residual contamination should be identified, and the location surveyed during earthworks. Where residual contamination remains, consideration should be given to lining service trenches as they pass through the hydrocarbon impacted area. The purpose of the mitigation is to limit the degree of contamination around the service to reduce risks to individuals

©NX Consulting Limited

during any future maintenance. Budget costs for this should be allowed for by the Quantity Surveyor, Contractor and client.

It is recommended that a barrier pipe, such as Protecta-Line (or similar) be adopted and/or further testing along the line of the proposed new pipework, once enabling works are completed.

NX Consulting are not responsible for the design of specialist gas protection measures and indicative measures are provided in this document only. It is recommended that the design of gas protection measures should be provided by a specialist consultant/supplier and carried out in line with BS 8485:2015+A1:2019 s.7.1 and 8.3 and a copy of the full Gas Protection Design Report should be submitted for approval to Directorate of Planning of Manchester City Council. Gas protection measures should be installed in accordance with BS8485: 2015. Based on a Type C development and CS2 classification is required. Gas protection measures should be installed as prescribed in BRE 414 with the ventilation of the sub-floor void designed to provide a minimum of one complete volume change per 24 hours. Prior to the adoption of any gas protection measures, agreement should be sought from the local authority environmental health department and building control.

No radon protection measures are necessary in the construction of new dwellings or extensions.

Residual organic vapours in made ground, drift deposits and shallow groundwater could present a risk to the integrity of standard damp proof membranes even after remediation. Hydrocarbon resistant membranes should be considered.

Depending on the findings of the enabling works, a vapour membrane may be required to mitigate risks of hydrocarbon vapours within the Made Ground and shallow groundwater/surface water ingress.

1st Line Defence Ltd has assessed that there is a Low Risk from items of German aerial delivered UXO and Allied UXO across the majority of the site, with a small area of Medium Risk within the south-west of the site.

Prior to occupation of the building, a Contamination Land Verification Report will be required by Manchester City Council to discharge outline planning conditions relating to contamination. The report should encompass all the findings of the remediation works on this site.

©NX Consulting Limited

EXECUTIVE SUMMARY **2**

1.0 INTRODUCTION **2**
1.1 Instruction 2
1.2 Previous Surveys 2
1.3 Objectives 3
1.4 Report Layout 3
1.5 Limitations 4

2.0 BACKGROUND **5**
2.1 Site Location & Setting 5

3.0 PREVIOUS INVESTIGATIONS **6**
3.1 Introduction 6
3.2 Fieldworks 10
3.3 Ground Conditions 11
3.4 Groundwater 14
3.5 Contamination Observations 14
3.6 Underground Service Plans 15
3.7 Below ground obstructions 15
3.8 Contamination 15
3.9 Asbestos 18
3.10 Ground Gas 18
3.11 Development Constraints 19

4.0 RISK ASSESSMENT AND TARGET CONCENTRATIONS **22**

5.0 REMEDIATION STRATEGY **27**
5.1 Aims 27
5.2 Summary of Remediation Stages for Enabling Works Contractor 27
5.3 Summary of Remediation Stages for Main Build Contractor 28
5.4 Site Setup, Organisation and Safety 29
5.5 Contractor's Responsibilities 30
5.6 Engineering Supervision and Verification 31
5.7 Removal of Below Ground Obstructions 31
5.8 Contamination & Verification Sampling 32
5.9 Control of Water 33
5.9 Exported to Landfill 33
5.10 Dust, Odour Control & Noise 34
5.11 Controlled Waters 34
5.12 Health and Safety during Remedial Construction 34

6.0 REQUIREMENTS FOR SUBSEQUENT SITE DEVELOPMENT **35**
6.1 Foundation Requirements and Earthworks 35
6.2 Management of Asbestos Impacted Soils 36
6.3 Placement of Soil Cover 36
6.4 Gas Protection Measures 37
6.5 Drainage and Services Installations 38

7.0 PILING RISK ASSESSMENT **39**
7.1 Piling method 39
7.2 Risk evaluation 39
APPENDICES 42
Appendix A – Drawings 43
Appendix B – NX Consulting Protocol for Validation of Soil Cover Systems 44

1.0 INTRODUCTION

1.1 Instruction

NX Consulting Limited has been commissioned by Bruntwood Sci-Tech Ltd (The Client) to produce a remediation strategy; for the proposed development on Land at Greenheys Business Centre, Pencroft Way, Manchester, M15 6JJ.

It is understood that the proposed scheme includes the development includes the construction of a 7-storey building comprising up to 17,249sq. m (GIA) commercial floorspace across 6 occupiable floors (Use Class E), plus plant level above; in addition to associated cycle parking, hard and soft landscaping, access and servicing and other associated works. The proposed site layout is presented in Appendix A.

The development works will be conducted in two phases, with the enabling works carried out by East Coast Construction Limited, and the main contractor (Wilmott Dixon) being responsible for provision of gas protection measures, specialist barrier pipework, importation of landscaped soils and clean cover systems.

The initial enabling works will be carried out by East Coast Construction between the October 2023 and January 2024.

1.2 Previous Surveys

Previous assessments conducted upon the site, which should be read in conjunction with this study; comprise the following:

- 'Pre-acquisition Phase 1 geoenvironmental survey of the MSP site', by NX Consulting, dated February 2012.
- 'Phase 1 and preliminary phase 2 geoenvironmental assessment of Ripon Street depot', by NX Consulting, dated May 2014.
- 'Phase 1 and Phase 2 geoenvironmental site investigation on land for the Bright Building (Formerly The Hub)', by NX Consulting, dated November 2014.
- 'Remediation Strategy on land for the Bright Building (Formerly The Hub)', by NX Consulting, dated February 2015.
- 'Detailed Phase 1 UXO assessment report of the New Base Building' by First Line Defence, dated May 2019.
- 'Phase 1 and preliminary phase 2 geoenvironmental assessment of New Base Building', by NX Consulting, dated May 2019.
- 'Remediation Strategy on land for the Bright Building (Formerly The Hub)', by NX Consulting, dated July 2019.
- 'Detailed Phase 1 UXO assessment report of the Greenheys Building' by First Line Defence, dated April 2023.
- 'Phase 1 and preliminary phase 2 geoenvironmental assessment of Greenheys Business Centre (Rev 3)', by NX Consulting, dated August 2023.

The Remediation Strategy Report should be read in conjunction with the reports listed above and drawings and specifications provided by the appointed structural engineers; DWllp. Particularly where details of enabling works, foundation detail,

water supply pipework and cover system in landscaped and P.O.S areas are presented.

NX Consulting Limited understand that Planning Consent has been granted for the site. However, it is anticipated that any consent contains conditions relating to the assessment of land contamination, mitigation of any risks to human health associated with such and verification that these had been adequately implemented.

Notwithstanding the above comments, previous assessment has indicated the requirement for some mitigation to protect future site users and the wider environment), and it is deemed prudent to formalise the inspections and verification works required to prepare the site for redevelopment and future use.

In addition, re-use of site generated, or materials may require development of a Materials Management Plan (MMP) for the site, and production and regulatory approval of a Remediation Strategy is a prerequisite for registering such a scheme under the Definition of Waste: Development Industry Code of Practice. East Coast Construction will be responsible for developing a CL:AIRE CoP Material Management Plan for the site enabling works.

It is anticipated that a programme of works to physically prepare the site for development will also be required and measures to address ground contamination are most efficiently implemented contemporaneously with site preparatory earthworks. Therefore, while not containing detailed specifications for works to improve ground stability, the following Remediation Strategy considers the likely requirements and their interaction with contamination remediation measures.

1.3 Objectives

The aims of the Remediation Strategy are as follows:

- To comply with the requirements of the Local Planning Authority (Manchester City Council) and their Environmental Health Department/Pollution Control Unit to ensure that future end users of the site are not put at risk from any chemical contamination arising from its former uses.
- To ensure that construction workers are not put at an unacceptable short-term risk in reclaiming/remediating and redeveloping the site.
- To satisfy any comments of the Environment Agency in ensuring that the proposed construction/reclamation/remediation works provide a degree of protection necessary to controlled waters.
- To provide a cost effective but robust reclamation/remediation scheme by utilising treating and re-using on site materials wherever possible and to minimise on and off-site movements but satisfy waste management licensing regulations. Reporting on volumes of material excavated from site and, where applicable, the methods and locations used in off-site disposal.

1.4 Report Layout

Section 2 of this report provides a background information with respect of the site such as site setting and description.

Section 3 details the intrusive investigations carried out to date with a summary of the environmental setting, ground conditions and chemical analyses.

Section 4 presents Tier 1 Guideline values to be used as assessment criteria for the site.

Section 5 presents the remedial strategy for the site and section 6 discusses the requirements for subsequent development and a piling risk assessment for the site.

1.5 Limitations

The accuracy of the data supplied by third parties should be considered in the context of any known site conditions for which NX Consulting Limited cannot be held liable.

The comments given in this report and the opinions expressed assume that the ground conditions (geology, hydrogeology, contamination) do not vary beyond the range revealed by this assessment. There may be, however, conditions within the site, which have not been identified from the information reviewed and consequently have not been considered in this report: confirmation of such uncertainties should be the focus of any future intrusive investigations.

The comments made in this report are based on the data available at the time of its completion. Any unusual or conflicting evidence discovered during any future site works must be presented to NX Consulting as soon as possible so that any implications may be considered.

This report is provided for the benefit only of the party to whom it is addressed. NX Consulting does not extend responsibility to any third party for the whole or any part of the contents. NX Consulting owes no duty of care in relation to this report to any third party. The investigation and reportage have been undertaken with all reasonable skill, care and due diligence. NX Consulting disclaims any responsibility to the client or others in respect of any matter(s) outside this agreed scope of the above works.

In addition to the above it should be noted that when investigating or developing land, sub-surface conditions might vary both spatially and over time. Whilst this investigation and subsequent interpretation has been undertaken to reasonably characterise current sub-surface conditions at the site within the scope of works and agreed budget, the absence of certain ground, contamination or groundwater conditions at the individual locations is not a guarantee that these conditions do not exist elsewhere on the site. Additional information, changes in legislation or revised practices may necessitate re-interpretation of part or all of this report.

© NX Consulting Limited

2.0 BACKGROUND

2.1 Site Location & Setting

This report is intended to support an application relating to the redevelopment of Greenheys Business Centre within Manchester Science Park. Greenheys Business Centre development is located to the north of the site adjacent to New Base Building, with associated access roads, car parking and landscaped areas.

The larger Manchester Science Park site is generally rectangular in shape, generally flat and located off Lloyd Street North, Manchester, M15 6SE (NGR: 384440E; 396280N).). A Site Location Plan, site photographs and a site layout drawing is presented as Figure 01 in Appendix A.

The desk study information collected in the phase 1 desk study, provided sufficient information to characterise the potential for ground contamination the site with a reasonable level of confidence; a number of potential sources were identified involving former garages, a factory, roads and a warehouse were present upon site. Other subordinate developments were present within the site boundary and wider surrounding area, including the demolition of former residential housing/infilling of associated basements; relic roads and infrastructure which had the potential to introduce a range of contaminants to the site, as well as heterogeneous ground conditions and associated stability for foundations.

2.2 The Proposed Development

The development includes the construction of a 7-storey building comprising up to 17,249sq. m (GIA) commercial floorspace across 6 occupiable floors (Use Class E), plus plant level above; in addition to associated cycle parking, hard and soft landscaping, access and servicing and other associated works.

3.0 PREVIOUS INVESTIGATIONS

3.1 Introduction

Previous investigations of the site have comprised both desk study and intrusive investigations as listed in Section 1 of this text. A summary of findings relevant to the proposed remediation of the site is given in the following sections.

The NX Consulting desk study carried out in April 2023 (NX534/R2) established a site history comprising a garage, residential housing, a warehouse and a depot, until it was cleared c.1990. Greenheys Business Centre is likely to have been built on the site between 1990 and 1994.

A full historical land use appraisal is presented in the NX Consulting Reports (Report No. NX534/R2 dated April 2023).

A summary of the environmental setting of the site was produced in the above referenced NX Consulting Reports and for ease of reference has been summarised overleaf.

The investigations were, in part, constrained by live services, access and vegetation. Many entries fully penetrated the Made Ground on the site, although some obstructions could not be penetrated. On this basis it is concluded that ground conditions at the site have been adequately characterised, and although there is always the possibility that localised sources could have been missed this issue would not necessarily have been resolved through additional entries or a second stage of investigation.

The number of soils and the soils analytical suite applied is considered appropriate for the site. The soil sampling and analysis was targeted to the areas where pollutant sources are more likely to be present, or key parts of migration pathways.

Issue	Data Reviewed	Summary
Geology & Mining	GroundSure report BGS Mapping	**Drift** – Glacial Till (Diamicton) on site and surrounding area. Glaciofluvial Sheet Deposits (sand and gravel) 266m north of site. **Solid** – Chester Pebble Beds Formation – Sandstone **Faults** – There are no bedrock faults or other linear features recorded within 500m of the site. **Coal Mining** – The site is indicated to be within an area, which may be affected by coal mining activities. However, the risks to the site from shallow coal mining hazards are deemed to be low due to the significant cover of sandstone bedrock directly overlying coal measures strata beneath the site.
Landfills	GroundSure Mapping	There are no Environment Agency defined licensed, registered or historic landfills sites within 250m of the site.
Hydrology	GroundSure Report	Drift - The site has been classified as a Secondary (Undifferentiated) Aquifer - Assigned where it is not possible to attribute either category A or B to a rock type. In general, these layers have previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type. Bedrock – Principal Aquifer (high intergranular and/or fracture permeability, usually providing a high level of water storage and may support water supply/river base flow on a strategic scale).
Hydrogeology	GroundSure Report	Guidance from the Environment Agency indicates that the superficial deposits are designated as a Secondary Undifferentiated Aquifer and underlying bedrock strata are designated as a Principal Aquifer. The are 6no. historic and 6no. active groundwater abstractions are recorded within 1km of the site. The site is also within a source protection zone 3 (Total Catchment). Given the underlying Principal Aquifer, the site sensitivity is regarded as low to moderate with regard to groundwater receptors. The Groundsure report indicates that no surface water features are situated within 250m of the site. A culverted watercourse is situated 5m west - Corn Brook (Hidden River in culvert https://hidden-manchester.org.uk/#/waterways/corn-brook), and no other surface water receptors are present within 250m of the site. There are 2no. active groundwater abstraction licences recorded within 500m of the site. Both are situated 490m SW off site. No historical or active surface water abstraction licences recorded within 1000m.
Flood Risk	GroundSure Report	Corn Brook is culverted to the west of Greenhey's Lane - https://hidden-manchester.org.uk/#/waterways/corn-brook

		According to GroundSure data, a portion of the western side of the site is within an Environment Agency indicative Zone 2 & Zone 3 flood plain. Zone 2 floodplain estimates the annual probability of flooding as one in one thousand (0.1%) or greater from rivers and the sea but less than 1% from rivers or 0.5% from the sea. Alternatively, where information is available they may show the highest known flood level. Zone 3 estimates the annual probability of flooding as one in one hundred (1%) or greater from rivers and a one in two hundred (0.5%) or greater from the sea. Again, as with Flood Zone 2, where information is available they may show the highest known flood level. The site does not benefit from Environment Agency defined flood defenses. A small section in the western portion of the site is at medium risk from river and coastal flooding. The remainder of the site is not reported to be at risk from river and coastal flooding. The site is at high risk from groundwater flooding. Groundwater flooding is caused by unusually high groundwater levels. It occurs when the water table rises above the ground surface or within underground structures such as basements or cellars. Groundwater flooding tends to exhibit a longer duration than surface water flooding, possibly lasting for weeks or months, and as a result it can cause significant damage to property. This risk assessment is based on a 1 in 100year return period and a 5m Digital Terrain Model (DTM). The rainfall run off from the Proposed Scheme is to be restricted to the equivalent greenfield run off rate, creating a significant betterment to the existing situation. The runoff is proposed to be attenuated within the Site before being discharged to either local water courses or Severn Trent Water sewer. SuDS features will be incorporated within the design where possible, and may include green and brown roofs. An additional 30% allowance for attenuation on Site will be implemented as a climate resilient measure. **Comments:** **DWLLP should establish whether or not a quantitative flood risk assessment is required.**
Radon	GroundSure Report	Both the Radon Atlas for England and Wales and the Groundsure report confirm that the site is in an area where less than 1% of homes are affected by radon (above the action level). Consequently, no radon protection measures are necessary in the construction of new dwellings or extensions.
Unexploded Ordnance	First Line Defence Report	The regional unexploded bomb risk map from Zetica indicates that the site is in an area at moderate risk from possible Unexploded Ordnance (UXO) resulting from the Second World War. A detailed UXO risk assessment report has been compiled by 1st Line Defence (Ref: DA17581-00) and dated May 2019, for the Greenheys Building. The majority of the site was deemed to be low risk. However, an area of cleared ground; which may be indicative of WWII bombing was recorded in the southwest. This area was deemed to be a medium risk and the following mitigation measures were recommended: The majority of the site is low risk with a small area of car park in the southwest being deemed a medium risk area. As such, the following recommendations were made:

		<u>All Works</u> 1. UXO Risk Management Plan 2. Site Specific UXO Awareness Briefings to all personnel conducting intrusive works. <u>Medium Risk Areas</u> Open Excavations (trial pits, service pits, bulk excavations, strip foundations etc.) 1 UXO Specialist On-site Support Boreholes and Piled Foundations Intrusive Magnetometer Survey of all borehole and pile locations/clusters down to maximum bomb penetration depth. Note – proactive on-site UXO support/survey should not be necessary for any works taking place at the location of and down to the depths of significantly worked post-war made ground/post-war fill. During the NX consulting preliminary intrusive works, an Unexploded Ordnance Awareness Briefing was carried out to personnel conducting intrusive works was undertaken on the first morning on site (12/04/23) with all relevant personnel in attendance. Additionally, a UXO Specialist was present on site where borehole positions were drilled within the area allocated Medium Risk. These works involved an Intrusive Magnetometer Survey of all Borehole locations down to a maximum bomb penetration depth (13/04/23).

3.2 Fieldworks

The preliminary phase of fieldworks were undertaken between 12th April 2023 and 19th April 2023. Due to limitations with accessing areas in the north of site, not all works were able to be completed meaning a second phase of supplementary works were carried out.

The second phase of supplementary works were carried out on 19th & 22nd July 2023. These works were also designed to delineate the extent of hydrocarbon contamination recorded within soil and groundwater during the preliminary works.

All arisings from the preliminary and supplementary site investigation were screened on-site for the presence of volatile organic compounds (VOC) using a MiniRae Photoionisation Detector (PID).

A plan showing all the exploratory hole locations are presented in Appendix A.

Underground services were surveyed, and hand dug trial pits formed to a depth of 1.20metres below ground level (m bgl) prior to the intrusive investigation; in line with NX Consulting health and safety methodology.

During the site investigation a total of 6no. Machine Excavated Trial Pits were formed to maximum depths of 2.80mbgl.

The exploratory hole retrieved continuous soil samples; these were then logged by an onsite engineer and representative samples were taken for geotechnical and chemical analysis.

During the site investigation 3no. Rotary Cored borehole was formed to a maximum depth of 20.00mbgl.

The exploratory hole retrieved continuous rock samples; these were then logged by an onsite engineer and representative samples were taken for geotechnical analysis.

24no. window sample boreholes were advanced across the site to depths of between 0.45mbgl. and 5.00mbgl. Representative samples were taken for geotechnical and chemical analysis. 17no. windowless sampler boreholes were drilled within both internal and external areas of the site, and 7no. handheld window sampler boreholes were undertaken within internal areas of the site. WS05, WS05a, WS12 & WS13 were all redrilled due to obstructions encountered within the hand pit excavations.

Environmental sample collection was carried out in accordance with BS EN ISO 22475-1:2006. All soil and groundwater samples were collected using either clean stainless-steel utensils or clean disposable gloves and placed directly into clean containers provided by the laboratory. Samples obtained during the investigation were subjected to a range of geochemical testing at appropriate UKAS accredited laboratories.

Testing was carried out in accordance with the procedures outlined in BS EN ISO14688-1:2002, 14688-2:2004, and 14689-1:2003.

Soil samples were tested for speciated PAH, asbestos screen, arsenic, boron (water soluble), cadmium, copper, chromium, lead, mercury, nickel, selenium, silver, zinc, total cyanide, free cyanide, phenols, pH, asbestos, total sulphur, sulphide, total sulphur, total organic carbon and nitrate analysis.

3.3 Ground Conditions

General

The following ground conditions summary has been utilised from information provided within the NX Consulting report. To obtain a more comprehensive picture of the ground conditions within the wider site, reference should be made to the NX Consulting Reports (ref: NX534/R3).

Made Ground was encountered in all the exploratory holes undertaken across the site to depths of between ground level and 1.50mbgl (WS01); with the deepest Made Ground recorded in the southeastern corner. The area with the shallowest confirmed depth of Made Ground was within WS09 in the southwestern corner; at a recorded depth of 0.25mbgl. Made Ground final depth was proven Made Ground was observed to directly bear onto drift deposits.

NX attempted to classify the Made Ground, (with a few exceptions) broadly into 6 distinct soil types;

- Tarmacadam or concrete hardstanding.
- Uncompact brown gravelly sand/sandy gravel (subgrade type material)
- Uncompact dark brown/grey/black fine to coarse slightly ashy slightly silty clayey sand/gravelly sand.
- Compact grey ashy sandy gravel of limestone (subbase type material)
- Soft to firm black/grey/brown ashy slightly silty very sandy very gravelly clay
- Soft to firm brown slightly ashy reworked clay with rare gravel.

Made Ground – Surface Cover

A surface cover of tarmacadam was present within external car parking areas. The internal areas (the floor slab within the Greenheys Building) were observed to comprise of a screed over a weakly bound angular gravel within a cement/concrete bound matrix. Intact concrete being recorded in parts.

An area of car parking and former factory within the McDougall Centre was investigated during the supplementary site investigation. The eastern half comprised an inactive external car parking area where a surface cover of tarmacadam was present. The western half and area of the former factory was surrounded by hoarding. This hoarding was removed to allow access to WS08, WS09 and TP05.

Ground conditions within the former factory area comprised a relatively flat lying concrete slab (possible former concrete slab) within the west with residential properties beyond. The ground conditions within the east comprised demolition arising material with full intact bricks and cobbles of brick and concrete present upon the surface. All ground within the hoarding was heavily overgrown with weeds (reaching up to 3m in height) with some semi mature trees present too. Access was difficult and had to be cleared using drilling equipment to enable the works to commence.

Made Ground – Internal Area

Recorded Made Ground within the Greenheys Building typically comprised an initial layer of screed (occasionally covered by laminate floor covering) over a weakly bound angular gravel within a cement/concrete bound matrix (acting slab). This was found to a maximum depth of 0.58mbgl within WS20 and likely to consist of an insitu relic footing. A metal girder was also found within this material between 0.1mbgl and 0.25mbgl.

The concrete encountered within WS12 & WS12A (eastern areas of the Greenheys Business Centre building) was found to be reinforced with 1cm diameter metal rebar present at depths of 0.05mbgl.

Made Ground recorded below the concrete floor slab typically comprised a 150mm to 250mm layer of sub-base type gravel consisting of compact fine to coarse ashy sandy gravel of brick, sandstone, cement, concrete, ash, limestone and other mixed lithology.

Uncompact black/grey/red/brown ashy slightly clayey gravelly cobbly sand with gravel of brick, sandstone, ash, slate, limestone and other mixed lithology was recorded beneath the sub base materials. These soils frequently consisted of full intact bricks, cobble setts and intact relic cellar/brick footings which slowed progression. Below this material and at the base of the Made Ground (overlying natural strata), soft to firm black/dark brown slightly ashy slightly sandy (reworked) clay was recorded. Reworded clay was found in all internal boreholes where Made Ground was recorded (WS14, WS15, WS16, WS17 & WS18).

WS12 and WS13 were not drilled to their intended depths due to solid obstructions encountered within the base of the hand pits. Both boreholes were relocated nearby and renamed WS12A and WS13A. These boreholes were also terminated due to obstructions preventing progress. All 4no. of these exploratory holes are situated within the southeastern corner of the building. Ground conditions within these positions generally comprised compact dark brown fine to coarse ashy silty sandy cobbly gravel of brick, sandstone, concrete, ash, clinker, limestone and other mixed lithology. Compact light grey gravel of brick, concrete and other mixed lithology was also noted within WS13.

Relic in situ brick walls were noted within hand pits within WS12 and WS12A, relic in situ brick walls were present in west and eastern faces of hand pit, (orientated N-S). Within WS13A a relic in situ brick wall was recovered as a core (between gl to 0.50mbgl).

Made Ground – External Areas

Within external areas, Made Ground typically comprised an initial layer of tarmacadam underlain by compact ashy gravelly sand/sandy fine to coarse angular gravel (subbase material) between 0.15m and 0.65m in thickness. This was found to be present to a maximum depth of 0.65mbgl in WS04. The subbase encountered within TP02 comprised a similar material with generally coarser gravel. The depth of the cobbley subbase was present was proven between 0.1m bgl to 1.15m bgl. The trial pit was terminated shortly after at 1.20m bgl due to poor stability and partial collapse.

Underlying the subbase, Made Ground consisted of a combination of soft to firm brown slightly ashy reworked clay with rare gravel of brick, ash, cement, slate, timber, clinker, concrete and/or generally loose brown slightly ashy slightly clayey sandy gravel of

brick, ash, cement, slate, timber, clinker, concrete /gravelly sand. This type of Made Ground was proven to a maximum depth of 1.50m bgl (WS01).

These soils were found across all external boreholes (with the exception of RBH01 and WS09); where Made Ground was only recorded to 0.35mbgl and 0.25mbgl, respectively.

Relic intact brick cobbles and likely boulders were noted within WS04 hand pit which slowed progression 0.65m & 1.1mbgl. WS05/WS5A hand pit was excavated to 0.45m bgl where a solid concrete obstruction recorded and prevented continuation of the borehole.

Superficial Deposits

Superficial deposits was encountered within the majority of exploratory holes between depths of 0.25m-11.00m bgl, with the exception of WS05, WS05A, WS12, WS12A, WS13 and WS13A where the Made Ground was not able to be fully penetrated.

Superficial deposits were encountered across the site generally, comprising an initial layer of loose to medium dense light brown, fine to coarse SAND with rare gravel to recorded depths of 1.50-2.60mbgl. Within window sampler boreholes, the sand was generally noted to become darker in colour and gravel content increased with depth. Machine excavated trial pits within the supplementary works noted similar features to the preliminary phase observations, but also indicates a separate lithology of SAND AND GRAVEL was present beneath the sand.

Beneath the sand (where penetrated) in all exploratory holes, firm to firm to stiff dark brown (rarely sandy) CLAY with rare fine to coarse sub angular to rounded gravel of mixed lithology was recorded. The clay appears to become stiff between 3.00mbgl to 4.00mbgl. Clay was present to the end of the drilling within the WS boreholes (5.00m bgl+) and was proven to a maximum depth of 7.0mbgl in RBH03.

Probable Glaciofluvial drift deposits comprising dense red/brown SAND AND GRAVEL (drillers description) was found beneath clay within all rotary boreholes, between 6.0mbgl and 11.0mbgl. Gravel content within this strata typically comprised angular to subrounded mudstone, sandstone and other mixed lithology. At 10.50mbgl to 11.00mbgl within RBH01 (just prior to bedrock) the sand was noted to become reddish brown in colour. This strata was only encountered within the preliminary phase of works.

Cable tool percussion boreholes formed upon the adjacent New Base site recorded Glaciofluvial drift deposits comprising medium dense to dense clayey gravelly sand / sandy sub rounded to rounded gravel (with occasional cobbles) were encountered to maximum depths of 9.80m bgl.

Uncorrected SPT 'N' values within the drift deposits ranged from 4-50, with an average 'N' value of 19.12 and generally increased with depth. The standard deviation for the data is 11.95.

Solid Geology

Solid geology was encountered within all of the rotary core boreholes at depths between 11.00-20.00mbgl. and noted to comprise poorly cemented weak to medium strong reddish brown fine to coarse grained SANDSTONE with rare mineral inclusions and intraclasts. Subhorizontal bedding fractures, thinly spaced, planar, smooth to slightly rough were also noted upon recovered core runs. Recovery from shallower depths was often poor due to the rock being poorly cemented. This generally improved

as drilling progressed. The colour of the sandstone was also noted to become reddish brown banded grey at 18.00mbgl in RBH01.

3.4 Groundwater

The following groundwater observations were monitored within boreholes during drilling at the following depths. Saturated sand and gravel depths are also provided:

Table 3.4.1 – – summary of groundwater level and dip data

Borehole ID	Depth to water (mbgl)	Depth to water (mAOD)	Depth to base of well (mbgl)
WS04	1.51	32.65	1.98
WS05B	1.80	30.57	4.56
WS08	1.50	31.79	2.55
WS09	1.75	31.88	2.51
WS10	1.81	29.56	4.65
WS11	1.94	31.38	3.11
WS14	1.97	32.37	2.07
WS16	1.98	32.81	2.08
WS17A	1.96	31.64	3.11
WS18A	2.11	31.72	2.99
WS19	2.00	32.32	2.49
WS20	2.13	30.98	3.65
WS22	2.01	32.34	2.43
RBH01	1.61	30.46	4.06
RBH02	1.60	29.91	4.67

3.5 Contamination Observations

Hydrocarbon odours were recorded within the north and northwestern areas of the site within WS08, WS10, WS17, WS17a, WS18, WS18a, WS20 & TP05. The odours were generally observed between 1.9m bgl and 2.5m bgl, besides WS10 where a faint hydrocarbon odour observed within lower depth of Made Ground (0.25mbgl to 0.65mbgl). No visual evidence of contamination was observed within WS10. Visual evidence of contamination was observed within WS08, WS17a, WS18a & WS20, where a sheen was observed on surface of liquid during water sample extraction. In addition to this, the strata generally appeared dark grey in colour at depths where hydrocarbon contamination was observed; however, this did not always represent hydrocarbon contamination was present as similar observations other boreholes where such contamination was not present (WS14 at 1.50m bgl)

Subsequent testing indicated that the soils are not significantly impacted by hydrocarbon contamination within respective areas.

During the preliminary works, the groundwater testing highlighted Total Petroleum Hydrocarbons (C10 – C35) values slightly exceeding the respective EQS screening values within WS05B. However, supplementary works were carried out and analysis was consistent with on-site observations whereby, groundwater concentrations of up to 350mg/l were recorded in exploratory boreholes within WS08, 17a, 18a, 20 & 22 above UKDWS and EQS guideline values.

All arisings from the preliminary and supplementary site investigation were screened on-site for the presence of volatile organic compounds (VOC) using a MiniRae Photoionisation Detector (PID). When tested against strata where olfactory and visual

Hydrocarbon contamination was observed, elevated concentrations were noted within during the supplementary works (within WS08, WS17a, WS18a, WS20 & TP05).

Site investigation/fieldwork observations, PID sampling and chemical analysis of soil samples indicated that the hydrocarbon contamination is present within a localised corner of the northwest of site.

3.6 Underground Service Plans

Underground services, comprising BT Lines, gas mains, CCTV, and possible fibre optic cables may all impact the site and the design team and Client should familiarise themselves with their presence. Surface drainage is also present elsewhere.

3.7 Below ground obstructions

Several exploratory probeholes noted the presence of concrete and brick cobbles and boulder obstructions within Made Ground. Namely: WS05, WS05A, WS12, WS12A, WS13 & WS13A. Historical mapping indicates that demolition rubble associated with relic housing, slabs/cellars and slabs are likely to be present upon site within the upper 3.0m bgl.

Obstructions were recorded at the following depths:

- WS05 – 0.45m bgl.
- WS05a – 0.75m bgl, with a relic insitu plastic pipe at 0.60m bgl.
- WS12 - 0.70m bgl.
- WS12a - 0.70m bgl.
- WS13 - 0.60m bgl.
- WS13a - 0.50m bgl.

Hard digging/slow excavation was noted within the Made Ground within the internal exploratory WS boreholes. Where cobbles and boulders were noted within shall Made Ground, possibly relating to former roads.

A portion of the site (University of Manchester area to the north of site, surrounded by hoarding) comprised demolition arising material with full intact bricks and cobbles of brick and concrete present upon the surface. Obstructions were not encountered within the area but should be anticipated considering its historical use as a factory.

3.8 Contamination

The chemical analysis results were compared against the Tier 1 criteria for a *commercial* end use to reflect the development proposals.

The chemistry analysis results, presented in Appendix F, were been compared against the Tier 1 criteria for a *commercial industrial with landscaping* end use to reflect the development proposals.

For risk assessment purposes a soil organic matter value of 1.0% was used.

Made Ground & Natural Soils

The chemical analysis of soil samples showed that there were no Tier 1 exceedances for the soils analysed to date, beneath the existing building and the proposed development, for both natural soils and Made Ground soils.

No asbestos (<0.001%) was detected within the chemical analysis of soil samples.

Risks to Controlled Water Receptors

Site Investigation Summary

Leachate and groundwater testing analysis indicated inorganic contaminants to be largely absent beneath the site. The testing highlighted above has recorded a number of inorganic contaminants within the leachate samples in both Made Ground and drift deposits; at concentrations exceeding the respective EQS screening values recorded in WS01, WS10 & WS14. UKDWS screening values were not exceeded within the tested samples. The exceedances within copper, chromium and lead highlighted above are considered to be marginal due to the limited concentrations of heavy metals recorded within the soils across the site.

The NX site investigation works encountered ground conditions comprising Made Ground predominantly cohesive clay deposits which will restrict vertical and lateral percolation of recorded low levels of copper, chromium, lead. Given the low mobility of these contaminants, the potential for the contaminants to represent suspended solids and development proposals comprising predominantly hardstanding impermeable surfaces reducing infiltration the risks to controlled water receptors post construction is deemed to be low.

As such, risks to Corn Brook and the Principal Aquifer post construction were deemed to be low from inorganic contamination.

During the preliminary works, the groundwater testing highlighted Total Petroleum Hydrocarbons (C10 – C35) values slightly exceeding the respective EQS screening values within WS05B. However, supplementary works were carried out and analysis was consistent with on-site observations whereby, groundwater concentrations of up to 350mg/l were recorded in exploratory boreholes within WS08, 17a, 18a, 20 & 22 above UKDWS and EQS guideline values.

DQRA

To ensure a low risk to controlled waters and human health receptors, it was recommended that a P20 type Detail Quantitative Risk assessment/Remedial Target Methodology and suitable remediation strategy be developed for the site. A piling risk assessment was also recommended to establish the most suitable pile type for the ground conditions encountered.

In September 2023, Remedial target concentrations were developed for localised hydrocarbon contamination identified in soil and groundwater. No soil targets were exceeded by site concentrations. Groundwater targets were exceeded for TPH aromatic fractions C10 to C12 and C12 to C16. However predicted concentrations down hydraulic gradient were not realised which suggests that plume migration may be more restricted than modelled data initially suggests.

It was recommended that an assessment of the likely source area should be undertaken during the enabling works, when the made ground 'turn over' was carried out and removal/treatment of the source material and localised impacted soils. Active groundwater remediation was not recommended. However, some localised dewatering in areas of high impact or where services intersect the shallow groundwater was deemed likely to be required.

Consideration was given to the potential for residual organic vapours in made ground, drift deposits and shallow groundwater which could present a risk to the integrity of standard damp proof membranes; even after remediation. It was recommended that hydrocarbon resistant membranes should be considered.

The piling risk assessment considered the adoption of CFA piles which generally result in good seals in low permeable layers where the clay thickness is equal to or greater than two pile diameters. Exploratory logs indicated that a minimum thickness of Glacial Till of approximately 3.5m and sufficient clay is likely to be present to ensure a seal and prevent seepage along the pile.

Further action within the DQRA Report included the following:

1) develop a construction environment management plan
2) develop a piling method statement
3) develop a remediation strategy
4) develop a material management plan

Outlying Remediation Appraisal

Once the enabling works were completed, contaminants were deemed to be isolated beneath buildings and areas of hardstanding, direct contact with asbestos fibres and heavy metals remain a potentially viable pathway in landscaping and P.O.S Area scenario. To address risks to site occupiers and maintenance staff from potential unrecorded contamination, the following remediation or mitigation should was also recommended:

- Excavation & removal from site of granular and cohesive made ground with heavy metals asbestos fibres from areas where future site levels are to be reduced.
- Placement of clean cover soil system within of soft landscaping, public open spaces or commercial gardens; where site levels are to be raised.
- Removal and replacement with clean cover systems within soft landscaping, public open spaces or commercial gardens where site levels are to be more or less unchanged.

The depths of material to be removed or the thickness of a soil barrier should comprise the following:

- Within areas of soft landscaping a minimum 600mm of clean cover / removal & replacement l of made grounds should be assumed.
- Within areas of areas of public open space to be grassed; a minimum 600mm of clean cover / removal & replacement of made ground should be assumed.
- A hard to dig layer or geotextile (designed to reduce infiltration) will be required within the cover system platform. If a geotextile is adopted then drainage should be introduced within the cover system layer to prevent waterlogged conditions within landscaped and P.O.S areas.

The risks presented to controlled water receptors are deemed to be low post construction due to the concentrations of solid analysis and significant cover of likely low permeability clay deposits underlying the site, over the Principal Aquifer.

<u>Potable Water Supply</u>

It is envisaged that new drainage and utility supplies will be at relatively shallow depth within the top 1200mm of the Made Ground deposits. It is considered likely that specialist supply pipe is required at the site. A UKWIR potable water supply risk assessment is required to establish the nature of water supply pipework for the proposed development. Preliminary information suggests special measures will be required in light of the presence of elevated hydrocarbon concentrations.

It was recommended that statutory services are consulted at an early stage, with respect to the ground conditions within which they will lay services, in order to enable them to assess at an early state any protection measures required.

Further testing was recommended along the line of proposed new pipework upon completion of the enabling works; to inform whether specialist protection measures are required.

3.9 Asbestos

None of the 15no tested samples of Made Ground have recorded asbestos, with preliminary quantification determining concentrations of 'Not Detected <0.001%' total mass.

Although unlikely, it should be noted that there may of course be areas of undetected contamination between our sampling points.

All Asbestos Containing Material (ACM) identified during the site enabling works must be dealt with in strict accordance with the Control of Asbestos Regulations (CAR) 2012, UK Waste Management Legislation and the Environmental Protection Act 1994.

As a contingency measure and to protect construction workers and future end users from any unrecorded asbestos contamination, it was recommended that the following protective measures be adopted during the proposed ground preparatory works:

- All site personnel should be provided with PPE when excavations and demolition works are taking place.
- A water bowser or other dust suppression equipment shall be provided in order to dampen exposed surfaces; during the movement of plant and removal of arisings.
- Provision of personal monitors for site staff to measure individual exposure to asbestos fibres.

Should off-site disposal be required, then additional asbestos quantification and waste classification testing should be undertaken to ensure that it is classified correctly and disposed at a suitably licenced facility.

All ACM impacted soils must be managed so as to ensure no airborne fibre release during construction or placement of impacted material in such a manner to ensure no future exposure risk.

3.10 Ground Gas

The preliminary risk assessment identified the risk from hazardous ground gas as moderate risk and low to moderate source generating potential in line with CIRIA 665, due to the potential for Made Ground and former developments on and within the surrounding area of the site.

6No.rounds of monitoring were undertaken with a barometric pressure of between 1006mb to 1025mb.

A summary of the soil gas monitoring results is presented in Table 3.1.1 below.

Table 3.1.1 – Summary of Gas Monitoring Results (NXC)					
NX Consulting Borehole Reference	**Max CO2 (%v/v)**	**Max Flow (l/hr)**	**Max GSV (l/hr)**	**Max CH4 (%v/v)**	**Max GSV (l/hr)**
External Boreholes					
RBH01	6.4	0.0	<0.01	0.0	<0.01
RBH02	4.7	0.0	<0.01	0.0	<0.01
WS04	0.4	0.0	<0.01	0.0	<0.01
WS05B	1.4	0.0	<0.01	0.0	<0.01
WS10	2.8	0.0	<0.01	0.1	<0.01
WS11	0.1	0.0	<0.01	0.0	<0.01
Internal Boreholes					
WS14	2.5	0.0	<0.01	0.1	<0.01
WS16	1.6	0.0	<0.01	0.1	<0.01
WS17	0.5	0.0	<0.01	0.0	<0.01

It was recommended that CIRIA 665 CS2 gas protection measures should be installed. In accordance with BS8485: 2015. Based on a Type C development and CS2 classification a gas protection score of 2.5 would need to be achieved. Independent validation of gas protection measures was recommended to achieve the required points score.

Gas protection measures should also be installed as prescribed in BRE 414 with the ventilation of the sub-floor void designed to provide a minimum of one complete volume change per 24 hours.

Prior to the adoption of any gas protection measures, agreement should be sought from the local authority environmental health department and building control.

3.11 Development Constraints

The potential risks which may exist on the site should be readily managed through implementation of an inspection regime to reduce uncertainty in the site conceptual model, good materials management and some basic mitigation measures to break the potential exposure pathways identified.

Ground Conditions & Earthworks

A significant amount of work will also be required to physically prepare the site for development and achieve the required stable development platform needed for the proposed buildings, car parking, access roads and supporting infrastructure. As this involves significant levels of site disturbance and importation of materials and soils for cover systems, the potential for introduction of new sources or creation of new pathways must be addressed.

The majority of the site is underlain by Made Ground comprising broken concrete, brick, cobble sets, tarmacadam,, sand, gravel and clay typically varying from loose to dense

in relative density or soft to firm in consistency, extending to between 0.15m and 1.5m depth (and probably to 3.0m depth locally). Numerous obstructions and/or oversized materials are present as surface deposits and within the made ground. Where construction of roads and other infrastructure or where level surfaces are required for parking areas, some ground improvement is likely to be required to achieve long-term stability.

Soft clayey sand/sand and gravel should be anticipated at shallow depth and groundwater is present in the upper 1.5m to 3.0m of strata. During site upfilling and replacement, consideration should be given for pre-earthworks drainage that allows for temporary fill surfaces to be sealed and shaped to shed water and operational restrictions during periods of rainfall.

The requirements for geotextiles to be used to separate earthworks materials should be assessed by a suitably qualified specialist contractor/manufacturer. The required design life should be no less than 120 years.

Details of laying and lapping shall be in accordance with the specialist contractors recommendations.

Excavations into the Made Ground, sand and Glacial Till should be viable using conventional hydraulic excavating plant. Where relict concrete, cobbles and boulders are present within the upper 1.50m+, breaking equipment may be needed to achieve the design depth required.

The stability of foundation excavations are likely to be variable and collapse and spalling of the granular strata (particularly where groundwater is present) and Made Ground materials should be anticipated. All excavations should be conducted in line with CIRIA Report 97 – Trenching Practice and BRE 440 Foundations, Basements and External Works 2002.

Trenchboxes or similar will be required to support drainage and deep excavations locally. Temporary support and dewatering will be required to maintain stability of excavations to remove contaminated soil.

Any replaced 'site won' or imported materials will again need to be compacted in a controlled manner in line with the Department of Transport, Specification for Highway Works Specification 600 & 800 series, subject to additional confirmatory earthworks testing.

Where possible all soils should be retained on site to reduce disposal costs.

It is possible that when the site turnover and services formation is carried out, groundwater ingress will occur into excavations, resulting in blowing sand conditions and a resulting volume loss to surrounding soils. Prior to demolition it would be prudent to survey in the positions of existing walls and any basement walls where close to existing site boundaries and/or infrastructure/underground services either left in-situ and/or utilize temporary support, should such conditions be encountered.

During site upfilling, consideration should be given for pre-earthworks drainage that allows for temporary fill surfaces to be sealed and shaped to shed water and operational restrictions during periods of rainfall.

Regulatory Approval

Potential delays in achieving approval with the regulatory authorities has the potential to result in programme impacts. Pre-commencement conditions relating to contamination and provision of a piling risk assessment have been placed upon the development.

The calculated critical concentration (remedial target) for groundwater assumes a continuous discharge from a point source. Due to time and project constraints, it was not possible to undertake further ground investigation to reduce this uncertainty before the demolition of the building and grubbing up of hardstanding is completed.

Groundwater samples taken for WS10, the monitoring well at the point the plume is predicted to leave the site, indicated all hydrocarbon contamination were below the laboratory limit of detection (<0.0001mg/l). The model predicted a concentration of 1.04mg/l after 100 days. Migration in the secondary A aquifer is clearly more restricted than indicated by modelled data. If it can be confidently confirmed that upgradient groundwater is not impacted and the source has been removed, or no longer exists; or the source is upgradient and off site, active remediation of groundwater is unlikely to be required.

Piling method statement should consider appropriate and necessary PPE to reduce exposure to ground contamination and include a toolbox talk to ensure drilling contractors are aware of ground conditions before any works commence.

Residual organic vapours in made ground, drift deposits and shallow groundwater could present a risk to the integrity of standard damp proof membranes even after remediation. Hydrocarbon resistant membranes should be considered.

A possible hydrocarbon vapour resistant membrane may be required dependent on the finding of the remediation enabling works and primary source removal of contaminated soils.

Compliance with the requirements of the regulators i.e. Manchester City Council, the Environment Agency, service providers (e.g drainage, water, gas and electricity, fibre optics) should be sought at the earliest opportunity and any potential delays built into the programme.

A final verification report will be required to discharge outlying planning conditions once the building is complete.

4.0 RISK ASSESSMENT AND TARGET CONCENTRATIONS

Human Health

Quantitative risk assessments have not been established to date to derive site specific clean up criteria for contamination. This is because the results recorded to date for soils have been recorded generally below Environment Agency Soil Guideline Values (SGVs), Generic Assessment criteria and C4SIs. NX Consulting propose continued use of SGVs and GACs for a commercial end use throughout the remediation works. If deemed necessary as a result of the finding of the any unexpectedly elevated concentrations of hydrocarbon contamination, site-specific clean up criteria will be reassessed via human health QRA.

With regards to site specific clean up criteria for hydrocarbon contaminated Made Ground where encountered, remediation proposals include removal of the source area/potential fuel tank/sump and provision of a capping system and CS2 gas protection measures, thus breaking the source-pathway-receptor linkage. Hydrocarbon resistant membrane will be adopted. If after the resultant findings of further intrusive works around the source area a vapour resistant membrane is required

The NX Consulting conceptual model should be continually re-assessed, throughout the construction works. As such, Tier 1 commercial values have been utilised at this time. The following table provides Tier 1 values for a range of potential contaminants for the site; for a commercial end use.

Controlled Waters

Remedial target concentrations have been developed for localised hydrocarbon contamination identified in soil and groundwater. No soil targets are exceeded by site concentrations. Groundwater targets are exceeded for TPH aromatic fractions C10 to C12 and C12 to C16.

The initial approach to numerically modelling the scenario was to develop the conceptual site model in ConSim. ConSim allows the physical properties of a confining layer and an unsaturated zone to be included in the site assessment. This tool makes ConSim a powerful numerical model for complicated geological sequencing, where retardation in the unsaturated zone is a critical consideration. However, during development of the model input parameters, the degree of uncertainty in the ground conditions offsite meant a high level of conservatism had to be assumed and generic reference values adopted for aquifer properties.

Since dissolved phase hydrocarbon contamination has already been detected in the Secondary A aquifer, the approach set out in the Environment Agency's R&D document – Hydrogeological Risk Assessment for Land Contamination has been adopted. This methodology is consistent with current UK legislation and guidance for assessing impacts on controlled waters.

A detailed quantitative risk assessment has been undertaken, adopting the Environment Agency methodology to hydrogeological risk assessment.

The table below summarises the output from the hydrological assessment, based on the soil and groundwater concentrations observed and assuming a compliance distance of 50m (source area to the site boundary).

Table 4.1– Groundwater Remedial Targets

Determinant	Max soil concentration	Remedial target	Max water concentration	Remedial target
	(mg/kg)		(mg/L)	
TPH Aromatic C10 – C12	31	566	4.5	0.42
TPH Aromatic C12- C16	440	1123	49	0.42
Naphthalene	1.7	750	0.01	0.66
Toluene	<0.01	550	0.003	3.2
Xylenes	0.2	900	0.12	3.25

	Residential with Homegrown Produce.	Residential without Homegrown Produce.	Commercial Industrial with Landscaping
Active Pathways	• Direct Ingestion • Dermal Contact • Consumption of Vegetables and Attached Soil • Inhalation of Indoor Vapour and Dust • Inhalation of Outdoor Vapours and Dust	• Direct Ingestion • Dermal Contact • Inhalation of Indoor Vapour and Dust • Inhalation of Outdoor Vapours and Dust	• Direct Ingestion • Dermal Contact • Inhalation of Indoor Vapour and Dust • Inhalation of Outdoor Vapours and Dust
Critical Receptors	Female Child 0-6yrs Old	Female Child 0-6yrs Old	Female Adult Worker >17 years old.

Determinand/Units	mg/kg	Source	mg/kg	Source	mg/kg	Source
Arsenic	37	LQM / CIEH S4ULs	40	LQM / CIEH S4ULs	640	LQM / CIEH S4ULs
Cadmium	11	LQM / CIEH S4ULs	85	LQM / CIEH S4ULs	190	LQM / CIEH S4ULs
Mercury (inorganic)	40	LQM / CIEH S4ULs	56	LQM / CIEH S4ULs	1,100	LQM / CIEH S4ULs
Nickel	180	LQM / CIEH S4ULs	180	LQM / CIEH S4ULs	980	LQM / CIEH S4ULs
Selenium	250	LQM / CIEH S4ULs	430	LQM / CIEH S4ULs	1,200	LQM / CIEH S4ULs
Chromium III	910	LQM / CIEH S4ULs	910	LQM / CIEH S4ULs	8,600	LQM / CIEH S4ULs
Chromium VI	6	LQM / CIEH S4ULs	6	LQM / CIEH S4ULs	33	LQM / CIEH S4ULs
Lead	450	C4SLs	450	C4SLs	750	C4SLs
Copper	2,400	LQM / CIEH S4ULs	7,100	LQM / CIEH S4ULs	68,000	LQM / CIEH S4ULs
Zinc	3,700	LQM / CIEH S4ULs	40,000	LQM / CIEH S4ULs	730,000	LQM / CIEH S4ULs
Boron	290	LQM / CIEH S4ULs	1100	LQM / CIEH S4ULs	240,000	LQM / CIEH S4ULs

Consulting Tier 1 Values Version 1 - CLEA 2009 (Software Version 1.06)

LQM /CIEH S4ULs Copyright Land Quality Management Limited. Reproduced with permission Publication No. S4UL3671. All right reserved.

Standard Land Use Scenario	Residential with Homegrown Produce			Residential without Homegrown Produce			Commercial			Source
Determinand/SOM	1% SOM	2.5% SOM	6% SOM	1% SOM	2.5% SOM	6% SOM	1% SOM	2.5% SOM	6% SOM	
Naphthalene	*2.3*	*5.6*	*13*	*2.3*	*5.6*	*13*	*190*	*460*	*1100*	LQM / CIEH S4ULs
Acenaphthylene	170	420	920	2900	4600	6000	83000	97000	10000	LQM / CIEH S4ULs
Acenaphthene	210	510	1100	3000	4700	6000	84000	97000	10000	LQM / CIEH S4ULs
Fluorene	170	400	860	2800	3800	4500	63000	68000	71000	LQM / CIEH S4ULs
Phenanthrene	95	220	440	1300	1500	1500	22000	22000	23000	LQM / CIEH S4ULs
Anthracene	2400	5400	1100	31000	35000	37000	520000	540000	540000	LQM / CIEH S4ULs
Fluoranthene	280	560	890	1500	1600	1600	23000	23000	23000	LQM / CIEH S4ULs
Pyrene	620	1200	2000	3700	3800	3800	54000	54000	54000	LQM / CIEH S4ULs
Benzo(a)anthracene	7.2	11	13	11	14	15	170	170	180	LQM / CIEH S4ULs
Chrysene	15	22	27	30	31	32	350	350	350	LQM / CIEH S4ULs
Benzo(b)fluoranthene	2.6	3.3	3.7	3.9	4	4	44	44	44	LQM / CIEH S4ULs
Benzo(k)fluoranthene	77	93	100	110	110	110	1200	1200	1200	LQM / CIEH S4ULs
Benzo(a)pyrene	*2.2*	*2.7*	*3*	*3.2*	*3.2*	*3.2*	*35*	*35*	*35*	LQM / CIEH S4ULs
Indeno(1,2,3-cd)pyrene	27	36	41	45	46	46	500	510	510	LQM / CIEH S4ULs
Dibenz(a,h)anthracene	0.24	0.28	0.3	0.31	0.32	0.32	3.5	3.6	3.6	LQM / CIEH S4ULs
Benzo(ghi)perylene	320	340	350	360	360	360	3900	4000	4000	LQM / CIEH S4ULs
Benzene	*0.087*	*0.17*	*0.37*	*0.38*	*0.7*	*1.4*	*27*	*47*	*90*	LQM / CIEH S4ULs
Toluene	*130*	*290*	*660*	*880*	*1900*	*3900*	*55,600*	*11000*	*18000*	LQM / CIEH S4ULs
Ethylbenzene	*47*	*110*	*260*	*83*	*190*	*440*	*5,700*	*13000*	*27000*	LQM / CIEH S4ULs
Xylenes	*56*	*130*	*310*	*79*	*180*	*430*	*5,900*	*14000*	*30000*	LQM / CIEH S4ULs
Aliphatic C5-C6	*42*	*78*	*160*	*42*	*78*	*160*	*3200*	*5900*	*12000*	LQM / CIEH S4ULs

Standard Land Use Scenario	Residential with Homegrown Produce			Residential without Homegrown Produce			Commercial			Source
Aliphatic C6-C8	*100*	*230*	*530*	*100*	*230*	*530*	*7800*	*17000*	*40000*	LQM / CIEH S4ULs
Aliphatic C8-C10	*27*	*65*	*150*	*27*	*65*	*150*	*2000*	*4800*	*11000*	LQM / CIEH S4ULs
Aliphatic C10-C12	*130*	*330*	*760*	*130*	*330*	*770*	*9700*	*23000*	*47000*	LQM / CIEH S4ULs
Aliphatic C12-C16	*1100*	*2400*	*4300*	*1100*	*2400*	*4400*	*59000*	*82000*	*90000*	LQM / CIEH S4ULs
Aliphatic C16-C35	*65000*	*92000*	*110000*	*65000*	*92000*	*110000*	*1600000*	*1700000*	*1800000*	LQM / CIEH S4ULs
Aliphatic C35-44	*65000*	*92000*	*110000*	*65000*	*92000*	*110000*	*1600000*	*1700000*	*1800000*	LQM / CIEH S4ULs
Aromatic C5-C7	*70*	*140*	*300*	*370*	*690*	*1400*	*26000*	*46000*	*860000*	LQM / CIEH S4ULs
Aromatic C7-C8	*130*	*290*	*660*	*860*	*1800*	*3900*	*56000*	*110000*	*180000*	LQM / CIEH S4ULs
Aromatic C8-C10	*34*	*83*	*190*	*47*	*110*	*270*	*3500*	*8100*	*17000*	LQM / CIEH S4ULs
Aromatic C10-C12	*74*	*180*	*380*	*250*	*590*	*1200*	*16000*	*28000*	*34000*	LQM / CIEH S4ULs
Aromatic C12-C16	*140*	*330*	*660*	*1800*	*2300*	*2500*	*36000*	*37000*	*38000*	LQM / CIEH S4ULs
Aromatic C16-C21	*260*	*540*	*930*	*1900*	*1900*	*1900*	*28000*	*28000*	*28000*	LQM / CIEH S4ULs
Aromatic C21-C35	*1100*	*1500*	*1700*	*1900*	*1900*	*1900*	*28000*	*28000*	*28000*	LQM / CIEH S4ULs
Aromatic C35-C44	*1100*	*1500*	*1700*	*1900*	*1900*	*1900*	*28000*	*28000*	*28000*	LQM / CIEH S4ULs
Aromatic+aromatic EC>44-70	*1600*	*1800*	*1900*	*1900*	*1900*	*1900*	*28000*	*28000*	*28000*	LQM / CIEH S4ULs
Phenol	280	550	1100	750	1300	2300	760	1500	3200	LQM / CIEH S4ULs
Cyanide	527			527			1400			*CLEA 2009*
PCBs	1.7			1.8			1.8			*CLEA 2009*

5.0 REMEDIATION STRATEGY

5.1 Aims

This report contains a summary of the findings of the previous investigations and the risk assessments carried out, and then uses the risk pathways identified to define clear remediation objectives which must be met to allow the site to be developed without significant risk to human health or the wider environment. The various options for achieving these objectives are explored and a preferred strategy is arrived at and presented.

This detailed Remediation Strategy is intended to confirm the preliminary recommendations made are appropriate, refine these into a final implementation plan and provide additional detail regarding the verification programme for the works.

If any unexpected contamination is encountered, then it will be necessary to characterise the source and submit the results of the supplementary investigations and assessments, and confirmation whether these require any amendments to the proposed scheme (as set out in this report).

This strategy does not provide estimates of volumes of material requiring excavation, haulage, treatment, storage, placement or disposal. The factual information provided in the site investigations may provide assistance in determining costs for the remediation programme, however estimating quantities to allow costing of works is outside the scope of this assessment.

The purpose of the remediation is to ensure the site is suitable for use for the proposed commercial development. As noted in the previous section from the point of view of human health assessment the development requires to meet the standards for a commercial end use with plant uptake land use scenario. In addition, the development requires to ensure there is no ongoing risk to the water environment related to soil and groundwater contamination.

As such the aims of this remediation strategy are the following:

- Resolve any potential and identified contamination issues in order to protect environmental receptors and render the site suitable for the proposed development.
- Satisfy the Environmental Agency and the Local Planning Authority with regards to soil and groundwater contamination.
- Provide a stable development platform (to agreed levels and gradients) for subsequent construction of the proposed development and associated infrastructure.

5.2 Summary of Remediation Stages for Enabling Works Contractor

The Enabling Works Contractor will design and implement the remediation with respect to addressing the ground conditions to meet the proposed development requirements.

It is considered that the following stages will be undertaken by the contractor as part of the remediation works.

- Produce a remediation method statement to incorporate the Contractor Designed approach.
- Obtain appropriate licences to undertake the remedial works;
- Provide a Working Plan and Construction Environmental Management Plan for the remedial works.
- Develop a material management plan.
- Demolition of the existing Greenheys Building.

- Part-time supervision of the works by a suitably qualified engineer to include detailed records, testing requirements, etc.
- Excavation and segregation of surface tarmac.
- Breakout and removal of slabs, hardstanding, roads and below ground structures (where necessary) and replacement with appropriate soil materials in line with DOT Series 600 Department of Highway Works.
- The 'turnover' ('grubbing out'/removal) of made ground soils down to natural ground; followed by screening/crush/re-compaction and placement of 'site won' soils and/or treated relic infrastructure. These works will be carried out beneath the site and up to existing boundary on all elevations.
- Crushing of all suitable artificial hard material and obstructing relic infrastructure (i.e. concrete/tarmac, brick, concrete etc).
- Protection and re-routing of site services (if necessary).
- Provide UXO clearance within the medium risk areas and inform staff in line with provided 1st Line Defence reporting.
- Excavate and segregate visibly contaminated hydrocarbon contaminated soils on the site and undertake treatment and/or removal for the residual contaminated fraction to achieve the assessment criteria detailed set out within this report.
- Remove free product present on groundwater via skimming or other method to a point of no discernible sheen. With subsequent appropriate disposal of free product and water arisings. The contractor should allow for all requirements in relation to disposal of pumped water and free product.
- Excavation works to remove contaminated soils for treatment (including excavation, segregation and temporary stockpiling of clean overburden where present). Drawings provided within Appendix A provides detail with respect to known areas of contamination.
- Provide safe entry for validation sampling of the excavated areas.
- Backfilling of the excavations to original ground level. Where possible the contractor should utilise validated remediated material for backfill.
- Validation of the site won soils, demolition arisings and imported stone and/or soils against remedial criteria to ensure material is suitable for reuse on site.
- Onsite environmental monitoring during the works This will incorporate weekly dust monitoring (including asbestos assessment at minimum of 4 locations).
- Provision of dust mitigation and odour suppression during the works.
- Provision of a piling mat in line with BRE470 Working Platforms for Tracked plant (where necessary).
- Provision of an Enabling Works Validation Report detailing the works undertaken including the laboratory results and assessment associated with the validation exercise.

5.3 Summary of Remediation Stages for Main Build Contractor

Note, the capping of the site or provision of gas/and or hydrocarbon resistant gas membranes for future buildings (which form part of the overall remediation strategy for the site) are not to be undertaken by the Main Build Contractor.

Proposed scope of works summary for the Main Build Contractor:

- Protection and re-routing of site services (if necessary). Seek utility company approval and possible further testing along the line of any new potable water supply.

- Brief all staff of UXO risks in line with the provided 1st Line Defence reports and recommendations.
- Develop a material management plan.
- Piling method statement should consider appropriate and necessary PPE to reduce exposure to ground contamination and include a toolbox talk to ensure drilling contractors are aware of ground conditions before any works commence.
- Part-time supervision of the works by a suitably qualified engineer to include detailed records, testing requirements, etc. Including report and dealing with unrecorded areas of contamination.
- Design and provide CIRIA 665 CS2 ground gas protection measures and (if required) possible vapour protection measures and hydrocarbon resistant damp proof membrane. Including verification and reporting to the satisfaction of Manchester City Council..
- Verification of imported soils prior to and including placement of a 600mm deep 'clean' soil cover system in landscaped areas.
- Validation of the remediated site in the form of a detailed Completion Statement confirming that the works set out in this document and agreed were completed and that the site is suitable for its intended use.

5.4 Site Setup, Organisation and Safety

Site works should be supervised when only deemed suitable by the contractor, by a suitably qualified Engineer, who will report to a Project Manager. Supervision may be part time for certain activities but must be full time if any grossly contaminated soil/fill is identified during construction works.

Site cabins and welfare provisions should be provided in accordance with the HSE Guidelines by the appointed Contractor.

All personnel shall undergo a site-specific health and safety induction prior to commencement of work on site.

Any proposed entry to a confined space or deep excavation must be restricted to a suitably qualified and equipped person and supervised at all times.

Works will be carried out with the proper regard to the following standards:

- Health and safety at work act 1974
- Management of Health and safety at work Regulations 1999
- Construction (Health, Safety and Welfare) Regulations 1994
- Construction (Head Protection) Regulations 1998
- Provision and Use of Work equipment Regulation 1998
- Lifting Operations and Lifting Equipment Regulations 1994
- Construction (design and management) Regulations 1994
- Health and Safety Executive "Protection of Workers and the general public during the redevelopment of Contaminated Land", HS(G)66, HMSO 1991
- The Control of Substances Hazardous to Health Regulations 1994
- Any successive legislation to the above

During any remediation works, all personnel on site will comply with guidance provided in the Health and Safety Executive (HSE) document "Protection of Workers and the general public during the redevelopment of Contaminated Land" & as detailed within the HSE 'Asbestos Essentials' document EM6. In summary, the following should be provided by the appointed contractor if contamination is found during the construction works:

- Protective clothing, footwear, glasses and gloves. (Personnel should be instructed in why and how they are to be used).
- Disposable coveralls should be provided where appropriate.
- Handwashing, eye-washing and boot-washing facilities.
- Smoking shall be limited to designated areas.

If at any time during the works personnel begin to feel unwell, they are to inform the Site Manager/Engineer, who will determine appropriate action.

All visitors to the site must enter and register at the main site contractor's office.

5.5 Contractor's Responsibilities

Prior to the commencement of any works the Contractor, in agreement with their appointed Engineer, shall:

- Satisfy requirements of the Client's contract documentation.
- Establish the boundaries of the site and the working areas
- Liaise with Local Authority regarding working hours, noise/dust/odour control, and protected trees.
- Liaise with the Local Water Company prior to any proposed discharge to local sewers. The Contractor will be responsible for obtaining all necessary permits, licenses and consents for disposal to the foul sewer. Contaminated waters pumped from any excavations should be stored in a holding tank and chemically tested prior to disposal. Any discharges to foul sewer should be recorded in relation to date, time, quantity and quality. All records should be maintained at all times and be made available upon request.
- Complete a full services search and liaise with all relevant utility companies regarding work in close proximity to existing services.
- Prepare a detailed method statement outlining how the objectives in the Remediation Strategy are to be achieved to be agreed with both the client and consultant.
- Prepare any necessary COSSH statement and Health and Safety Plan in accordance with current CDM regulations.
- Provide and erect secure Herras-type fence to protect site and any remedial activities and discourage entrance by the general public.
- Provide the engineer with consignment notes and Waste management tip tickets and records.
- The infilling of the excavations should be carried out in line with the earthworks specification for the site.

The Contractor shall satisfy the HSE with regards to all matters concerning health, safety and the welfare of personnel on site.

The contractor shall insure that:

- Personnel, plant, materials and other equipment related to the contract are confined within the boundaries of the site.
- Any live services lying within the site boundary are clearly marked and protected or appropriated arrangements have been made to truncate them.
- Good practise relating to personal hygiene are adopted.
- Suitable precautions are taken to prevent the spread of soil and debris onto public roads.
- Suitable precautions are implemented to prevent offsite migration of any found pollutants via airborne dust and vapours.

- Refuelling of mobile plant is undertaken in a designated area. Above ground fuel storage tanks shall comply with the requirements of the Pollution Prevention Guideline PPG2. A spill kit shall be kept adjacent to any fuel storage area.

5.6 Engineering Supervision and Verification

The Engineer shall ensure that the requirements of the Remediation Strategy are complied with in a safe and orderly manner.

The responsibilities of the Engineer shall include but are not limited to the following:

- Retrieval of soil and water samples from within the made ground and the subsequent scheduling of appropriate laboratory analysis to enable validation of various aspects of the works, and to advise the project manager of progress and unforeseen occurrences.
- Liaise with statutory authorities as required by the contractor.
- Liaise with Client as required.

When onsite, the Engineer will maintain a record of the works to include the following:

- Daily record sheets and summary of the day's activities.
- Date and weather conditions
- Test results

All areas of reduced excavation should be recorded by the use of digital photography of the excavation with a suitable scale indicator (such as survey staff) prior to backfilling. All photographs should include landmarks or other indicators proving their geographical location and indicate the entire area of backfilling, as well as detailed assessments of banks and boundaries.

On satisfactory completion of the works the Engineer will provide a verification report outlining and including the following:

- A summary of the desk study, site investigation report.
- A summary of the preparatory works undertaken and remediation strategy.
- Details of who carried out the respective remedial works.
- Details and justification of any changes from the original remediation strategy, including unforeseen ground conditions.
- Copies of any correspondence with Regulators relating to specific aspects of remedial works.
- Substantiating validation data included as follows:
    - Laboratory and in-situ test results (Geotechnical and Chemical)
    - Chemical test results relating to clean up criteria
    - Representative plans depicting treated areas and any amendments to strategy as a result of finding further contamination (if necessary).
    - Photographic records
    - Waste management tip tickets and records
- Recommendations with regards to the handling of contaminated soils.

The remedial recommendations will be produced in accordance with results obtained for the remediation strategy investigation and thus may differ significantly from the recommendations originally presented in the site investigation report.

5.7 Removal of Below Ground Obstructions

Obstructions in the form of boulders, in-situ relic foundations, structures and infrastructure, associated with the former site uses, should be anticipated. These materials will require 'grubbing out' and treatment (screening, crushing, segregation and reuse where appropriate)

on site as part of the site preparation. Unsuitable materials will require removal from site to suitably licensed waste management facility.

Where relic structures are found to retain fluid contaminants, they shall be drained and removed from site. The engineer should be notified to ensure that the appropriate action is taken, and records made for final validation.

Deep excavations for the removal of structures etc will be unstable in the short term and side support may be necessary.

Suitable materials derived from the grubbing-up shall be stored in a location on site, to be agreed with the engineer, prior to crushing. Any unsuitable materials shall be removed to a suitable licensed landfill site as stipulated within the earthwork's specification.

5.8 Contamination & Verification Sampling

To conform with Condition 28 of the planning conditions (as set out below) requires the prior submission of unexpected contamination details if found to be provided on a phased basis:

"In the event that contamination is found at any time when carrying out the approved development that was not previously identified, it must be reported in writing immediately to the Local Planning Authority. An investigation and risk assessment must be undertaken and, where remediation is necessary, a remediation scheme must be prepared for that phase of development, submitted to and approved in writing by the Local Planning Authority. Following completion of measures identified in the approved remediation scheme a verification report must be prepared, submitted to and approved in writing by the Local Planning Authority".

Although unlikely, areas of potential contamination, not identified in the site investigation, may be encountered during the remedial works. The contractor should stop works, notify the Engineer immediately providing reasonable notice for site attendance.

Any grossly contaminated soil/fill found during construction works shall be placed in temporary stockpiles on hardstanding or high density Visqueen and be suitability covered to minimize the potential for dust/odour nuisance and prevent surface water runoff. Samples of arisings material will be taken to determine whether this material is suitable for re-use on site following crushing in line with the earthwork's specification.

Should any visual or olfactory evidence of contamination be identified during the removal of below ground obstructions and the turning over of made ground appropriate samples shall be taken by the Engineer for chemical analysis. The Engineer should check the nature of materials excavated for visual and olfactory evidence of contamination throughout the remedial works. Depending on the results, the excavated materials shall either be returned to the works beneath the proposed cover system or disposed of, off-site to a suitable licensed facility.

Excavations should not be left open for longer than necessary, should be safely battered back and should be securely cordoned-off using 2m high Herras-type fencing, with appropriate warning signs whenever excavations works are suspended.

PID assessment will be carried out in excavations and on the stockpiles on a daily basis with mitigation measures being incorporated as required.

Once the excavation of soils has been completed then samples will be taken from the base and sides of the excavations and where possible samples of residual groundwater taken prior to placement. We propose a minimum of 3 samples per side of any excavation. Stockpile sampling should be carried out as follows:

5.9 Control of Water

During the removal of below ground obstructions and the excavation through of the Made Ground, perched water may be encountered.

Groundwater shall be control in accordance with CIRIA report 113 "Control of Ground Water to Temporary Works".

Arrangements should be made to prevent ponding in any excavation, the Contractor shall ensure that ground levels are of sufficient gradient to enable the collection of surface water run-off in sumps or grips.

Any potentially contaminated water shall not be allowed to migrate into other areas until the results of the analysis are available and, if required, a suitable means of water treatment has been agreed.

Pumping from over excavated sumps may be required to maintain satisfactory working conditions.

5.9 Exported to Landfill

Any soils to be exported from site should be allocated an appropriate waste code, following the steps within Technical Guidance WM3: Waste Classification - Guidance on the classification and assessment of waste 2015.

The results appended to this document indicate that the samples tested are likely to be classified as NON-HAZARDOUS and HAZARDOUS WASTE. This should be confirmed by the appointed waste management contractor following submission of all available test results carried out at the site to date.

Any material exported from the site to landfill should be hauled by a registered waste carrier in accordance with the requirements of the Duty of Care Regulations, 1991 and the Landfill (England and Wales) Regulations 2005.

A transfer note should then be completed, signed and retained by the parties involved. The transfer note should include the volume of waste, the nature of the material and a statement of its chemical composition, details of the source and destination sites, and details of the haulier.

In order to protect the general public from dust and vapour emissions, wagons that are used for the haulage of the contaminated material from the site must be sheeted. In addition, the Contractor must ensure that no fluids seep from the wagons.

All hazardous waste going for disposal at landfills must be classified according to the new European Waste Catalogue (EWC).

Contaminated soils are minor entries in the EWC. Waste contaminated soils may be classified as either hazardous or non-hazardous depending on the concentrations of "dangerous substance" in the waste soil. An assessment of the composition of the waste soil will therefore be undertaken to determine if it is hazardous waste.

The WAC set threshold concentrations for leachable components of the waste stream and landfill operators will have waste acceptance procedures in place to ensure that only compliant waste is landfilled. Most waste will need to be treated before it can be landfilled to reduce its quality and the hazard it presents. Leaching compliance testing will be required in accordance with BS EN 14899:2005.

5.10 Dust, Odour Control & Noise

The excavation of fill should not present a significant problem with regard to emission of dust during the excavations and transport. However, at all times during the excavation works, Best Practicable Means shall be employed to minimise dust and odour generation and their emission off site.

In general terms, remedial and preparatory works are not considered likely to give rise to any significant odour problems. Whilst considered unlikely, if highly odorous materials are encountered which may give rise to nuisance to neighbouring properties, odour control measures can be considered at that time and an appropriate method statement supplied by the Contractor.

Any odorous materials should be covered at the end of each working day and any stockpiles will be located away from any residential properties. This should be continually assessed through the works.

The requirements of BS 5228:2009 'Noise and vibration control on construction sites' should be adhered to at all times. All machinery should be fitted with effective silencers and should be serviced at regular intervals. No items of plant should be operated with engine covers raised. The location of any crushing plant should take into consideration the location of neighbouring properties and other noise sensitive receptors and should be located away from these areas and located adjacent to proposed stockpile locations, where possible and practicable.

5.11 Controlled Waters

The superficial drift strata beneath the site are classified a Secondary (Undifferentiated) aquifer resources with underlying solid geology classified as a Principal aquifer. It is imperative that no pathways are created which results in impact of the underlying sandstone aquifer.

True sandstone aquifer groundwater levels are likely to be encountered at a significant depth and are unlikely to have an adverse impact on the site, although localised perched groundwater is present within granular pockets within the Made Ground and Glacial till deposits.

The risk to Controlled Water receptors from leaching and groundwater migration is considered to be low post construction.

5.12 Health and Safety during Remedial Construction

During construction works the workforce will need to adopt full HSE measures to ensure that the elevated concentrations of contaminants, established during construction works, requiring cover, treatment and/or removal are dealt with according to current guidelines and codes of practice. Suitably experienced and competent staff should be employed to carry out any on-site remediation.

Site personnel are not permitted to enter unstable excavations, nor excavations in which contamination is present, nor unsupported excavations deeper than 1.2m, in accordance with standard HSE protocols. Gas alarms should be utilised in all excavations and measures put in place to protect site worker when working in and around all excavations. Alarms should monitor for CH4, C02, CO, H2S and volatile compounds. Risk assessments and mitigation measures should be developed for in the event of elevated concentrations being recorded.

NX Consulting are not the Planning Supervisor for this scheme and therefore, a site pre-tender health and safety plan has yet to be made available and will not form part of this scope of works.

6.0 REQUIREMENTS FOR SUBSEQUENT SITE DEVELOPMENT

6.1 Foundation Requirements and Earthworks

The proposed ground floor plan and proposed site plan for the proposed development are presented within Appendix A. It is anticipated that site levels will not change significantly, other than removal and replacement (where appropriate) of landscaping areas surrounding the proposed structure.

The Made Ground and Glacial till deposits are considered unsuitable as an adequate founding stratum due to the possible risks of unacceptable total and differential settlements occurring and a bored pile solution is likely to be the adopted foundation solution. This should be confirmed by a suitably qualified piling contractor. A piling matt will be required in line with BRE470 Working Platforms for Tracked plant.

Unsuitable site materials will require 'grubbing out' and treatment (screening, crushing, segregation and reuse where appropriate) on site as part of the site preparation and to prevent obstruction of piled foundations. Soils and materials that cannot be reused on site, will require removal from site to suitably licensed waste management facility.

Site won and imported suitable earthworks materials will need to be classified and compacted in accordance with Table 6/1 of Department of Transport Specification for Highways Works. Any imported materials used for upfilling will require chemical validation to demonstrate that they are suitable for a commercial end use.

As a result of potential spalling and collapse within areas of deeper fill, temporary support may be necessary during service excavations and unrecorded underground services may be present beneath the site.

The earthworks designer should assess the requirement for pre-earthworks drainage that allows for temporary fill surfaces to be sealed and shaped to shed water and operational restrictions during periods of rainfall.

Dewatering of excavations is unlikely to exceed the volumes or conditions of the groundwater activity exclusion within Section 5 of the groundwater abstraction and impoundment legislation as detailed below, therefore a groundwater abstraction permit would not be required. If the conditions set out below can not be met further assessment must be completed.

The restriction on abstraction does not apply to an abstraction or series of abstractions of water carried out in the course of building or engineering works for the purpose of dewatering from a sump or excavation if

a) the abstraction or series of abstractions are temporary and in any event carried out over a period of less than six consecutive months beginning with commencement of the first abstraction,
b) each abstraction does not cause or is not likely to cause damage to a conservation site or specific features in such a site,
c) each abstraction does not cause or is not likely to cause damage to protected species, and
d) either—
(i)the water abstracted is immediately discharged to a soakaway, or
(ii)the volume of water abstracted is less than 100 cubic metres of water per day and there is no intervening use of that water before discharge (but see paragraph (2))
e) The abstraction is not undertaken within 500 metres of a conservation site or within 250 metres of a spring, well or borehole

Any water entering excavations will be pumped to holding containers, visually assessed for the presence of contamination and treated by separation for removal of sediment, and if required, separation of free phase contamination. The disposal point for groundwater is likely to be to foul sewer under consent, but this should be confirmed before works commence on site.

Abstracted water must not be discharged back to ground or directly to a surface water drain without the appropriate environmental permit from the Environment Agency.

A Materials Management Plan (MMP) will be required to support the potential retention and re-use of made ground arisings to demonstrate these have a clear and intended purpose and are therefore not a waste. The MMP will include details of stockpile areas, the volume of material for reuse and where this will be sourced.

Site preparatory works associated with this project are likely to involve the re-use of both natural and made ground soils on site.

The MMP will document how all of the materials to be excavated during the proposed site preparatory and remediation earthworks are to be dealt with. A updated version of the MMP may also be required to set out reuse of material excavated during the construction phase, once initial earthworks have been completed.

The MMP must be in place before any material is excavated, the qualified person declaration must be in place before any material is reused.

All material included in the material management plan must be tracked in a clear and transparent manner and a final verification report produced.

6.2 Management of Asbestos Impacted Soils

No asbestos was identified within the site investigation works. To protect end users from localised areas of identified asbestos contamination, it is recommended that any potential soils encountered within future works are delineated, excavated and either removed from site or managed in such a way as to mitigate against potential risks.

The resultant void should be backfilled with geotechnically and chemically suitable material.

Soils that are imported must be stockpiled separately to allow for validation. It is the responsibility of the Contractor and the Contractor's appointed engineers to validate the material as being suitable for use. It is crucial that the stockpiles are kept clean of any construction materials in order to prevent them being inadvertently identified as contaminated and rejected for use on site.

Samples should be submitted to the analytical laboratory for a 5-7day turnaround of results. A shorter turnaround time can be achieved upon the request of the client with a surcharge fee for expedited results requests. The appointed Engineer should respond within 24 hours of receiving laboratory results from each stockpile; notifying the Contractor if the materials are suitable for their intended use. This procedure should be adopted for every stockpile brought to site for purposes of remediation and topsoil laying.

6.3 Placement of Soil Cover

To protect end users from isolated areas of lead and potential asbestos contamination, a 'clean' soil cover system (consisting of a minimum 450mm thick layer including 150mm of topsoil) is required over deposits of made ground, in all new landscaped areas.

Imported materials will require chemical and visual validation in accordance with NX Consulting's Protocol for Validation of Soil Cover Systems (presented in Appendix B) to demonstrate that they are suitable for a commercial end use and taken to depths sufficient to provide a sufficient cover system for all new landscaped areas and materials used which are capable to support root growth.

Soils that are imported must be stockpiled separately to allow for validation. It is the responsibility of the Contractor and the Contractor's appointed engineers to validate the material as being suitable for use. It is crucial that the stockpiles are kept clean of any construction materials in order to prevent them being inadvertently identified as contaminated and rejected for use on site.

Samples should be submitted to the analytical laboratory for a 5-day turnaround of results. A shorter turnaround time can be achieved upon the request of the client with a surcharge fee for expedited results requests. The appointed Engineer should respond within 24 hours of receiving laboratory results from each stockpile; notifying the Contractor if the materials are suitable for their intended use. This procedure should be adopted for every stockpile brought to site for purposes of remediation and topsoil laying.

Soils which are to be used in landscaped areas, from imported materials, will be required to have concentrations of determinands at or below the Tier 1 Values provided within Appendix A.

The Contractor must maintain adequate site records regarding imported soil including date of delivery, type of material location of stockpiles onsite, date of sampling by the Engineer, date of rejection or approval for use by the Engineer. Stockpiled materials must not be used until receipt of approvals by the Engineer.

Where any material fails the chemical criteria, it shall not be suitable for use in the capping layer. The Contractor shall make provision for the costs of sampling, testing and removal of unacceptable materials from excavations and shall make provisions for delays associated with material testing and classification prior to disposal.

6.4 Gas Protection Measures

Gas protection measures should be installed in accordance with BS8485: 2015. Based on a Type C development and CS2 classification Based on the results recorded to date, identifies that GSV values fall into Characteristic Situations 2 measures. It is recommended that the design of gas protection measures should be provided by a specialist consultant/supplier and carried out in line with BS 8485:2015+A1:2019 s.7.1 and 8.3 and a copy of the full Gas Protection Design Report should be submitted for approval to Directorate of Planning of Manchester City Council.

Dependent on the foundations and sub floor construction utilised, some or all of the following protective measures may be required:

- Reinforced cast in-situ floor slab (suspended or non-suspended) with a proprietary methane resistant membrane.
- Membrane to be sealed across whole building including cavity walls.
- Possibly ventilated subfloor void, depending on sub floor construction.
- All joints and penetrations to be sealed.

Gas protection measures should be installed as prescribed in BRE 414 with the ventilation of the sub-floor void designed to provide a minimum of one complete volume change per 24 hours.

Independent validation of gas protection measures is needed to achieve the required points score.

No radon protective measures are required.

A vapour membrane may be required subject to the findings of the enabling works remediation.

6.5 Drainage and Services Installations

It is recommended that statutory services are consulted at an early stage, with respect to the ground conditions within which they will lay services, in order to enable them to assess at an early state any protection measures required. This includes submission of a United Utility potable water risk assessment. Once approved, by United Utilities, the nature of water supply pipework should be submitted to Manchester City Council Director of Planning prior to construction being commenced.

Underground services, comprising BT Lines, gas mains, combined and foul sewers, CCTV and possible fibre optic cables may all impact the site and the design team and Client should familiarise themselves with their presence.

All drainage installation will encounter Made Ground. Any suitable Made Ground arisings from drainage trenches etc, if not returned to the original excavation must be placed beneath proposed hard end-use areas of the site, placed beneath a cover of suitable thickness in landscaped areas, or disposed off-site adhering to the guidelines outlined above.

Redundant drains and infrastructure are likely to be present associated with the former warehouse, depot and garage, this could also include below ground tanks and sumps.

All redundant drainage and associated infrastructure such as interceptors may include residual contaminated sludge and waters. These must not be released to ground. All drains exiting the site will be identified, as far as possible, and capped.

All sludges and contaminated waters contained in drains encountered during earthworks will be carefully removed from the drains and infrastructure, transferred into containers for removal off-site subject to chemical sampling, waste classification and duty of care requirements.

Chemical sampling to allocate a waste code should consider the likely waste material derived from site activities and will likely include heavy metals, speciated TPH & PAH. Since all made ground will be excavated, with a full depth turn over it is likely that most gullies, drains and below ground structures will be identified and decontaminated prior to the construction phase.

New services and infrastructure should be kept as shallow as possible to avoid the need for dewatering.

An approach to mitigate contaminant migration into service trenches where these pass through any residual areas of organic contamination, should be included in the CEMP. All areas of residual contamination should be identified, and the location surveyed during earthworks.

Where residual contamination remains, consideration should be given to lining service trenches as they pass through the impacted area. The purpose of the mitigation is to limit the degree of contamination around the service to reduce risks to individuals during any future maintenance. Budget costs for this should be allowed for by the Quantity Surveyor, Contractor and client.

Low level organic concentrations (particularly PAHs) can present a risk of impregnation of potable water pipes at concentrations that may not be considered a risk within the overall redevelopment setting. It is recommended that a barrier pipe, such as Protecta-Line (or similar) be adopted and/or further testing along the line of the proposed new pipework once enabling works are completed.

7.0 PILING RISK ASSESSMENT

A remediation strategy is being prepared for the site and this focuses on source removal where contamination is encountered during made ground turnover. The remediation approach will be supported by the findings of this risk assessment, which assumes there is hydraulic separation between the secondary A aquifer and the underlying principal aquifer.

To support the remediation proposal, all piling on site must be undertaken following a methodology to retain the low permeable layer provided by the Glacial Till deposits and prevent the creation of migration pathways.

7.1 Piling method

It is understood that ground conditions support the use of continuous flight auger (CFA) to install the concrete piles.

CFA is a cast in-situ method of piling suited to environmentally sensitive sites where soft natural strata and/or water-bearing strata would usually require deep casings to be used.

A hollow stem auger is advanced into the ground at a constant penetration rate to the desired pile depth. The auger is then extracted, at the same time concrete is pumped down the hollow inside of the auger, continuously filling the resultant void space.

Pressure and volume of the pumped concrete is controlled by instrumentation in the piling rig to ensure positive pressure is maintained as the concrete is pumped into the ground, this prevents the drilled hole from collapsing as the auger is withdrawn. Maintaining a positive pressure also prevents wash out of concrete in aquifers with high transmissivity, although some localised dispersion is likely. The borehole is completely filled with concrete to surface. Steel reinforcement can then be inserted as required.

Some soils are bought to surface as the auger is retracted.

7.2 Risk evaluation

Studies into piling approaches[1] indicate CFA has the least ground disturbance and draw down when drilling through low permeable confining layers.

The degree of displacement depends on the speed of rotation relative to the speed of penetration. Theoretically, according to the study, it should be possible to adjust the rotation speeds so that the volume of soil removed is equal to the volume of concrete placed. If this is achieved, displacements of the surrounding ground should be negligible. There have also been instances of severe ground loss due to over-rotation and the risk is larger in soil deposits containing sand layers below the water table (the geological setting at the Greenheys site).

Research also suggested there was a negligible change in hydraulic gradient after piling, suggesting CFA piles do generally result in good seals in low permeable layers where the clay thickness is equal to or greater than two pile diameters. Individual pile diameters at Greenheys will be between 450 to 600mm, giving a required cohesive layer thickness of 900 to 1200mm or more.

[1] Piling in layered ground: risks to groundwater and archaeology, Science Report SC020074/SR, published by Environment Agency, dated 2006

Exploratory logs indicate a minimum thickness of Glacial Till of approximately 3.5m. Sufficient clay should be present to ensure a seal and prevent seepage along the pile.

Good workmanship and operation of the CFA rig is essential as is the requirement for a method statement that considers the specific ground conditions and details how drilling will be undertaken to minimise displacement and ensure good seals.

Consideration should also be given to the use of casing through made ground and Glaciofluvial sands in the area of hydrocarbon impact, to prevent migration of mobile contamination during the drilling process.

The table below summarises key risk drivers when considering piling activities and the possible creation of contaminant linkages.

Table 7.2.1 - piling risk drivers

Pollution risk	Likelihood	Mitigation
Creation of preferential pathways, through a low permeability layer	Moderate	The use of CFA piles should reduce this risk, providing the piling approach is well designed. Piling method statement must consider possible migration pathways and develop an approach to mitigate
Creation of preferential pathways, through a low permeability surface layer, to allow upward migration of landfill gas, soil gas, or contaminant vapours to the surface	Low	Organic contamination is above the cohesive layer, piling will not increase the potential for vapour migration to surface. Mine workings have not been identified on site and mines gas is not anticipated.
Direct contact of site workers and others with contaminated soil arisings	Low	Minimal arisings likely during CFA piling. Providing appropriate health and safety training, planning and monitoring are in place for the works the risks are anticipated to be low. Piling contractors must be made aware of the potential issues associated with potentially contaminated material and this should be included in their piling method statement. Potential exposure can be mitigated with suitable PPE and contaminated arisings will be disposed of offsite as waste.
Direct contact of the piles or engineered structures with contaminated soil or leachate causing degradation of pile materials	Low	Contamination is restricted to an area of Glaciofluvial sand in the southwest area of the site. Contamination should not be in contact with deeper pile material. Whilst it is unlikely shallow contamination would cause degradation of the pile material, the effect should be considered in the piling method statement and the use of chemical resistant concrete should be considered. However this would depend on the degree of remediation undertaken prior to piling.
The movement of solid contaminants down into an aquifer during pile driving	Low	Research indicates CFA drilling displace material horizontally with minimal downward heave. Some material may be brought to surface as the auger is retracted.

Pollution risk	Likelihood	Mitigation
Contamination of groundwater by concrete, cement paste, or grout	Low	The viscosity and set time of the concrete mix, as well as the bleed potential, will need to be precise to provide confidence the pile has been suitable created. This is particularly important in granular strata with a high groundwater flow. Consideration of this should be detailed in the method statement.

7.3 Piling method statement

The selected piling contractors should produce a method statement detailing the approach to ensure continued protection of the low permeable Glacial Till, having full regard to this risk assessment and potential risk drivers summarised in the table above.
The method statement should include maximum drill rates to minimise the degree of draw down and displacement and to provide confidence the final concrete pile has achieved a good seal.

The method statement should include the approach to cleaning the drill rig between locations and how contaminated arisings will be managed.

It is considered unlikely that contaminated water will be brought to the surface during piling. However, for completeness the method statement should also include a section on managing contaminated waters as a precaution.

Piling using CFA causes minimal displacement of ground and does not create significant volumes of arisings or result in dust. However, the piling method statement should consider appropriate and necessary PPE to reduce exposure to ground contamination and a toolbox talk to ensure drilling contractors are aware of ground conditions before any works commence.

The drillers method statement should be reviewed and approved by the Principal Contractor prior to any works commencing on site.

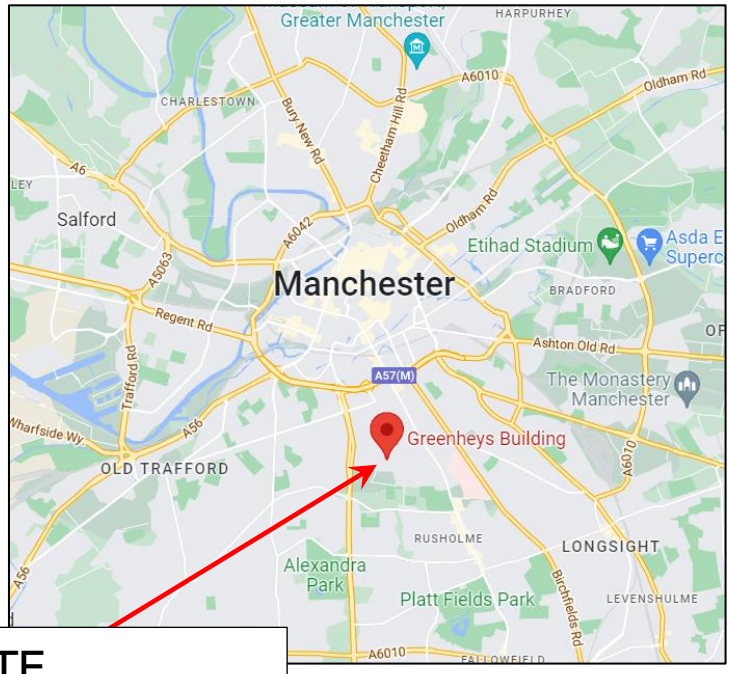
APPENDICES

Appendix A – Drawings

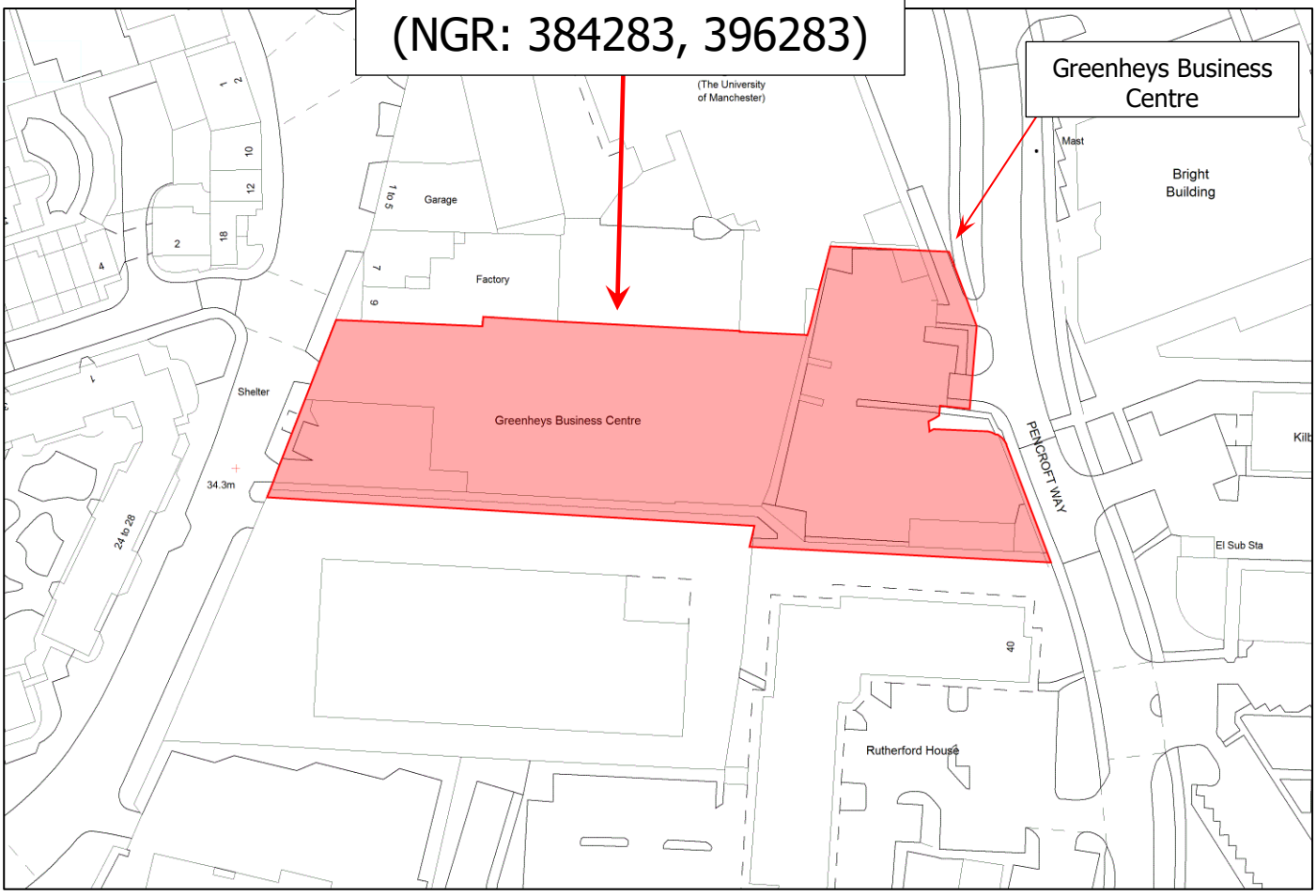
Appendix B – NX Consulting Protocol for Validation of Soil Cover Systems

Appendix A – Drawings





SITE
(NGR: 384283, 396283)



nxconsulting
Next Generation Engineering Consultancy Services

Tel: 0161 904 0187
E-mail: admin@nxconsulting.org.uk
Web: www.nxconsulting.org.uk

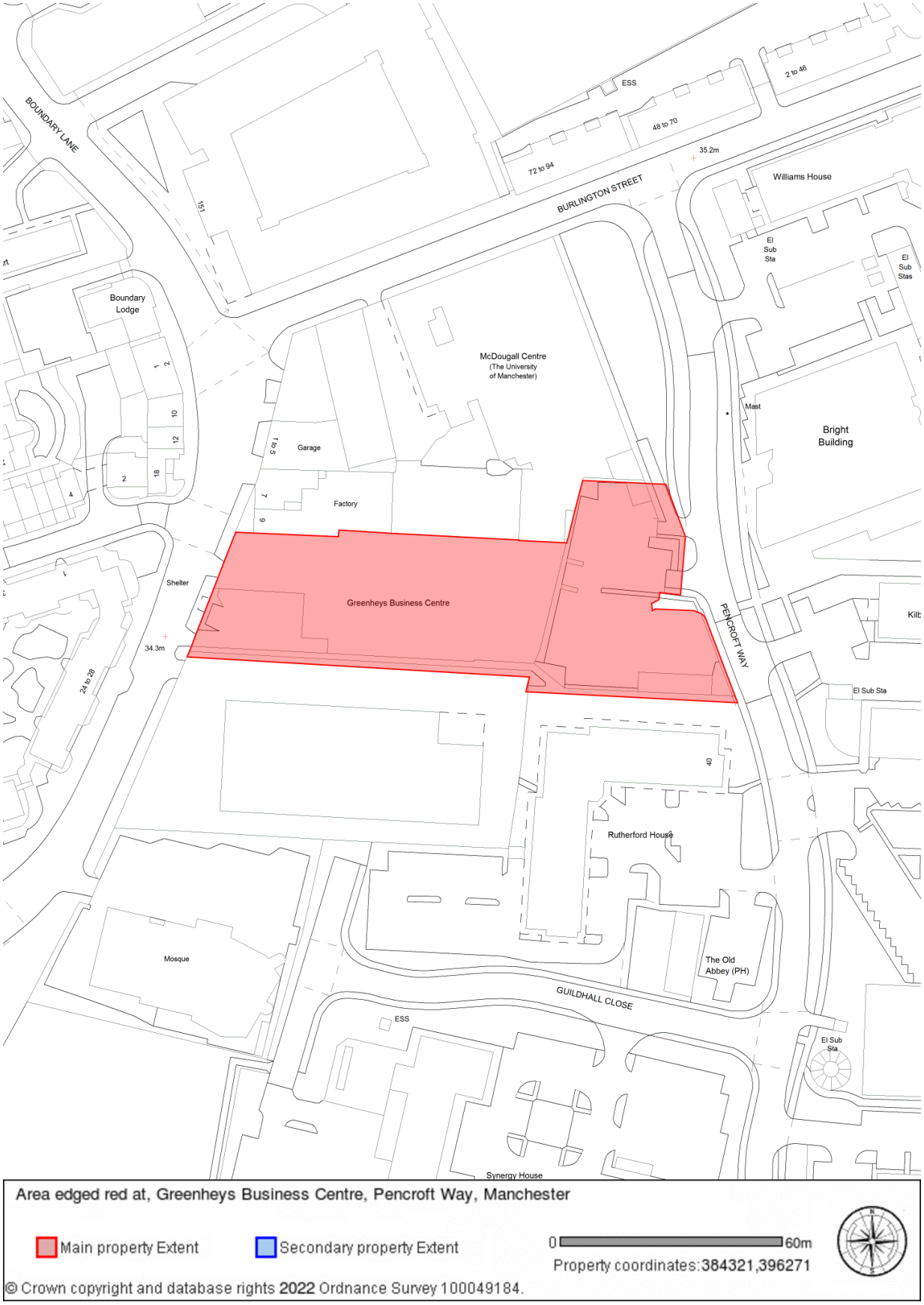
Ref: NX534 Figure 1

Project:

GREENHEYS BUSINESS CENTRE, PENCROFT WAY, MANCHESTER, M15 6JJ

Title:

Site Location Plan



nxconsulting

Next Generation Engineering Consultancy Services

Tel: 0161 904 0187
E-mail: admin@nxconsulting.org.uk
Web: www.nxconsulting.org.uk

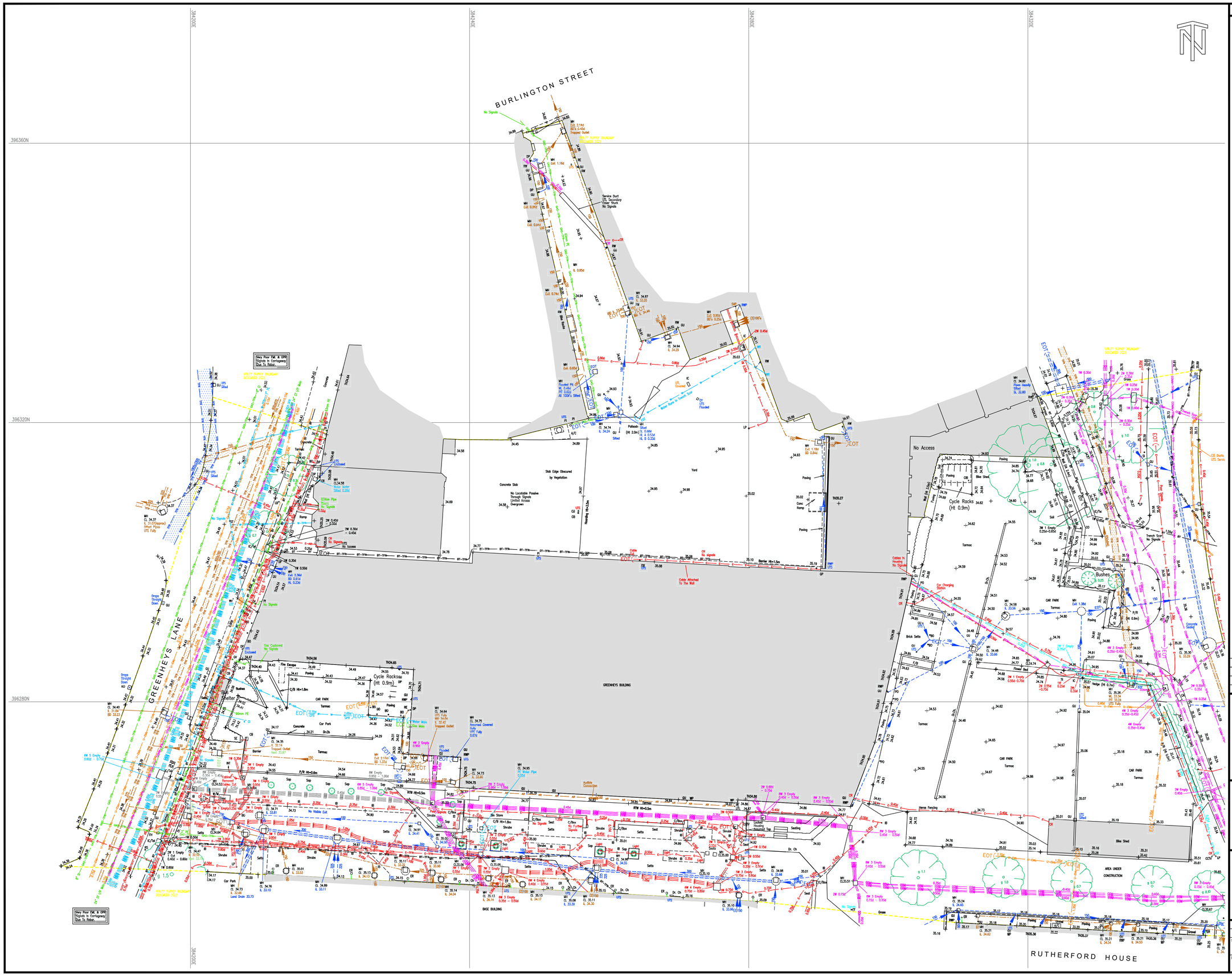
Ref: NX534 Figure 2

Project:

GREENHEYS BUSINESS CENTRE, PENCROFT WAY, MANCHESTER, M15 6JJ

Title:

Site Boundary Plan



NOTES

KEY

Grid & Datum - Local Plane Grid related to OS National Grid & Datum By GNSS RTK Observations

STANDARD ABBREVIATIONS

STREET FURNITURE

A/C - AIR CONDITIONING
AE - AERIAL
AL - ALARM
AV - AIR VALVE
BA - BUOYANCY AID
BB - BELISHA BEACON
BD - BUILDING DIVIDE
BH - BOREHOLE
BL - BASEMENT LIGHT
BO - BOLLARD
BP - BOUNDARY POST
BR - BOULDER
BU - BUS STOP
CA - CABLE
CB - CONTROL BOX
CC - CLOSE CIRCUIT TV
CIB - CIGARETTE BIN
Col - COLUMN
CT - CLOSE CIRCUIT TV POLE
DP - DOWN PIPE
DR - DRAIN
Dr.Ch - DRAINAGE CHANNEL
DU - DUCT
E - ELECTRIC
EP - ELECTRICITY POLE
ER - EARTH ROD
FA - FENDOR ANCHOR
F/B - FLOWER BED
FH - FIRE HYDRANT
FL - FLOODLIGHT
FS - FLAG STAFF
GA - GAS
GM - GAS METER
G - GIRTH
GP - GATE POST
GU - GULLY
GV - GAS VALVE
Hyd - HYDRANT
IC - INSPECTION COVER
IT - TRAFFIC COVER
JB - JUNCTION BOX
KO - KERB OFFLET
LA - LADDER
LB - LITTER BIN
LC - LIGHTING COLUMN
LI - LIGHT
LP - LAMP POST
MBO - MOORING BOLLARD
MA - MAST
MH - MANHOLE
MO - MONUMENT
MP - MILE POST
MR - MOORING RING
MW - MONITORING WELL
NP - NAME PLATE
OH - OVERHEAD
OSBM - ORDNANCE SURVEY BENCH MARK
PA - PLAY APPARATUS
PB - POLICE BOX
PH - PUBLIC HOUSE
PI - PIPE
PL - PLANT
PM - PARKING METER
PN - PLANTER
PO - POST
PP - PETROL POL PUMP
RH - RIDGE HEIGHT
RS - ROAD SIGN
RTW - RETAINING WALL
RWP - RAINWATER PIPE
SM - STAMCHIONS
SC - SPEED CAMERA
SD - SATELITTE DISH
S/F - SAFETY FENCE
SG - SIGNAL
SI - SIGN
SMP - SERVICE MARKER POST
SS - SECURITY SENSOR
ST - STOP TAP
SU - STUMP
SV - STOP VALVE
SW - SWITCHGEAR
TA - TANK
TA - TAP
TBM - TEMPORARY BENCH MARK
TCB - TELEPHONE CALL BOX
TE - TELEPHONE
TM - TICKET MACHINE
TS - TRAFFIC SIGNAL
TP - TELEGRAPH POLE
UTL - UNABLE TO LIFT
VDP - VEHICLE DETECTOR PAD
VP - VENT PIPE
WB - WHISTLE BLOW
WM - WATER METER
WO - WASH OUT
WP - WASTE PIPE

FENCE TYPES

B/W - BARBED WIRE
C/B - CLOSE BOARDED
C/I - CORRUGATED IRON
C/P - CONCRETE PANEL
HR - HAND RAILING
I/R - IRON RAILING
PAL - PALISADE
P/C - POST & CHAIN
P/P - POST & PANEL
P/R - POST & RAIL
PSB - PEDESTRIAN SAFETY BARRIER
P/W - POST & WIRE
W/M - WIRE MESH

LEVELS

BL43.45 - BED LEVEL
EV43.45 - EAVE LEVEL
IL43.45 - INVERT LEVEL
43.45 - SPOT LEVEL
RF43.45 - ROOF LEVEL
RL43.45 - RIDGE LEVEL
SB43.45 - SOFT BED LEVEL
SL43.45 - SOFFIT LEVEL
TH43.45 - THRESHOLD LEVEL
WL43.45 - WATER LEVEL

SYMBOLS

HEDGE
GATE
BUILDING
TREE CANOPY
CONTROL STATION
TACTILE PAVING
TREE

UNDERGROUND SERVICE KEY

Foul/Combined water drain
Foul/Combined drain 300Ø and above
Surface water drain
Surface water drain 300Ø and above
End of trace
Electric cables
HV cables
Gas
Water
Telephone
Catv
CCTV
Comms
Fibre Optics
Pipe
Vents
Fuel
Offsets
Vapour Recovery
Gauge Lines
Unidentified GPR
Unidentified EML
Taken From Records
Assumed Routes
Empty Ducts
Earth Rod
Rising Main
Overhead
Heating Pipes
Traffic Signals

Where chamber extents are significantly greater than the cover size, their approximate extents are shown thus;

ABBREVIATION KEY

AR assumed route
BB base bend
BD backdrop
CC cable chase
CL cable level
CR cable riser
DP down pipe
EOT end of trace
EP electricity pole
FH fire hydrant
G gully
GV gas valve
HOR head of run
HL high level
IC inspection chamber
IL invert level
MH manhole
PR pipe riser
RE rodding eye
RWP rainwater pipe
SV stop valve
SVP soil vent pipe
TE trapped exit
TFR taken from records
TP telegraph pole
UTF unable to find
UTL unable to lift
UTS unable to survey
UTT unable to trace
WC water closet
WL water level
WM water meter
WO wash out valve

UTILITY SURVEY NOTES

ELECTROMAGNETIC AND/OR GROUND PENETRATING RADAR TECHNIQUES HAVE BEEN USED TO LOCATE AND MAP UNDERGROUND UTILITIES AND FEATURES ON THIS DRAWING. N D OLIVER & CO LTD HAVE MADE EVERY ENDEAVOUR TO MAKE SURE THAT THE INFORMATION CONTAINED WITHIN THIS DRAWING IS ACCURATE AND OF THE HIGHEST QUALITY. HOWEVER, THE RESULTS FROM THESE TYPES OF SURVEYS ARE NOT INFALLIBLE AND SHOULD THE LOCATION OR DEPTH OF SERVICES/FEATURES BE OF PARTICULAR IMPORTANCE TO A PROJECT, THEN IT IS STRONGLY ADVISED THAT TRIAL EXCAVATIONS SHOULD BE UNDERTAKEN TO CONFIRM SURVEY RESULTS.

N D OLIVER & CO LTD HAVE USED ALL RECORD DRAWINGS THAT WERE AVAILABLE TO US BY THE CLIENT OR BY THE RELEVANT UTILITY COMPANIES AT THE TIME OF SURVEY. WHERE THESE RECORDS ARE SCHEMATIC IN NATURE AND/OR OF POOR PAPER SIZED, MATERIAL IS NOT GUARANTEED. SERVICES LOCATED FROM RECORD DRAWINGS WILL BE SHOWN AND ANNOTATED AS TAKEN FROM RECORDS (TFR). HISTORIC RECORD INFORMATION IS OFTEN INCOMPLETE/INACCURATE AND CANNOT BE RELIED UPON.

A SINGLE LINE INDICATING A UTILITY MAY INDICATE THE PRESENCE OF MULTIPLE SERVICES WITHIN CLOSE PROXIMITY TO EACH OTHER. WHERE A SINGLE LINE TYPE IS SHOWN WE RECOMMEND HAND DIGGING WITHIN 0.5m, TO EXPOSE HIDDEN SERVICES.

WHERE QUOTED, DEPTH INFORMATION OF UNDERGROUND SERVICES/FEATURES IS STATED, DEPTHS ARE GENERALLY WITHIN +/- 10% ACCURATE, BUT CANNOT BE GUARANTEED. ANY DEPTHS SHOWN ARE USUALLY TO THE TOP OF THE SERVICE/FEATURE, UNLESS STATED OTHERWISE. GRAVITY SEWERS AND DRAINS ARE USUALLY TO INVERT (BASE OF DRAINAGE CHANNEL) UNLESS OTHERWISE STATED.

AT N D OLIVER & CO LTD WE USE SKILLED STAFF AND MODERN CALIBRATED EQUIPMENT TO PERFORM OUR SURVEYS. HOWEVER, THE COMPLETENESS OF ANY UNDERGROUND SURVEY CANNOT BE 100% GUARANTEED AND WE CANNOT BE HELD RESPONSIBLE FOR ANY INACCURACIES BEYOND THOSE THAT COULD BE REASONABLY EXPECTED BY A COMPETENT COMPANY.

CONTRACTORS UTILISING OUR DRAWINGS FOR INTRUSIVE WORK SHOULD TAKE ALL REASONABLE MEASURES TO WORK SAFELY IN ACCORDANCE WITH HSG47 GUIDELINES 'AVOIDING DANGER FROM UNDERGROUND SERVICES'.

Rev	Date	Drawn	Description	Ch'k'd	App'd

N D OLIVER & CO
CHARTERED GEOMATIC SURVEYORS
Jupiter House, 21 Roebuck Lane, Sale, Manchester, M33 7SY
T: 0161 973 3495 F: 0161 962 6819
E: mail@ndoliver.com www.ndoliver.com

Client
BDP
11 DUCIE STREET
PICCADILLY BASIN
MANCHESTER
M1 2JB

Title
GREENHEYS BUILDING
MANCHESTER SCIENCE PARK
M15 6JJ

TOPOGRAPHICAL SURVEY
SHEET 1 OF 2

Surveyed	PK	Drawn	PK	Drawn Date: 16/12/2022
Checked	AM	Approved	NDO	
Scale	1:250 @ A1	Project	9872	Status ORIG
		CAD File	\\NDO-SBS\Projects\9872\DRAWING\9872_005.DWG	
Drawing No	9872 / 005 / 1			Rev 0

BURLINGTON STREET

GREENHEYS LANE

BRONTE STREET

PENCROFT WAY

Proposed site boundary

Greenheys Redevelopment Building

BASE Building

GENERAL NOTES

Do not scale this drawing.

Contractor to check all dimensions and report all errors and omissions to the Engineer.

Details shown on this drawing are schematic only and are subject to detailed design by architect

Rev	Detail	By	Auth	Date

Revisions

DW Consulting LLP

Marsland House
Marsland Road
Sale, M33 3AQ

Tel: 0161 969 4144

www.dwllp.com

Hornbeam House
Hornbeam Park,
Hookstone Road
Harrogate, HG2 8QT

Tel: 01423 855930

Client

Bruntwood SciTech

Project

Greenheys Redevelopment
Manchester Science Park

Drawing Title

Proposed Site Layout

Drawing Status

scheme

Drawing No.

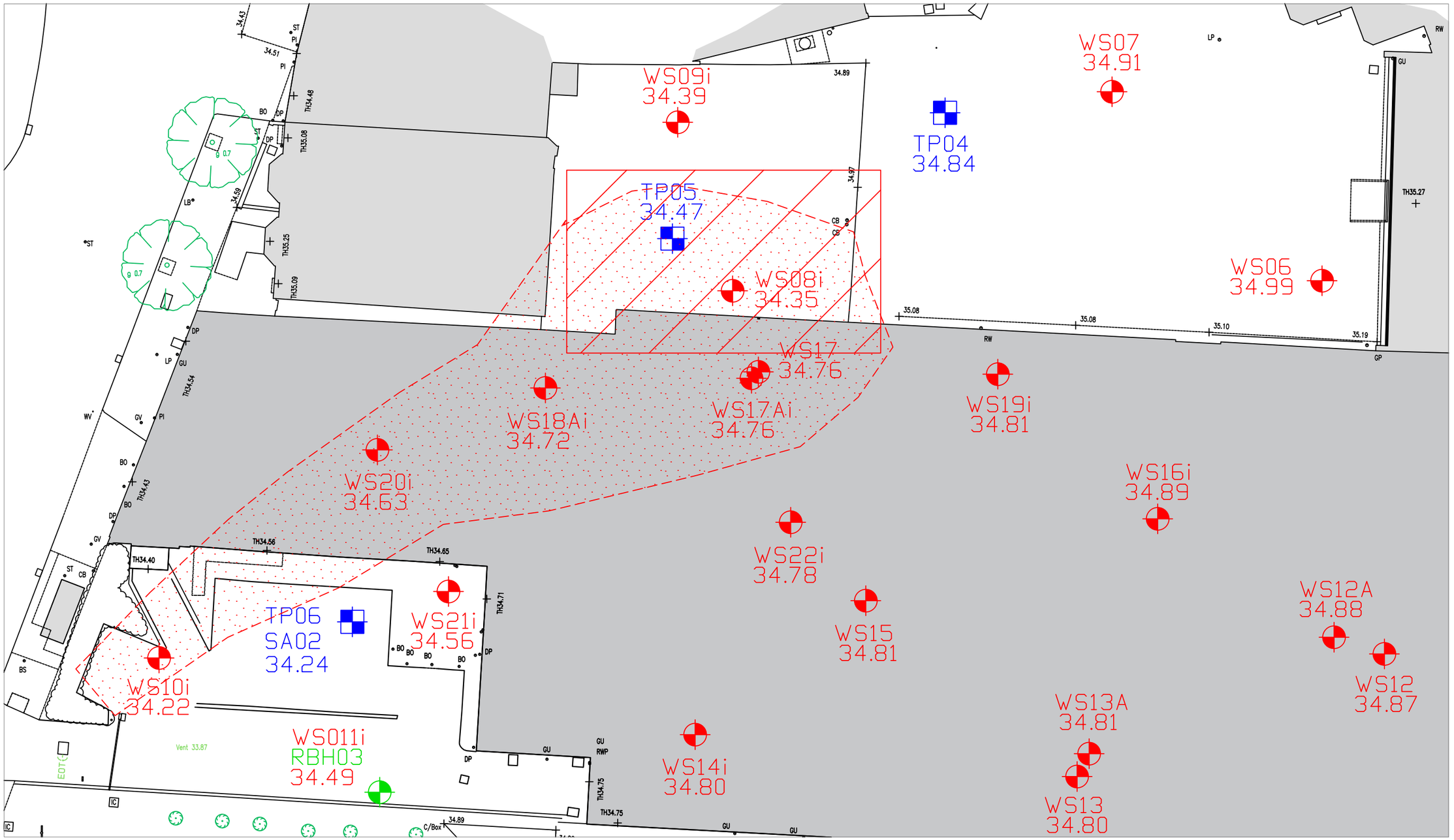
GRE-DWC-XX-DR-C-200

Scale	Sheet Size	Revision
1:250	A1	P01

Date	Drawn	Checked	Auth
Jan'23			

© This drawing may not be copied without prior written permission

DWG INFO: Z:_DW LLP\DW LLP JOBS\DW2025 BIOBANK MSP\ FRA AND DRAINAGE STRATEGY\GRE-DWC-XX-DR-C-200



Key

Possible area of source

Groundwater plume

Rev	Detail	By	Chk	Date

Revisions

Client: Bruntwood SciTech

Project: Greenheys Business Centre, Manchester

Drawing Status

nxconsulting
Office: 0161 904 0187
Mobile: 07808 670 068
Web: www.nxconsulting.org.uk

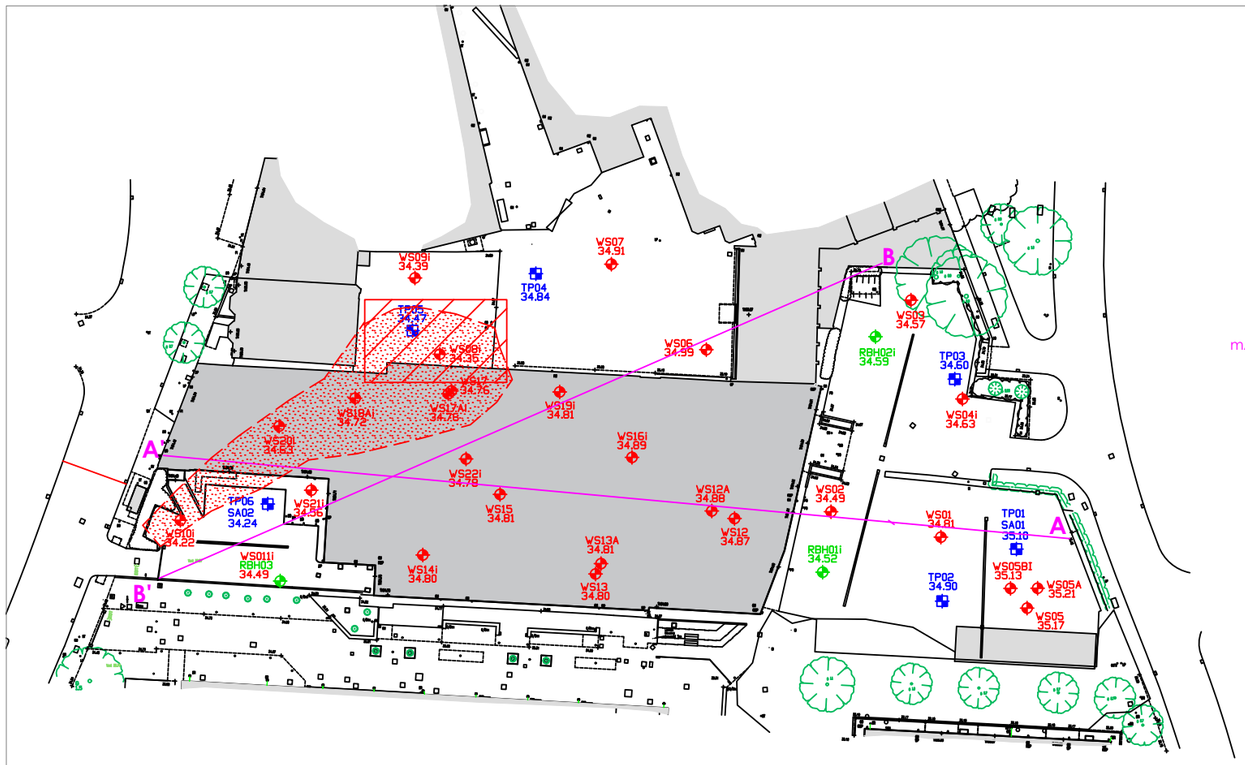
Drawing Title: Geological cross sections with groundwater

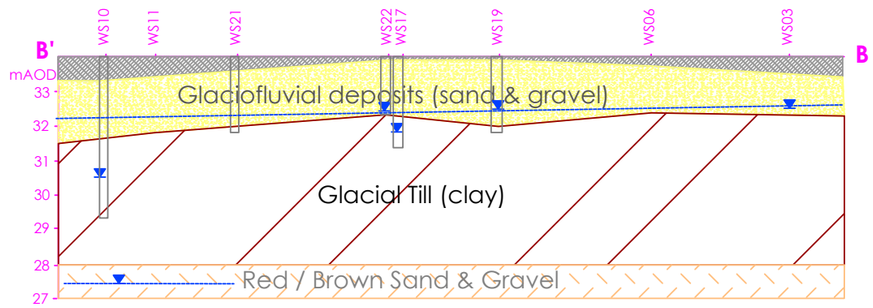
Project No.	Discipline	Drawing No.
NX534	E	

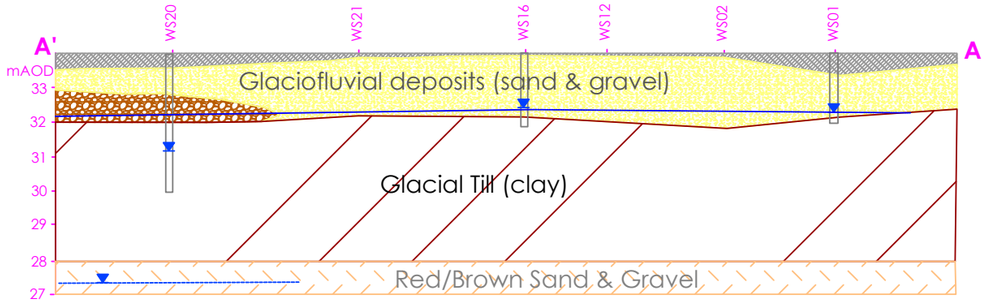
Scale	Sheet Size	Revision
	A3	

Date	Drawn	Checked	Auth
04.09.23	LH		

© This drawing may not be copied without prior written permission







Rev	Detail	By	Chk	Date

Revisions

Drawing Status

Client: Bruntwood SciTech

Project: Greenheys Business Centre, Manchester

nxconsulting
Office: 0161 904 0187
Mobile: 07808 670 068
Web: www.nxconsulting.org.uk

Drawing Title: Geological cross sections with groundwater

Project No.	Discipline	Drawing No.
NX534	E	RA02

Scale	Sheet Size	Revision
As shown on x-section	A3	

Date	Drawn	Checked	Auth
04.09.23	LH		

© This drawing may not be copied without prior written permission

Appendix B – NX Consulting Protocol for Validation of Soil Cover Systems

NX Consulting Limited Protocol for Validation of Soil Cover

Isolation of potentially contaminated or unsuitable materials in garden and landscaped areas beneath a cover of "clean" subsoil, and topsoil is often recommended on developments to allow safe use and/or occupation of the land; most notably when it contains inorganic contaminants at concentrations above guidance threshold values.

A cover is only required in proposed garden and/or landscaped areas (i.e. not beneath drives, garages or houses). The soil cover, hard standing breaks direct contact pollutant linkages between the potentially contaminated soils and future residents or end users.

The CML initiative requires house builders to submit to the NHBC (or other warranty providers) a validation report confirming the thickness and chemical suitability of the soil cover.

Validation reports are normally prepared by independent geoenvironmental consultants such as NX Consulting. Soil cover validation requires independent assessment of the chemical suitability of the soil and the thickness of the placed subsoil and topsoil.

Inspection and Sampling of cover soil at source

Soil quality is best determined by sampling at the **source** at least 7 working days before importation to the development site. If this is achieved, further, on-site (post-placement) quality testing should not usually be necessary providing that confirmation can be given that the material arriving at site is the same soil as that tested.

Inspection and Sampling of cover soil following import to site

In some cases, soil is often delivered to site prior to sampling and chemical testing. Such soils should be stockpiled in a secure location on site and NX Consulting should be contacted to arrange for visual inspection, sampling and chemical testing. It is strongly recommended that soils should not be placed in garden and landscaped areas, prior to confirmation of the suitability of the soil by NX Consulting. This normally takes two weeks from initial notification.

Suitable soil material should:

- be clean and free of foreign debris, building waste materials or contaminants;
- not have a stone content of greater than 20% by visual estimation
- have a maximum stone size of 150mm in any one direction.
- not have been sourced from an area within 7m laterally, or 3m vertically, of Japanese Knotweed plants, and not contain any Japanese Knotweed fragments (rhizomes, leaves, stems etc).

The number of samples taken will be dependant on the nature of the source and the quantity of material to be imported and the testing ratio should be agreed with the Local Authority (EHO) before testing is undertaken. However, the YALPAG guide should be referred to as below:

Proposed Testing Frequency and Analysis

Soil Source	Testing frequency	Analysis suite
Imported soils brownfield source	A minimum of 6 samples or dependent on source and receptor, 1 per 100m3	Standard metals/ metalloids ((should include as a minimum As, Cd, Cr, Cr, VI, Cu, Hg, Ni, Pb, Se, Zn).), PAH (16 USEPA speciation), TPH (CWG banded), asbestos, pH and SOM (or calculated from TOC). Any additional analysis dependant on the history of the donor site (e.g. phenol, total cyanide, BTEX, MTBE).
Imported Soils Greenfield Source	A minimum of 3 samples or, dependent on source and receptor, between 1 per 50m3 and 1 per 250m3.	Standard metals/ metalloids (should include as a minimum As, Cd, Cr, Cr, VI, Cu, Hg, Ni, Pb, Se, Zn), PAH (16 USEPA speciation), asbestos, pH and soil organic matter (SOM) (or calculated from total organic carbon (TOC).

Cover layers can often include a “difficult to dig” or capillary break layer of coarse natural or recycled aggregate. Where this aggregate is sourced from recycled materials (such as crushed demolition arisings) asbestos screening tests should also be undertaken.

The Client\Contractor will be notified of the soil’s suitability (or otherwise) immediately following receipt of the results (typically taking 7 working days). Chemical assessment (Tier 1) criteria for imported soils are presented below.

On receipt of written confirmation from NX Consulting, the Client should instruct his Contractor to commence importation. It will probably be necessary to stockpile the cover prior to placement in garden\landscaped areas. NX Consulting should inspect the stockpiled material prior to placement, to confirm that it is the same material as previously tested, **and** the Contractor should provide the Client with appropriate haulage notes.

Cover Thickness Validation

Soil **thickness** can only be checked after placement, but should be done before turfing, fencing etc. Thickness could be checked via the excavation of an appropriate number of inspection trial pits. Typically one trial pit for every two gardens will be required.

The thickness of cover is dependant on the nature and degree of contamination (and often the Local Authority whose area the site lies within), but typically between 600mm and 1,000mm is required. Where underlying materials do not contain contaminants above critical concentrations but contains materials generally considered undesirable as a near-surface material in garden areas (colliery spoil, construction\demolition rubble etc) then a 300mm thick cover, in accordance with NHBC Standards, Chapter 9.2, should be adequate.

Soil cover is usually placed many weeks after completion of the preparatory\remedial works, and issue of the associated Verification Report. Consequently, site visits, to generate supplementary

letter reports, are typically required after soil cover has been placed in the gardens of each plot, or set of plots.

Cover material can sometimes be sourced on-site from foundation\drainage excavations in natural in-situ strata, but import is often necessary.

Issue of Soil Cover Validation Reports

Validation reports will be issued by NX Consulting following the confirmation of the placed thickness within each plot, or set of plots. Each report will contain the following information;

- details of the provenance of the subsoil and topsoil,
- chemical test data,
- an interpretation of the chemical data indicating whether the soils are suitable for use in a clean cover layer,
- a drawing indicating the location of cover thickness validation trial pits,
- photographs of the excavated trial pits confirming the thickness of placed soils,
- a data table indicating the thickness of cover soils within each trial pit excavated.

Soil Cover Validation Reports will be issued to the Local Authority and to the NHBC by email.

NX Consulting Tier 1 Values Version 1 - CLEA 2009 (Software Version 1.06)

	Residential with Homegrown Produce.	**Residential without Homegrown Produce.**	**Commercial Industrial with Landscaping**
Active Pathways	• Direct Ingestion • Dermal Contact • Consumption of Vegetables and Attached Soil • Inhalation of Indoor Vapour and Dust • Inhalation of Outdoor Vapours and Dust	• Direct Ingestion • Dermal Contact • Inhalation of Indoor Vapour and Dust • Inhalation of Outdoor Vapours and Dust	• Direct Ingestion • Dermal Contact • Inhalation of Indoor Vapour and Dust • Inhalation of Outdoor Vapours and Dust
Critical Receptors	Female Child 0-6yrs Old	Female Child 0-6yrs Old	Female Adult Worker >17 years old.

Determinand/Units	mg/kg	Source	mg/kg	Source	mg/kg	Source
Arsenic	37	LQM / CIEH S4ULs	40	LQM / CIEH S4ULs	640	LQM / CIEH S4ULs
Cadmium	11	LQM / CIEH S4ULs	85	LQM / CIEH S4ULs	190	LQM / CIEH S4ULs
Mercury (inorganic)	40	LQM / CIEH S4ULs	56	LQM / CIEH S4ULs	1,100	LQM / CIEH S4ULs
Nickel	180	LQM / CIEH S4ULs	180	LQM / CIEH S4ULs	980	LQM / CIEH S4ULs
Selenium	250	LQM / CIEH S4ULs	430	LQM / CIEH S4ULs	1,200	LQM / CIEH S4ULs
Chromium III	910	LQM / CIEH S4ULs	910	LQM / CIEH S4ULs	8,600	LQM / CIEH S4ULs
Chromium VI	6	LQM / CIEH S4ULs	6	LQM / CIEH S4ULs	33	LQM / CIEH S4ULs
Lead	450	C4SLs	450	C4SLs	750	C4SLs
Copper	2,400	LQM / CIEH S4ULs	7,100	LQM / CIEH S4ULs	68,000	LQM / CIEH S4ULs
Zinc	3,700	LQM / CIEH S4ULs	40,000	LQM / CIEH S4ULs	730,000	LQM / CIEH S4ULs
Boron	290	LQM / CIEH S4ULs	1100	LQM / CIEH S4ULs	240,000	LQM / CIEH S4ULs

LQM /CIEH S4ULs Copyright Land Quality Management Limited. Reproduced with permission Publication No. S4UL3671. All right reserved.

Standard Land Use Scenario	Residential with Homegrown Produce			Residential without Homegrown Produce			Commercial			Source
Determinand/SOM	1% SOM	2.5% SOM	6% SOM	1% SOM	2.5% SOM	6% SOM	1% SOM	2.5% SOM	6% SOM	
Naphthalene	*2.3*	*5.6*	*13*	*2.3*	*5.6*	*13*	*190*	*460*	*1100*	LQM / CIEH S4ULs
Acenaphthylene	170	420	920	2900	4600	6000	83000	97000	10000	LQM / CIEH S4ULs
Acenaphthene	210	510	1100	3000	4700	6000	84000	97000	10000	LQM / CIEH S4ULs
Fluorene	170	400	860	2800	3800	4500	63000	68000	71000	LQM / CIEH S4ULs
Phenanthrene	95	220	440	1300	1500	1500	22000	22000	23000	LQM / CIEH S4ULs
Anthracene	2400	5400	1100	31000	35000	37000	520000	540000	540000	LQM / CIEH S4ULs
Fluoranthene	280	560	890	1500	1600	1600	23000	23000	23000	LQM / CIEH S4ULs
Pyrene	620	1200	2000	3700	3800	3800	54000	54000	54000	LQM / CIEH S4ULs
Benzo(a)anthracene	7.2	11	13	11	14	15	170	170	180	LQM / CIEH S4ULs
Chrysene	15	22	27	30	31	32	350	350	350	LQM / CIEH S4ULs
Benzo(b)fluoranthene	2.6	3.3	3.7	3.9	4	4	44	44	44	LQM / CIEH S4ULs
Benzo(k)fluoranthene	77	93	100	110	110	110	1200	1200	1200	LQM / CIEH S4ULs
Benzo(a)pyrene	*2.2*	*2.7*	*3*	*3.2*	*3.2*	*3.2*	*35*	*35*	*35*	LQM / CIEH S4ULs
Indeno(1,2,3-cd)pyrene	27	36	41	45	46	46	500	510	510	LQM / CIEH S4ULs
Dibenz(a,h)anthracene	0.24	0.28	0.3	0.31	0.32	0.32	3.5	3.6	3.6	LQM / CIEH S4ULs
Benzo(ghi)perylene	320	340	350	360	360	360	3900	4000	4000	LQM / CIEH S4ULs
Benzene	*0.087*	*0.17*	*0.37*	*0.38*	*0.7*	*1.4*	*27*	*47*	*90*	LQM / CIEH S4ULs
Toluene	*130*	*290*	*660*	*880*	*1900*	*3900*	*55,600*	*11000*	*18000*	LQM / CIEH S4ULs
Ethylbenzene	*47*	*110*	*260*	*83*	*190*	*440*	*5,700*	*13000*	*27000*	LQM / CIEH S4ULs
Xylenes	*56*	*130*	*310*	*79*	*180*	*430*	*5,900*	*14000*	*30000*	LQM / CIEH S4ULs
Aliphatic C5-C6	*42*	*78*	*160*	*42*	*78*	*160*	*3200*	*5900*	*12000*	LQM / CIEH S4ULs

Standard Land Use Scenario	Residential with Homegrown Produce			Residential without Homegrown Produce			Commercial			Source
Aliphatic C6-C8	*100*	*230*	*530*	*100*	*230*	*530*	*7800*	*17000*	*40000*	LQM / CIEH S4ULs
Aliphatic C8-C10	*27*	*65*	*150*	*27*	*65*	*150*	*2000*	*4800*	*11000*	LQM / CIEH S4ULs
Aliphatic C10-C12	*130*	*330*	*760*	*130*	*330*	*770*	*9700*	*23000*	*47000*	LQM / CIEH S4ULs
Aliphatic C12-C16	*1100*	*2400*	*4300*	*1100*	*2400*	*4400*	*59000*	*82000*	*90000*	LQM / CIEH S4ULs
Aliphatic C16-C35	*65000*	*92000*	*110000*	*65000*	*92000*	*110000*	*1600000*	*1700000*	*1800000*	LQM / CIEH S4ULs
Aliphatic C35-44	*65000*	*92000*	*110000*	*65000*	*92000*	*110000*	*1600000*	*1700000*	*1800000*	LQM / CIEH S4ULs
Aromatic C5-C7	*70*	*140*	*300*	*370*	*690*	*1400*	*26000*	*46000*	*860000*	LQM / CIEH S4ULs
Aromatic C7-C8	*130*	*290*	*660*	*860*	*1800*	*3900*	*56000*	*110000*	*180000*	LQM / CIEH S4ULs
Aromatic C8-C10	*34*	*83*	*190*	*47*	*110*	*270*	*3500*	*8100*	*17000*	LQM / CIEH S4ULs
Aromatic C10-C12	*74*	*180*	*380*	*250*	*590*	*1200*	*16000*	*28000*	*34000*	LQM / CIEH S4ULs
Aromatic C12-C16	*140*	*330*	*660*	*1800*	*2300*	*2500*	*36000*	*37000*	*38000*	LQM / CIEH S4ULs
Aromatic C16-C21	*260*	*540*	*930*	*1900*	*1900*	*1900*	*28000*	*28000*	*28000*	LQM / CIEH S4ULs
Aromatic C21-C35	*1100*	*1500*	*1700*	*1900*	*1900*	*1900*	*28000*	*28000*	*28000*	LQM / CIEH S4ULs
Aromatic C35-C44	*1100*	*1500*	*1700*	*1900*	*1900*	*1900*	*28000*	*28000*	*28000*	LQM / CIEH S4ULs
Aromatic+aromatic EC>44-70	*1600*	*1800*	*1900*	*1900*	*1900*	*1900*	*28000*	*28000*	*28000*	LQM / CIEH S4ULs
Phenol	280	550	1100	750	1300	2300	760	1500	3200	LQM / CIEH S4ULs
Cyanide	527			527			1400			*CLEA 2009*

Standard Land Use Scenario	Residential with Homegrown Produce	Residential without Homegrown Produce	Commercial	Source
PCBs	1.7	1.8	1.8	*CLEA 2009*

LQM /CIEH S4ULs Copyright Land Quality Management Limited. Reproduced with permission Publication No. S4UL3671. All right reserved.