

GROUNDTECH
CONSULTING

Job title:	Brunswick Mill
Report type:	Geo-Environmental Appraisal
Prepared for:	Arrowsmith Investments Limited
Date:	July 2023

Document Control Form	
PROJECT	*BRUNSWICK MILL*
REPORT NAME	*GEO-ENVIRONMENTAL APPRAISAL*
REPORT REFERENCE	*GRO-22462-4516*
STATUS	*FINAL*
ISSUE DATE	*05 JULY 2023*
REVISION	
CLIENT	*ARROWSMITH INVESTMENT LIMITED*
CLIENT CONTACT	*JASON DONES*
For and Behalf of Groundtech Consulting	
SIGNATURE	
AUTHOR	Jacob Roby BSc (Hons)
SIGNATURE	
CHECKED	Richard Wyatt MEng (Hons) FGS
SIGNATURE	
REVIEWED	James Doyle BSc (Hons) CGeol FGS

SUMMARY

Site Details	
Site Location	*The site is located circa 2.0km east of Manchester City Centre and is approximately centred on National Grid Reference 393530, 398720.*
Site Area	*The site is irregular in shape and covers an area of approximately 1.11 hectares. The topography of the site is generally level, with a gentle incline in the south west.* *The site currently consists of Brunswick Mill in the north east, and the area of land which previously contained India Mills to the south west. The Ashton Canal and towpath are to the immediate south west.*
Ground Model	
Made Ground Soils	*Made Ground was encountered beneath the site to depths of between 2.3m and 4.0m bgl where fully penetrated in WS08, WS10, WS11, TP05 to TP07 and BH01 to BH03.* *The surfacing generally consisted of a mixture of cobbles and concrete. The remainder comprised variably clayey gravelly sand, gravelly sandy clay and sandy clayey gravel. The minor constituents included brick, concrete, ceramics, plastic, fabric, sandstone, wood, slate, ash, tarmac, slag and glass.*
Natural Soils	*Firm becoming stiff with depth grey brown variably cobbly gravelly sandy silty Clay with minor constituents of shale, coal, and sandstone was encountered in BH1, BH2, BH3, HP02, TP05 to TP07, WS08, WS10 and WS11 from depths between 1.0m and 4.0m bgl to depths of up to 17.8m bgl.* *Medium dense brown variably clayey Sand was present in BH2 and WS10 from depths between 3.0m and 15.2m bgl to depths between 3.5m and 15.5m bgl.*
Bedrock	*Weathered Sandstone deposits recovered as dense to very dense brown sandy silty clayey Gravel and gravelly sandy Cobbles were observed in BH1 from 13.0m to 17.0m bgl and in BH3 from 14.0m to 15.0m bgl.* *More competent bedrock was encountered in the form of very weak to weak red brown fine grained Sandstone in BH1 to BH3 from depths between 15.5m and 17.8m bgl to depths between 24.0m to 26.0m bgl where the deeper boreholes were terminated.*
Groundwater	*Perched groundwater was encountered in the Made Ground of HP04, HP07, HP08, HP09, HP10, TP01 and TP04 at depths of between 1.0m and 3.0m bgl.* *Groundwater was in BH3 at 20.0m bgl in the Sandstone and in WS11 at 3.45m bgl in the sandy Clay.*
Ground Engineering Assessment	
Foundations	*The most suitable solution for the proposed apartment development is considered to be piled foundations transferring loads through the underlying Made Ground and natural Clay and Sand strata to the very weak Sandstone which has been encountered between 15.5m and 17.8m bgl. The most suitable type of pile for the development is considered to be Continuous Flight Auger (CFA) bored pile, this should be discussed with the preferred piling contractor.* *The development layout needs to consider an easement associated with the canal along the northern and western boundary.*

Archaeology	*There are archaeological restrictions on the site that require consideration.*
Concrete	*The results of laboratory pH and sulphate content indicate that ACEC Class AC-3 and sulphate class DS-3 conditions prevail in accordance with BRE Special Digest 1 "Concrete in aggressive ground" 2005.*
Highways / Pavements	*CBR values of 2% to 5% are likely to be achieved in any shallow undisturbed natural soils for pavement design purposes. Untreated Made Ground should be assumed to have a CBR value of less than 2.5%, unless proven otherwise.*
SuDS	*SuDS drainage is unlikely to be a feasible option at the site due to the presence of deep Made Ground and natural cohesive soils beneath the site which are capable of poor infiltration rates.*
Constraints	*The main constraints associated with the site include the following:* • *Deep Made Ground up to 4.0m bgl.* • *Relic structures and obstructions encountered within the trial pits, including brick walls, concrete slabs, and the partially demolished walls from the previous methodist chapel.* • *Easement associated with the adjacent canal.* • *Stockpiles of waste and fly tipping against the side of the external mill walls, including multiple LPG gas cannisters.* • *Existing tank located adjacent to the existing mill on the north western boundary. This will need decommissioning and removal offsite.* • *Incline towards the Ashton Canal towpath in the south west of the site.* • *6F2 stockpile running adjacent to the north western site boundary.* • *Heterogenous nature of the Made Ground.* • *Perched groundwater.* • *Instability in Made Ground as observed in the trial pits.*
GQRA and Revised (PL) Assessment	
Human Health	*Geo-environmental testing has recorded elevated concentrations of metals and PAHs within the granular Made Ground soils. In addition, elevated concentrations of hydrocarbons were recorded in HP11 which was excavated adject to an above ground tank. Asbestos was detected in two of thirty-two samples that were screened.* *It is proposed to develop the site with apartments which will include areas of soft landscaping therefore the risk to human health is considered to be Moderate.*
Vapours	*Potential sources of volatiles have been identified and the risk from vapours is considered to be Moderate to High.*
Controlled Waters	*Groundwater testing indicates that elevated concentrations of Nickel, Zinc and PAHs are present in the samples that were taken from beneath the site. The site has historically been surrounded by industrial premises which are indicated to be the source of the contamination. In addition, the site is underlain by natural cohesive deposits which will have prevented the downward migration of potential contaminants. At present, the risk to groundwater is Moderate to Low and a second round of groundwater monitoring is required. The risk to nearby surface water is Low.*
Permanent Ground Gas	*Interim gas monitoring results currently place the site into CS2 and gas protection measures will be required. This will be confirmed upon completion of the monitoring. The site is also located in an area*

requiring basic radon precautions within foundations. In addition, allowance should be made for the membrane to be resistant to vapours as well. The risk from permanent ground gases is Moderate to High.

Final Appraisal

The following work is considered necessary in order to progress the site to the construction phase:

- *Completion of gas monitoring programme*
- *Issue gas assessment*
- *Second round of groundwater testing*
- *Further environmental testing of 6F2 stockpile if utilised*
- *Removal of piles of waste and fly tipping in the external area*
- *Demolition and Refurbishment Asbestos survey*
- *Production of Remedial Specification*
- *Vapour modelling, if required*
- *Tree survey by qualified arboriculturist*
- *Detailed foundation design*
- *Confirmation of the recommendations made within this report with the Regulators*

TABLE OF CONTENTS

1.0 INTRODUCTION 1

1.1 Project Objectives 1
1.2 Proposed Development 1
1.3 Limitations 1

2.0 SITE SETTING 3

2.1 Location 3
2.2 Site Description 3

3.0 PREVIOUS INVESTIGATION SUMMARY 5

3.1 Previous Investigation 5
3.2 Phase 1 Report Summary 5
3.3 Investigatory of Works 6
3.4 Ground Model 7
3.5 Geo-Environmental Testing 8

4.0 SCOPE OF INVESTIGATION AND RATIONALE 9

4.1 Project Objectives 9
4.2 Scope of Works 9
4.3 Soil Sampling 10
4.4 Geo-Environmental Testing 10
4.5 Gas and Groundwater Monitoring 11
4.6 Groundwater Sampling 12

5.0 GROUND MODEL 13

5.1 Made Ground 13
5.2 Natural Ground 14
5.3 Bedrock 14
5.4 Groundwater 14
5.5 Watching Brief 15
5.6 Excavation/Borehole Stability 15
5.7 Excavation/Borehole Progress 16

6.0 GROUND ENGINEERING 17

6.1 Geotechnical Testing Results 17
6.2 Existing Foundations 17
6.3 Assessment Background 19
6.4 Geotechnical Parameters 20
6.5 Preliminary Foundation Design 21
6.6 Building Near Trees 23
6.7 Floor Slabs 24
6.8 Construction 24
6.9 Concrete Classification 24
6.10 Highway / Pavement Design 25
6.11 Sustainable Urban Drainage System (SuDS) 25

7.0 LAND QUALITY 26

7.1 Geo-Environmental Testing Results - Soils 26
7.2 Generic Quantitative Risk Assessment - Soils 30
7.3 Geo-Environmental Testing Results - Groundwater 31
7.4 Generic Quantitative Risk Assessment - Groundwater 34

7.5 Permanent Ground Gases 35
7.6 Revised Pollution Linkage Assessment 37
7.7 Outline Remedial Strategy 44
7.8 Asbestos in Soils 45
7.9 Health and Safety - Construction and Ground Workers 45
7.10 Waste Classification by Assessment 46
7.11 Waste Acceptance Criteria (WAC) Results 46

8.0 FINAL APPRAISAL 48

8.1 Land Quality 48
8.2 Ground Engineering 48
8.3 Required Further Work 49

9.0 RELEVANT INDUSTRY REFERENCES 50

APPENDIX 1 - Plans
APPENDIX 2 - Site Photographs
APPENDIX 3 - Exploratory Hole Logs
APPENDIX 4 - Geo-Environmental Testing Results (Soils)
APPENDIX 5 - Geo-Environmental Testing Results (Groundwater)
APPENDIX 6 - Geotechnical Testing Results
APPENDIX 7 - Interim Gas Monitoring Results
APPENDIX 8 - Generalised Ground Model
APPENDIX 9 - Generic Screening Values (Residential without Plant Uptake)
APPENDIX 10 - CIRIA Risk Assessment Methodology
APPENDIX 11 - JIWG Receptor Decision Tool
APPENDIX 12 - Waste Classification Report
APPENDIX 13 - Relevant Legislative Background
APPENDIX 14 - Limitations

Plans		
Plan Reference	*Revision*	*Title*
GRO-22462-P01	-	*Project Location Plan*
GRO-22462-P02	-	*Exploratory Hole Location Plan*
GRO-22462-P03	-	*Obstructions Plan*
GRO-22462-P04A – P04M	-	*Foundation Cross Sections*
GRO-22462-P05	-	*Generalised Ground Model*
GRO-22462-P06	-	*Contamination Plan*
GRO-22462-P07	-	*Illustrative Revised CSM*

1.0 INTRODUCTION

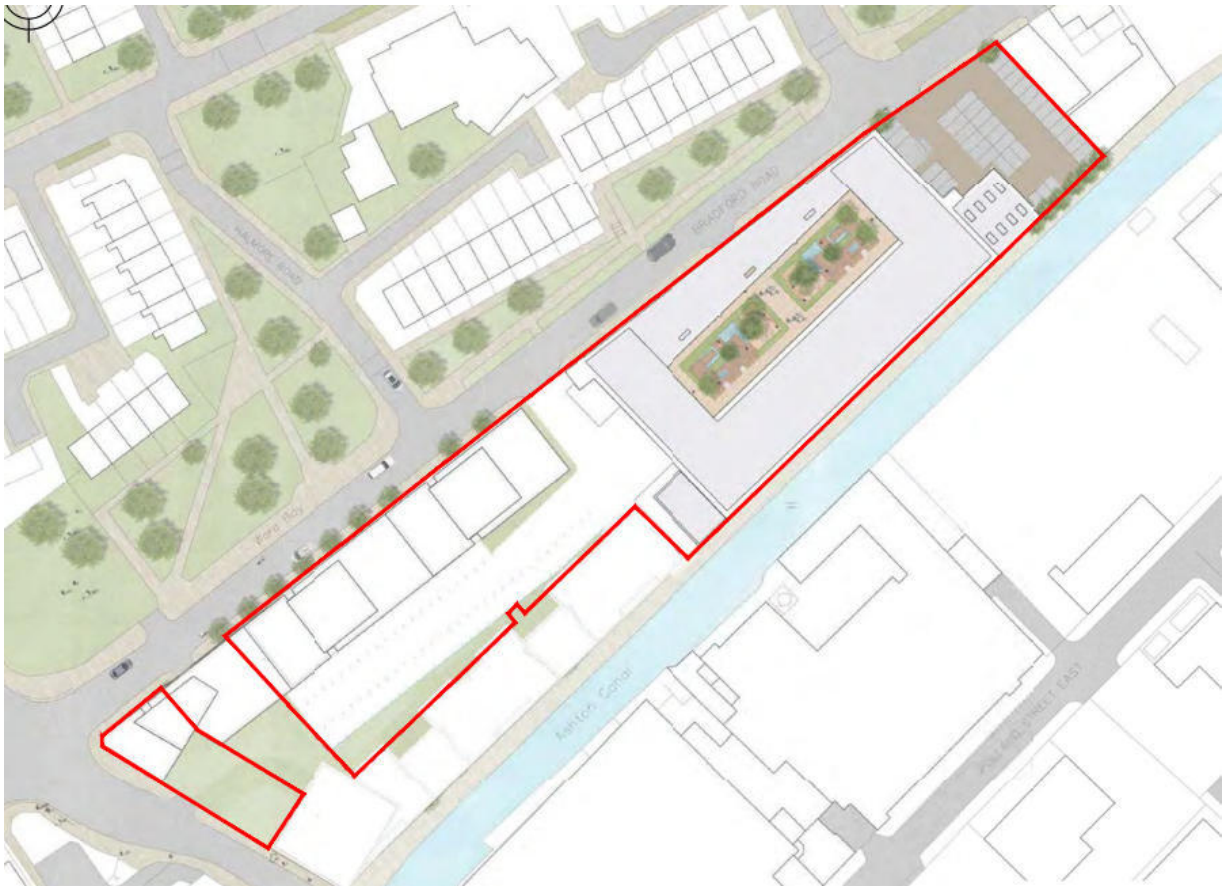
1.1 Project Objectives

Groundtech Consulting Limited have been instructed by Civic Engineers on behalf of Arrowsmith Investment Limited to undertake a Ground Investigation at Brunswick Mill in Manchester.

The investigation was undertaken in accordance with BS 5930:2020, BS 10175:2017, BS 8576:2013 and Eurocode 7. The Appraisal has been prepared in accordance with current UK Legislation and to discharge Land Quality pre-commencement planning conditions.

1.2 Proposed Development

The proposed development is residential end use comprising the redevelopment of the current mill building into 153 No. residential apartments, and the construction of two additional blocks containing 124 No. residential apartments on the adjacent land to the south west.



Proposed Development

1.3 Limitations

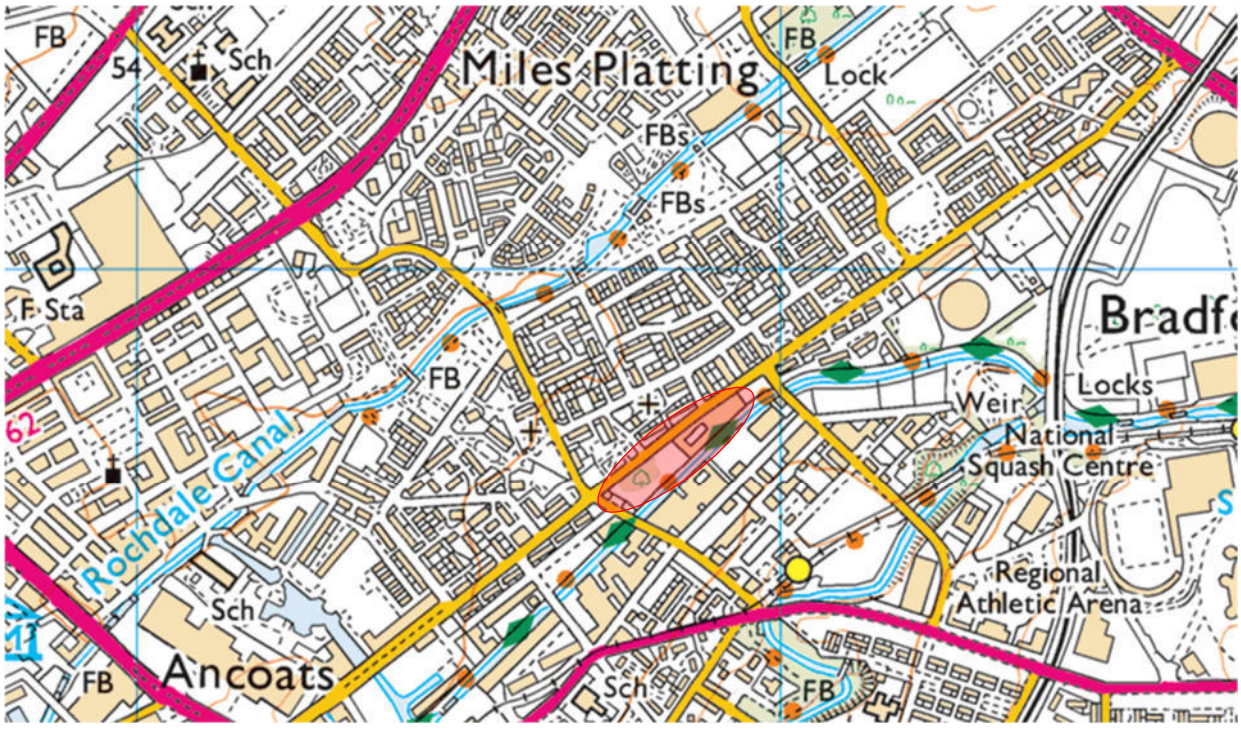
Other conditions may exist on the site that have not been taken into account in this assessment as they are outside the scope of works. Groundtech Consulting are not responsible for these circumstances that are not outlined in the report.

The assessment has been prepared for the exclusive use of the client. No third parties may rely on or reproduce the contents of the report without the written permission of Groundtech Consulting Limited. If any unauthorised third party comes into possession of the report, they rely on it at their own risk and Groundtech Consulting Limited will not be obliged to provide a duty of care.

2.0 SITE SETTING

2.1 Location

The site is located circa 2km east of Manchester City Centre, as shown on the Project Location Plan *GRO-22462-P01* and is approximately centred on National Grid Reference 393530, 398720.



Project Location

Access to the site is gained off Bradford Road to the north west.

2.2 Site Description

The site is irregular in shape and covers an area of approximately 1.11 hectares. The topography of the site is generally level with an approximate 2.0m incline in the south west towards the Ashton Canal towpath.

Site Features
The site currently consists of Brunswick Mill in the north eastern half of the site, and an area of undeveloped land which previously contained India Mills to the south west. The Ashton Canal towpath runs adjacent to the external area alongside the canal in the south east.

Brunswick Mill is four to seven storeys in heigh and is of brick construction with many of the windows being bricked up as well. A number of bricked archways are present at ground floor level. Midway along the north western elevation of the mill building is a larger archway which leads to the central part of the site. The mill building spans the width of the site from Bradford Road to Ashton Canal.

An old above ground steel tank is present along the southern elevation of the mill building adjacent to Bradford Road. The tank is located in a brick bund.

To the south west of the mill building is an area of derelict land which is covered with stone and rough vegetation. Across this area are several soil bunds formed from demolition waste. A stockpile of 6F2 material is present alongside the north west boundary on the footprint of the proposed properties.

A gravel access track leads from the south western corner of the site to a raised area of gravel which runs adjacent to the canal and was probably formerly used for car parking.

Terraced houses and a methodist chapel previously existed in the south west corner block on the southern boundary of the site before it was partially demolished in 2018. A relic brick wall of this building exists on this area above a suspected LP gas main.

Stockpiles of waste, litter and fly tipping are present scattered around the central area of the external site adjacent to the existing Brunswick Mill building. This includes multiple LPG gas cannisters.

Boundaries and Surrounding Features

The site boundaries are formed by a mixture of brick walls and metal fences.

The site is surrounded by the following features/land uses:

- *North - Garage, Bradford Road and residential properties.*
- *East - Ashton Canal and industrial units.*
- *South - Beswick Street, Ashton Canal and commercial properties.*
- *West - Bradford Road and residential properties.*

Site photographs are presented in *Appendix 2* and any relevant features are recorded on the Preliminary Development Constraints Plan *GRO-22462-P02*.

3.0 PREVIOUS INVESTIGATION SUMMARY

3.1 Previous Investigation

A previous Phase 1 and Phase 2 investigation was undertaken by LK Consult Limited, with the Phase 1 report referenced *LKC 18 1200* being published in June 2018, and the Phase 2 Ground Investigation referenced *LKC 21 1683* being undertaken in November 2021. A summary of the reports is presented below.

3.2 Phase 1 Report Summary

Historical Map Consultation
Brunswick Mill (north east site area):

- *Existed since the mid-19th century.*
- *Chimney was constructed in the south west corner in 1908.*
- *Split and used as warehouse, works, and depot in the mid-1960s.*
- *Works annotated as 'clothing factory' in 1968.*
- *Whole building annotated as 'warehouse' in 1989.*

India Mills (south west site area):

- *Existed since the mid-19th century.*
- *Annotated as Manchester Works (finishing and storage) by 1908.*
- *Changed to Emka Works by 1949.*
- *Annotated as clothing works/factory in mid to late 1960s.*
- *Demolished by 2006.*

Corner Block (south west corner of the site):

- *Terraced houses existed since late 19th century.*
- *Demolished and replaced by Methodist Chapel since 1908.*
- *Building disused since 1953.*
- *Partially demolished in 2018.*

Geology and Hydrogeology
Made Ground is recorded beneath the site and is underlain by superficial Glacial Till and the Etruria Formation (Sandstone) bedrock. The Glacial Till is classified as a Secondary (Undifferentiated) Aquifer, and the Etruria Formation is indicated to be a Secondary A Aquifer.

The site is not within a SPZ.

Hydrology
The nearest surface water feature is the Ashton Canal immediately south west.

There are no groundwater abstractions within 1km of the site.

The site is not at risk from river or coastal flooding. There is potential for groundwater flooding below ground level in the east of the site. There are two surface water abstractions within 250m, one of them being c.6m north east in the Ashton Canal.

A discharge consent is located c.222m south east relating to storm sewage overflow.

The nearest pollution incident occurred c.53m west in 1996, with green oil residue in the Ashton Canal. It was labelled as a category 3 – minor impact.

Mining

- *The site is not within a Development High Risk Area.*
- *The site is in a surface area that could be affected by underground mining in four seams of coal at 200m to 1,100m depth, last worked in 1961.*
- *There are no mine entries within 20m of the site.*
- *The Holt Town brick field was located c.79m east, which consisted of opencast extraction of clay and shale. This operation has since ceased.*

Landfills

No known landfills are located within 250m of the site. The nearest is c.312m east, Cambrian Street Depot, which deposits inert waste. Two potential landfills are located within 250m, these include a brickfield c.20m south, potentially infilled by 1893, and a reservoir located c.160m south east, also infilled by 1893.

Radon

The radon potential for the site is indicated to be <1%. (However, the new radon maps published in December 2022 show the site to be in an area where the probability is 5 to 10% and basic radon measures will be required).

Potential Contaminants

There have been several sources of potential contamination outlined, including former buildings on site, Made Ground, Cotton Mill and Clothing Works, garage to the north east, offsite chemical works (tar distillery), offsite potentially infilled ground, and surrounding industries. These could be potential sources of asbestos, ash, clinker, heavy metals, PAHs, sulphates, inorganic compounds, solvents, soaps, detergents, TPHs, and ground gases.

Conceptual Site Model

The overall risk to human health was considered to be *Moderate,* and the overall risk to groundwater was considered to be *Moderate to Low*.

An intrusive site investigation including chemical testing, geotechnical testing, and gas standpipe monitoring was recommended.

3.3 Investigatory of Works

The following scope of works was undertaken by LK Consult Limited on the 10th and 11th November 2021:

- *13 No. windowless sample boreholes (WS101 to WS110) were advanced to depths between 0.9m and 5.45m bgl.*
- *4 No. hand pits (HD1 to HD4) were dug to depths between 0.3m and 1.2m bgl.*

3.4 Ground Model

Surfacing
The surfacing of the mill courtyard (WS101 to WS104 and HD1 to HD4) generally comprised concrete, with cobble flagstone encountered locally in HD4, WS102B, WS103 and WS104. WS108 was undertaken on the north western site boundary, and was also surfaced by concrete.

Made Ground
Three main populations of Made Ground were encountered during the investigation and are described below:

- *Dark grey red/brown black sandy silty gravel with constituents of brick, ash, clinker, breezeblock, coal, glass, concrete, and rootlets was encountered in HD1, HD2, HD4, WS102, WS102B, WS103, WS104, WS105, WS105B, WS107, WS109, and WS110 from depths between ground level and 0.1m bgl to depths between 0.55m and 1.65m bgl.*

- *Brown grey gravelly silty sand with minor constituents of brick, coal, ash, clinker, and timber was encountered in HD1, HD2, WS101, WS106, WS108 from depths between ground level and 0.25m bgl to depths between 0.55m and 2.15m bgl.*

- *Brown gravelly sandy silty clay with minor constituents of brick, ash, coal, plastic, timber, tile, and aluminium was encountered in HD1, HD2, WS101, WS102B, WS103, WS104 and WS107B from depths between ground level and 1.2m bgl to depths between 0.9m and 2.0m bgl.*

Locally to WS101, brown gravelly sandy silt with minor constituents of brick and coal was encountered from a depth of 0.55m bgl to a depth of 0.7m bgl.

Locally to HD3, sandstone was encountered from a depth of 0.15m to 0.3m bgl.

Natural Strata
Two main stratifications were encountered during the investigation and are described below:

- *Firm to stiff grey brown gravelly sandy variably silty Clay in WS101, WS102B, WS103, and WS104 from depths between 1.2m and 2.0m bgl to depths of up to 5.45m bgl.*

- *Stiff to very stiff dark brown orange/grey Clay was encountered in WS106, WS109, and WS110 from depths between 1.6m and 2.0m bgl to depths between 4.35m and 5.45m bgl.*

Monitoring standpipes were installed in WS101, WS103, WS104, WS106, WS108, and WS109 to depths between 2.0m and 4.5m bgl.

Bedrock
Bedrock was not encountered during the investigation.

Groundwater
No groundwater was encountered during the investigation.

Watching Brief
Visual evidence of contamination was recorded in the form of ash and clinker in the Made Ground soils. Olfactory evidence of contamination was recorded in the form of a hydrocarbon odour in WS102B, WS103, WS104, and WS105B.

Evidence of instability was noted in WS109 after the borehole collapsed to 2.0m bgl.

3.5 Geo-Environmental Testing

Testing for various Contaminants of Concern (CoCs) was undertaken on 19 No. samples of the Made Ground and 4 No. samples of the natural strata.

The environmental testing targeted the following CoCs - heavy metals, speciated PAHs, asbestos, TPH CWG, VOCs, cyanide, and phenols. A number of CoCs were recorded above the generic screening values for residential development (with plant uptake) and are summarised below:

- *Arsenic*
- *Lead*
- *Naphthalene*
- *Fluorene*
- *Phenanthrene*
- *Fluoranthene*
- *Benzo(a)anthracene*
- *Chrysene*
- *Benzo(b)fluoranthene*
- *Benzo(a)pyrene*
- *Indeno(123-cd)pyrene*
- *Dibenzo(ah)anthracene*
- *Aromatic TPH CWG C12-C16*
- *Aromatic TPH CWG C16-C21*
- *Aromatic TPH CWG C21-C35*

The sources of these elevated contaminants are likely to be the historic cotton and textile industry activity, the tank on the north western boundary adjacent to Brunswick Mill, activity from the Ashton Canal to the east, activity from the surrounding industries including the MOT garage to the north east, and the construction and demolition of the India Mills, terraced houses and methodist chapel in the external site.

4.0 SCOPE OF INVESTIGATION AND RATIONALE

4.1 Project Objectives

The aim of the Groundtech Consulting fieldwork was to:

Determine the stratification beneath the site.
Maintain a watching brief for visual and olfactory evidence of contamination.
Obtain samples using methodology in current guidance for contamination analysis.
Identify realistic pollution linkages to groundwater.
Obtain relevant geotechnical parameters for preliminary foundation design to address both ULS and SLS conditions.
Determine geometrics of existing foundations.
Determine if targeted supplementary investigation in areas of concern is required and for remedial design.
Install monitoring standpipes for gas and groundwater monitoring.
Assess the identified pollution linkages in the CSM.

4.2 Scope of Works

The following scope of works was completed between the dates of 2nd May and 12th May 2023:

- *15 No. windowless sample boreholes (WS01 to WS11) were advanced to depths between 0.1m and 4.0m bgl using a Dando Terrier rig.*
- *7 No. machine excavated trial pits (TP01 to TP07) were advanced to depths between 1.5m and 3.0m using a JCB 3CX excavator.*
- *3 No. cable percussive boreholes (BH1 to BH3) were advanced to depths between 16.0m and 20.0m bgl.*
- *3 No. rotary core follow on boreholes were advanced in BH1 to BH3 to depths between 22.0m and 26.0m bgl.*
- *14 No. hand excavated trial pits (HP01 to HP13A) were excavated to depths between 0.5m and 1.2m bgl.*

On completion of the works, the exploratory were surveyed in.

The exploratory hole locations are presented on Groundtech Plan *GRO-22462-P03* and the exploratory hole logs are in *Appendix 3*.

The exploratory holes were positioned to establish the stratification beneath the site, and target any areas of concern as summarised in the table below:

Location	Target Rationale
BH1 to BH3	*Proposed new build apartment blocks*
WS01 to WS08 *TP01, TP02, TP04 to TP07*	*General coverage (external site)*
WS09 to WS11	*General coverage (mill courtyard)*
TP03	*6F2 stockpile*
HP11	*Former fuel tank*

HP01 to HP04, HP11, HP12	*Determine geometry of existing external wall foundations*
HP05, HP06, HP09, HP10	*Determine geometry of existing internal wall foundations*
HP07, HP08	*Determine geometry of existing internal column foundations*
HP13, HP13A	*Expose presence of LP gas main*

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

- *BS 5930 'Code of Practice for Site Investigations' 2015.*
- *BS EN 14688-1:2002 'Geotechnical Investigation and Testing – Identification and classification of soil'.*
- *BS EN ISO 14689:2002 'Geotechnical investigation and testing – Identification and classification of rock'.*

4.3 Soil Sampling

During the intrusive investigation, representative samples were taken at regular intervals, changes of strata and where evidence of contamination existed. Laboratory analysis was scheduled on the samples obtained.

The samples obtained are summarised in the table below:

Soil Sample	Number
Environmental Sample	*82*
Disturbed Sample	*56*
Undisturbed U100 Sample	*10*

The samples have been obtained in accordance with current environmental and geotechnical guidance. The sampling plan has been designed to obtain samples from all required strata using the correct methodology.

Disturbed samples of soil for geo-environmental testing were placed in the correct sampling containers as required by the laboratory in accordance with their MCERTS and UKAS Accreditation. Transportation was arranged in a timely manner and the samples were at the correct temperature.

The sample locations and depths are recorded on the exploratory logs.

4.4 Geo-Environmental Testing

To inform the Generic Quantitative Risk Assessment, the following geo-environmental testing was scheduled to assess the risk from contamination on the site. The testing is based on the potential sources identified in the PRA and observations made during the Ground Investigation.

Contaminants of Concern	Matrix	Number
Arsenic, Cadmium, Chromium (total and hexavalent), Copper, Lead, Mercury, Nickel, Selenium, Zinc, Organic Matter, Sulphate, and pH.	*Soil*	*32*
Speciated Polycyclic Aromatic Hydrocarbons (PAHs)	*Soil*	*32*
Asbestos Screening	*Soil*	*32*
Asbestos Quantification	*Soil*	*2*
Total Petroleum Hydrocarbons (TPH CWG)	*Soil*	*11*

Volatile Organic Compounds (VOCs)	*Soil*	*5*
Semi Volatile Organic Compounds (SVOCs)	*Soil*	*2*

Arsenic, Cadmium, Chromium (total and hexavalent), Copper, Lead, Mercury, Nickel, Selenium, Zinc, Organic Matter, Sulphate, and pH.	*Groundwater*	*2*
Speciated Polycyclic Aromatic Hydrocarbons (PAHs)	*Groundwater*	*2*
Total Petroleum Hydrocarbons (TPH CWG)	*Groundwater*	*2*
Volatile Organic Compounds (VOCs)	*Groundwater*	*2*
Semi Volatile Organic Compounds (SVOCs)	*Groundwater*	*2*
DOC and CaCO3	*Groundwater*	*2*

The Geo-Environmental Laboratory Soil Testing Results are presented in *Appendix 4* and the Groundwater Testing Results are in *Appendix 5.*

Representative disturbed samples were obtained for all soil types encountered. Selected samples were scheduled for testing at an approved laboratory in accordance with BS 1377 'Method of Test for Soils for Civil Engineering Purposes' 1990. The following tests were scheduled:

British Standard	Test Method	Number
Part 2	*Plasticity Index Analysis*	*5*
Part 2	*Water Content*	*5*
Part 3	*pH Value*	*5*
Part 3	*Water Soluble Sulphate*	*5*
Part 7	*Undrained Shear Strength in Triaxial Compression*	*4*
Part 5	*Unconfined Compression Test (UCS)*	*3*

The Geotechnical Laboratory Testing Results are presented in *Appendix 6*.

4.5 Gas and Groundwater Monitoring

Gas and groundwater monitoring installations were constructed in the boreholes. The standpipes consisted of polyvinyl chloride (PVC) and high-density polyethylene (HDPE) pipe - a bentonite seal was placed around the plain pipe and a clean gravel pack was placed around the slotted pipe. A summary of the installation construction is presented in the table below:

Location	Depth (m bgl)	Response Zone (m bgl)	Targeted Strata	Reason
BH3	*3.00*	*1.00 – 3.00*	*Made Ground/Clay*	*Ground Gas*
WS02A	*2.00*	*1.00 – 2.00*	*Made Ground*	*Ground Gas*
WS05	*2.00*	*1.00 – 2.00*	*Made Ground*	*Ground Gas*
WS07A	*1.50*	*1.00 – 1.50*	*Made Ground*	*Ground Gas*
WS08	*4.00*	*1.00 – 4.00*	*Made Ground/ Clay*	*Ground Gas*
BH1	*24.00*	*18.00 – 24.00*	*Sandstone*	*Ground Gas/Groundwater*
BH2	*21.00*	*18.00 – 21.00*	*Sandstone*	*Ground Gas/Groundwater*
BH3	*21.00*	*18.00 – 21.00*	*Sandstone*	*Ground Gas/Groundwater*

Permanent gas and flow rate monitoring was carried out using a GFM 436 infrared gas monitor with integral electronic flow analyser. The measurements taken are listed below:

- *Oxygen (O_2), carbon dioxide (CO_2) and methane (CH_4) as the percentage volume in air (%v/v).*
- *Hydrogen sulphide (H_2S) and carbon monoxide (CO) as the percentage volume in air (%v/v).*
- *Lower Explosive Limit (%LEL) of methane.*
- *Atmospheric and borehole pressure, including pressure trend.*
- *Flow measurements (l/hr).*
- *Weather conditions.*

Both peak and steady state conditions were monitored to understand the behaviour of the permanent ground gas, the steady state conditions were recorded by allowing the gas monitor to run for a minimum of 3 minutes.

Interim gas and groundwater monitoring results are presented in *Appendix 7*.

4.6 Groundwater Sampling

Well development was carried out to ensure no cross contamination from the drilling activities remained in the water column in the well. During the return visit, the installations were purged to a minimum three times the volume of the water column in the borehole prior to sampling. Purging was undertaken at a slower rate than the well development, and the sampling at a slower rate again.

The method of sampling selected was using a low flow pump due to the contamination identified during the Ground Investigation. Groundwater samples were taken from BH01 and BH03.

Where possible, a water meter was used to test the pH, temperature, and conductivity before sampling until equilibrium conditions were met, in accordance with BS 10175 guidelines.

Samples were sent to the UKAS Accredited laboratory the same day sampling was carried out in general accordance with BS 5930 and BS 5667.

5.0 GROUND MODEL

5.1 Made Ground

Made Ground was encountered beneath the site to depths of between 2.3m and 4.0m bgl where fully penetrated in WS08, WS10, WS11, TP05 to TP07 and BH01 to BH03.

Surfacing
Different surfacing was encountered within the existing Mill courtyard and interior. WS09 to WS11 and HP01 to HP03 were surfaced by cobbles to a maximum depth of 0.2m bgl. HP04, HP06, HP09, and HP10 were surfaced by concrete to a maximum depth of 0.2m bgl. HP05, HP07, and HP08 were surfaced by chipboard and wooden planks to a maximum depth of 0.2m bgl.



Exploratory Hole Locations

Three main Made Ground populations were recorded during the investigation and are described below:

- *Dark brown, grey or black ashy variably clayey to gravelly sand with a high cobble content of brick and minor constituents of concrete, ceramics, plastic, fabric, sandstone, wood, slate, ash, tarmac, slag and glass was the main Made Ground strata encountered in the majority of locations across the site from depths between ground level and 0.15m bgl to depths between 0.1m and 3.0m bgl.*

- *Brown grey gravelly sandy clay with minor constituents of brick, concrete, sandstone and shale was encountered in BH1, BH2, WS11, HP04, HP06 and HP07 from depths between 0.2m and 3.0m bgl to depths between 0.7m and 4.0m bgl.*

- *Dark grey to black slightly sandy slightly clayey gravel of brick, concrete, metal, rubber, fabric, wood, tarmac, sandstone, and plastic was encountered in TP01, TP05, TP06, HP13 and HP13A from depths between ground level and 0.55m bgl to depths between 1.2m and 2.7m bgl.*

The following exploratory were terminated in the Made Ground:

Location	Depth (m bgl)	Reason
WS01	*0.20*	*Concrete obstruction*
WS01A	*1.20*	*SPT refusal*
WS02	*0.20*	*Sandstone obstruction*
WS02A, WS03 to WS05	*2.00*	*SPT refusal*
WS06	*0.60*	*Brick obstruction*
WS06A	*0.60*	*Concrete obstruction*
WS07	*0.80*	*Concrete obstruction*
WS07A	*1.95*	*SPT refusal*
WS09	*0.90*	*Drain*
TP01	*2.20*	*Concrete slab*
TP02	*1.80*	*Concrete slab*

5.2 Natural Ground

The natural strata encountered generally confirmed the published geological records. Two main natural stratifications were encountered during the investigation and are described below:

- *Firm becoming stiff with depth grey brown variably cobbly gravelly sandy silty Clay with minor constituents of shale, coal, and sandstone was encountered in BH1, BH2, BH3, HP02, TP05 to TP07, WS08, WS10 and WS11 from depths between 1.0m and 4.0m bgl to depths of up to 17.8m bgl.*

- *Medium dense brown variably clayey Sand was present in BH2 and WS10 from depths between 3.0m and 15.2m bgl to depths between 3.5m and 15.5m bgl.*

5.3 Bedrock

Weathered Sandstone recovered as dense to very dense brown sandy silty clayey Gravel and gravelly sandy Cobbles were observed in BH1 from 13.0m to 17.0m bgl and in BH3 from 14.0m to 15.0m bgl.

More competent bedrock was encountered in the form of very weak to weak red brown fine grained Sandstone in BH1 to BH3 from depths between 15.5m and 17.8m bgl to depths between 24.0m to 26.0m bgl where the deeper boreholes were terminated.

5.4 Groundwater

Groundwater was encountered in the following exploratory holes:

Location	Depth (m bgl)	Stratum
BH3	*20.00*	*Sandstone*
HP04	*1.20*	*Made Ground*
HP07	*1.00*	*Made Ground*
HP08	*1.20*	*Made Ground*
HP09	*1.20*	*Made Ground*
HP10	*1.00*	*Made Ground*
TP01	*1.30*	*Made Ground*
TP04	*3.00*	*Made Ground*
WS11	*3.45*	*Sandy Clay*

No groundwater was encountered in the remaining exploratory holes.

5.5 Watching Brief

A watching brief was maintained for visual and olfactory evidence of contamination.

Potential olfactory evidence of contamination in the form of an ashy organic odour was recorded at locations TP01, TP02, TP04, TP07, WS01A, WS02A, WS04, WS06, HP01, HP02, HP03, HP12, WS09, WS10 and WS11. The odours were generally faint to moderate and linked to ash and slag.

A strong odour was noted in HP11 where the material was visibly oily, this was adjacent to an existing above ground tank which is the likely source.

Visual evidence of potential contamination was recorded in the Made Ground at locations HP01 to HP03 and WS09 to WS11 in the form of ash and slag.

Anthropogenic material was generally present throughout the Made Ground soils particularly in the area of HP12 where numerous amounts of waste was present within the Made Ground which had been piled against the external mill walls.

Care was taken while removing the cobble surfacing in HP01 to HP03 and WS09 to WS11, as Brunswick Mill is a Grade II listed building. The cobbles were carefully removed and reinstated without causing damage.

5.6 Excavation/Borehole Stability

Evidence of collapse was noted in TP05 to TP07 at the based of the Made Ground at approximately 2.5m bgl, where backfill material in the form of loose bricks were encountered within the Made Ground.

TP04 also collapsed from a depth of 2.8m bgl within the Made Ground and may be associated with groundwater being encountered at 3.0m bgl.

Soil percolation testing could not be carried out in the Mid-Block area of the site due to significantly deep areas of Made Ground and collapse within the trial pits prior to reaching the natural Clay strata.

5.7 Excavation/Borehole Progress

WS01, WS02, WS06, WS06A, WS07 and WS09 terminated at depths of less than 1.0m bgl due to the presence of buried brick, concrete and sandstone cobbles. These obstructions were observed within the hand dug trial pits.

TP01 was terminated at 2.2m bgl due to the presence of a concrete slab and brick wall. TP02 was terminated at 1.8m bgl due to the presence of a concrete slab.

Buried pipes were encountered within the Made Ground in HP01, HP03 and WS09. HP01 could not be advanced beyond the pipe which was running parallel to the wall.

Built up Made Ground had to be cleared around HP11 and HP12, with the excavator, to reach original ground level before the hand pits could be commenced. Numerous buried waste material and a tree root was present in the vicinity of HP12 which prevented the footings being exposed.

A hand pit was attempted adjacent to the top of the internal archway which is present just above ground level internally. The floorboards were already removed in this location and the void associated with the archway was backfilled predominantly with fabric. The material was removed to circa 0.5m bgl but continued downwards and excavation through the fabric was not possible.

No access was available for the window sampling rig into the Corner Block in the south west of the site at the time when it was present on site. Access had to be created by lifting the gate with the JCB.

A large stockpile of crushed brick and concrete was present across the north western half of the external site area. Exploratory holes were therefore limited within the footprint of the stockpile. TP03 was excavated into the stockpile to assess the material.

An area with archaeological limitations was highlighted to Groundtech Consulting in the north eastern half of the external site area. No machine excavated trial pits were undertaken in this area as requested.

An Obstructions Plan is presented as *GRO-22462-P03*.

6.0 GROUND ENGINEERING

6.1 Geotechnical Testing Results

Comparison of water content and the value of 0.4 times the Liquid Limit in accordance with BRE Digest 412 'Desiccation in Clay Soils' suggests significant desiccation has taken place when 0.4 times the Liquid Limit is greater than the actual water measured water content. This is a rudimentary method but also a good guide.

Results of the plasticity testing and the volume change potential of the Clay is summarised in the table below:

Reference	Depth (m bgl)	Modified PI	Volume Change Potential	Desiccated
BH1	*4.50*	*33.3*	*Medium*	*Y*
BH2	*4.00*	*28.7*	*Medium*	*N*
BH3	*3.50*	*40.1*	*High*	*N*
WS10	*2.00*	*29.1*	*Medium*	*Y*
WS11	*3.00*	*29.4*	*Medium*	*N*

Quick Undrained Triaxial testing was undertaken on four samples of the undisturbed natural Clay and the results are presented in the table below:

Reference	Depth (m bgl)	Undrained Shear Strength (kPa)	Relative Strength
BH1	*4.00*	*97*	*High*
BH2	*5.00*	*49*	*Medium*
BH2	*8.00*	*95*	*High*
BH3	*11.0*	*153*	*Very High*

Unconfined Compressive Strength (UCS) testing was undertaken on three samples of the Sandstone bedrock. The results are summarised in the table below:

Reference	Depth (m bgl)	Load Failure (kN)	UCS (MPa)
BH2	*18.43 – 18.65*	*106.18*	*18.7*
BH2	*21.55 – 21.83*	*110.28*	*19.4*
BH3	*23.36 – 23.56*	*108.12*	*19.0*

6.2 Existing Foundations

Fourteen hand dug pits were undertaken at the site to target specific objectives within the existing mill building and in the exterior site. The objectives and findings of these pits are discussed below, and the cross sections are presented on Groundtech Plans *GRO-22462-P04A to P04M*.

HP01 to HP04

HP01 to HP04 were undertaken in the central courtyard of the Brunswick Mill building in order to determine the geometrics of existing foundations.

HP01 was excavated against the north western wall, a pipe was encountered at 0.45m bgl and the pit was terminated at 0.7m bgl before a footing was observed.

HP02 was excavated along the south eastern wall and reached 1.2m bgl without encountering a footing. Natural soft brown Clay was encountered at approximately 1.0m bgl beneath the Made Ground.

HP03 was excavated to 1.2m bgl on the north western wall. No footing was encountered. A pipe was also observed at 0.25m bgl, the hole was able to be progressed due to the smaller nature of the pipe. The base of the wall appeared to be present at 0.9m bgl, as excavation continued under the building with no obvious footing encountered.

HP04 was excavated on the north eastern wall to 1.2m bgl, and again, no footing was encountered. A groundwater seepage was observed at 1.2m bgl.

HP05 and HP06

HP05 and HP06 were undertaken within the mill building interior in order to determine the depths and extent of the foundation footings.

HP05 was dug in the eastern area of the building and was excavated to 1.2m bgl. No footing was encountered. Groundwater seepage was encountered at 1.0m bgl.

HP06 was excavated in the southern area of the building to a depth of 0.7m bgl, where a concrete footing was encountered which extended across the base of the pit to a minimum length of 0.6m. Further excavation of the pit was not possible due to the restricted floor space in this area.

HP07 and HP08

HP07 and HP08 were undertaken in the eastern area of the mill building interior in order to determine the geometrics of the current column foundations in this area.

HP07 was excavated to a depth of 1.2m bgl, where the top of the column foundation was encountered from 0.2m to 0.4m bgl and extended outwards from the column to a maximum length of 0.5m. A void of circa 0.15m was present beneath wooden planks overlying the footing. Made Ground was recorded beneath the concrete footing, with groundwater seepage at 1.0m bgl.

HP08 was excavated to a depth of 1.2m and a similar ground model as HP07 was encountered, with a 0.2m thick foundation being encountered from 0.15m to 0.35m bgl, extending approximately 0.5m from the base of the column. Made Ground was recorded beneath the footing, with a groundwater seepage at 1.2m bgl.

HP09 and HP10

HP09 and HP10 were undertaken within the northern area of the building interior in order to determine the depth and extent of the foundations in the areas where a proposed lift shaft will be constructed.

HP09 was excavated to a depth of 1.2m bgl, with a footing encountered at 1.0m bgl. The footing extended 0.4m from the wall and is at least 0.2m thick. Groundwater seepage was encountered at 1.2m bgl.

HP10 was dug to a depth of 1.0m bgl, with a footing encountered at 0.7m bgl. The footing extended 0.5m from the wall and is at least 0.3m thick. The pit was terminated due to a large amount of groundwater ingress at 1.0m bgl.

HP11 and HP12

HP11 and HP12 were undertaken in the external site area to the south west, against the walls of the Brunswick Mill building, in order to determine the depth and extent of the foundation footings.

HP11 was excavated to a depth of 1.2m bgl, with a footing encountered at 0.5m bgl. The footing extended 0.5m from the wall and continued to the base of the pit, meaning it is at least 0.7m thick. A second footing was encountered at 1.2m bgl which extended 0.5m from the wall. As the pit was terminated at 1.2m bgl, the full depth of the footing is unknown.

HP12 was excavated to a depth of 0.5m bgl and no footing was encountered. The presence of excess waste and a tree root against the mill wall prevented the pit from continuing further. In addition, the brickwork at this location was degraded and falling apart.

HP13 and HP13A

HP13 and HP13A were undertaken in the south west corner of the external site, and were excavated to depths of 1.2m bgl. The purpose of these trenches was to locate the presence of an LP gas main that was indicated in this area of site.

A brick wall from the former methodist chapel was located above the area of the suspected gas pipe, and a gas manhole was present in the adjacent footpath in alignment with the indicated gas pipe location. Trenches were dug either side of the wall, which extended below the ground to at least 1.2m bgl, but no gas pipe was encountered in either trench.

It is recommended to remove the wall and associated footings and excavate a trench closer to the site boundary in order to locate the gas pipe.

6.3 Assessment Background

The ground engineering investigation has been undertaken to formulate an accurate ground model in order to undertake preliminary foundation design. The ground model has been constructed with a moderate to high level of confidence.

Background

The site and the surrounding areas have had mostly industrial land uses since the mid to late 1800s. Brunswick Mill has been present since the earliest historical maps, and the India Mills building has been present until 2006 at the latest. The south west corner of the site contained terraced houses and then a methodist chapel, until the latter was partially demolished in 2018.

The proposed development comprises the construction of new build residential apartment properties including associated hardsurfacing, access roads, and limited areas of soft landscaping. Loadings associated with the proposed structures onsite are unknown at this stage and it is assumed that site levels will not alter significantly.

Enabling Works

All below ground obstructions, structures and foundations associated with the former buildings across the site should be grubbed up. The obstructions have been encountered at depths of between 0.2m and 2.2m bgl. The Made Ground will also require processing as there is a high content of anthropogenic materials.

No topsoil is present across either site areas. Vegetation and trees will require removal and chipping where they are not proposed to be retained.

Earthworks will be required to create a level platform for development in the external site where there are two distinct levels with a circa 2m change in elevation, separated by the currently existing towpath. A

retaining wall may be required along the embankment of the towpath as it is not part of the proposed development area.

Ground Model

Made Ground was encountered to a maximum depth of 4.0m bgl in BH1, generally Made Ground was deeper in the north eastern area of the site towards the current Brunswick Mill. Additionally, BH2 and BH3 recorded Made Ground to maximum depths of 3.5m and 2.5m bgl respectively, and Made Ground was not fully penetrated in the majority of locations.

The natural ground encountered generally comprised medium to very high strength Clay to a maximum depth of 17.8m bgl. Granular strata in the form of medium dense to very dense Sand, Gravel, and Cobbles was encountered locally in WS10 and BH1 to BH3 from depths between 3.0m and 15.2m bgl.

Weathered Sandstone was observed in BH1 from 13.0m to 17.0m bgl and in BH3 from 14.0m to 15.0m bgl. Recovered as very weak to weak red brown fine grained Sandstone in BH1 to BH3 from depths between 15.5m and 17.8m bgl.

Perched groundwater was encountered in the Made Ground of HP04, HP07, HP08, HP09, HP10, TP01 and TP04 at depths of between 1.0m and 3.0m bgl. Groundwater was in BH3 at 20.0m bgl in the Sandstone and in WS11 at 3.45m bgl in the sandy Clay.

Limitations

The main constraints associated with the site include the following:

- *Deep Made Ground up to 4.0m bgl.*
- *Relic structures and obstructions encountered within the trial pits, including brick walls, concrete slabs, and the partially demolished walls from the previous methodist chapel.*
- *Easement associated with the adjacent canal.*
- *Stockpiles of waste and fly tipping against the side of the external mill walls, including multiple LPG gas cannisters.*
- *Existing tank located adjacent to the existing mill on the north western boundary. This will need decommissioning and removal offsite.*
- *Incline towards the Ashton Canal towpath in the south west of the site.*
- *6F2 stockpile running adjacent to the north western site boundary.*
- *Heterogenous nature of the Made Ground.*
- *Perched groundwater.*
- *Instability in Made Ground as observed in the trial pits.*

6.4 Geotechnical Parameters

The geotechnical test results have been evaluated to derive geotechnical parameters for the soils underlying the site. A '*depth to SPT N value*' graph is presented on Groundtech Plan *GRO-22462-P05* in *Appendix 8* to provide a generalised ground model for the site.

Characterisation of the geotechnical parameters above has been undertaken to select a characteristic value, which is a cautious estimate of the value affecting the occurrence of the limit state. The characteristic values for Ultimate Limit State (ULS) conditions selected are presented in the table below:

Stratum	Parameter	Selected Characteristic Value
Medium strength Clay	*Undrained Shear strength (Cu)*	*49kPa*
High strength Clay	*Undrained Shear strength (Cu)*	*95kPa*
Very High Strength Clay	*Undrained Shear strength (Cu)*	*153kPa*
Medium dense Sand	*Drained angle of friction (ϕ')*	*32°*
Weathered Sandstone	*Drained angle of friction (ϕ')*	*38°*
Sandstone	*Unconfined Compressive Strength*	*18.7MPa*

6.5 Preliminary Foundation Design

The proposed development is for the redevelopment of Brunswick Mill into residential apartments, and the construction of two additional residential apartment blocks in the adjacent land in the south west.

The majority of exploratory holes were undertaken in the external area to the south of the mill, with the exception of HP01 to HP10, and WS09 to WS11, which were undertaken in the courtyard and interior of Brunswick Mill.

Brunswick Mill
If additional loadings are proposed for the existing mill, an assessment of the existing foundations should be undertaken to determine if they have sufficient capacity.

Bearing strata or dimensions of foundations were not determined in several of the hand excavated trial pits and further investigation may be required.

Former India Mills
In the area of the proposed new apartments, Made Ground was recorded to a maximum depth of 4.0m and was underlain by natural medium to very high strength Clay and medium dense to very dense sand, gravel and cobbles. Very weak to weak Sandstone was observed at depths of between 15.5m and 17.8m bgl.

Consideration will need to be given to obstructions that have been encountered beneath the site at depths of between 0.2m and 2.2m bgl. These will need to be grubbed up to allow foundations to be installed.

Foundations for the new apartments should be designed such that they do not undermine or surcharge any structures around that boundary of the site, including the adjacent canal wall. The development layout should also take into account any easement associated with the canal.

The proposed structure could be up to seven storeys in height if it is to be designed to match the existing mill and is expected to generate large column loads. Therefore, a traditional shallow foundation solution will not be a suitable option for the apartment block. At this stage, the loadings of the proposed structure are unknown and designs will need to be confirmed when they are available.

Loads will be transferred to the piles from ground beams, pile caps and floor slabs of the superstructure. Transverse loading on the piles and the requirement for reinforcement should be taken into consideration in the detailed design to satisfy Equilibrium Limit State conditions.

Pile Foundations
The most suitable solution for the proposed apartment development is considered to be piled foundations transferring loads through the underlying Made Ground and natural Clay and Sand strata to the very weak

Sandstone which has been encountered between 15.5m and 17.8m bgl. When permanent and variable actions are available, the utilisation factor can be confirmed or otherwise in accordance with EC7.

Driven piles are not considered an option due to the depth to and strength of the Glacial Till deposits. The most suitable type of pile for the development is considered to be Continuous Flight Auger (CFA) bored pile, this should be discussed with the preferred piling contractor. Good workmanship will be required when installing the piles to ensure the assumptions in the design by calculation are met.

Piled Solution – Design by Calculation

Preliminary design by calculation has been carried out using due skill and care using the allowable load method for pile design. The preliminary design by calculation is based on the following ground model:

- *Made Ground to 4.0m*
- *Medium to very high strength Clay to 15.2m*
- *Medium dense Sand to 15.5m*
- *Very weak Sandstone to 20m*

For a single bored pile 600mm in diameter and 20m in length end bearing in the very weak Sandstone, an allowable load of 2000kN has been calculated. If greater loads are required, the piles should be installed in groups. If piles groups are used, the compressive resistance will be the sum of the individual piles that make up the group when they are end bearing on non-compressive strata and the stability of the pile group will be governed by a single pile end bearing on bedrock. This should be considered when the site layout and loadings are confirmed.

The preliminary design for piles end bearing in a rock socket in the Sandstone calculated significant total design resistances. Checks should be undertaken to confirm the design resistances calculated by the preliminary design do not significantly exceeded the safe working loads based on the total compressive strength of the concrete pile to be provided by the structural engineer. The safe working load of the concrete pile will likely dictate the design. The number of piles in the pile group will depend on the forces acting on the piles and should be discussed with the structural engineer and piling contractor. A suitably designed pile group should be designed and constructed to support the superstructure, and basement structure if required.

The design of pile groups should include the potential impact on adjacent structures due to potential loss of ground.

The depth of rock socket has been taken as 4.5m into the residual bedrock. The extent of the socket will depend on the competency of the bedrock and consistency across the development area. The end bearing resistance will depend on the drilling technique and magnitude of disruption of the Sandstone which may reduce the base resistance.

The ground conditions and the below ground construction indicate downdrag will not be an issue and has not been taken into consideration in the preliminary design.

An appropriate working platform should be constructed in accordance with BR470 guidance.

Design Validation

The piling type, length, depth of reinforcement and design should be discussed with a specialist piling contractor. They can then undertake the detailed design including drawings and specifications to provide

fitness for purpose design. In accordance with EC7, static load testing is recommended to validate the design, static load testing may also a more efficient design to be produced. Static load testing will be required and can be undertaken on preliminary piles or more than 1% of working piles to 1.5 times the characteristic load.

The piling works should be carried out in accordance with Execution Standard EN 1536 for Bored Piles.

Construction Recommendations

The recommendations in this appraisal are preliminary and the detailed design should be developed in advance and during the construction phase. If the ground conditions or groundwater regime encountered during the construction phase differ significantly to the conditions encountered during the Ground Investigation, work should cease and Groundtech Consulting contacted for further advice.

During the construction phase, supervision by a suitably qualified geotechnical engineer should be on a continuous basis to check the design assumptions are correct and construction conforms to design in accordance with EC7. Supervision should include inspections, Control Ground Investigations and monitoring by a suitably qualified geotechnical engineer.

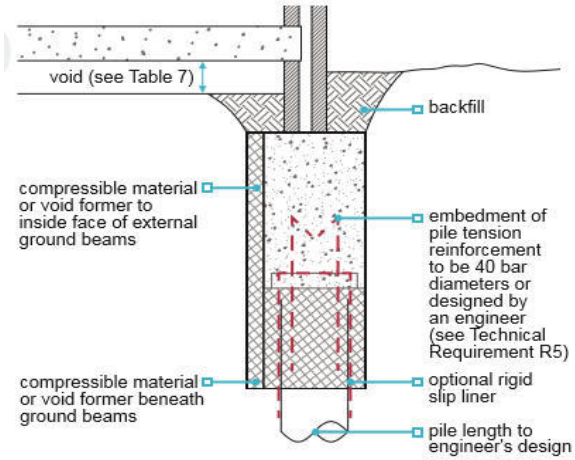
6.6 Building Near Trees

Trees and bushes are present around the site. Foundation excavations may encounter cohesive strata locally in the vicinity of existing, proposed or recently removed trees, foundations should be adjusted in full accordance with current guidance.

All foundations should be deepened below roots of greater than 5mm diameter during excavations for footings. The clay is of a low to medium volume change potential.

A survey of all trees and hedges on the site and within 30m of the site boundary should be undertaken to identify tree species, locations and heights. This information will be required in order to assess the effects of trees on the cohesive strata and inform a foundation schedule.

Where heave precautions are deemed necessary, the pile installation design will need to accommodate the following precautions in the design.



Heave precautions for pile and beam foundations

6.7 Floor Slabs

Floor slab design should take into consideration the presence of deep Made Ground to 4.0m bgl. A suspended floor slab is considered to be suitable for the proposed development that is compatible with the proposed piled foundations. The slab loadings are not available at this stage.

The clays beneath the site are of low to medium volume change potential therefore, a 100mm void should be incorporated beneath ground beams and suspended in-situ concrete ground floors, while a 250mm void should be incorporated under suspended precast concrete floors if they are utilised.

Floor slab construction should include basic radon precautions in accordance with BR 211.

6.8 Construction

The trial pits indicate that instability of excavations is anticipated during the construction phase as the sand strata encountered within the trial pits collapsed on multiple occasions and required further excavation. If excavations are subject to adverse weather conditions, this may provide further instability. Instability of the Made Ground is likely such as in TP04 to TP07 and should be considered in the groundworks method statements.

Tracked high specification plant is recommended to maintain the build programme. Breaking equipment will also be required to penetrate obstructions identified by the Ground Investigation and they are widespread given the history of the site – obstructions were encountered in WS01 to WS07, WS09, TP011 and TP02 during the Groundtech Investigation. The obstructions will have to be grubbed up during the enabling works phase. Made Ground was not fully penetrated in numerous locations on the site as shown on Obstructions Plan *GRO-22462-P03*.

Perched groundwater has been encountered in the Made Ground at a number of locations. Therefore, dewatering of excavations may be required locally and will largely depend on the proposed site levels.

6.9 Concrete Classification

Made Ground
Water soluble sulphate testing was undertaken on thirty samples of the Made Ground. The range of soluble sulphate (SO_4) recorded is 40.1mg/l to 1700.4mg/l and associated pH values ranged between 7.33 and 11.63 indicating alkaline conditions.

For a dataset containing more than ten results, the mean of the highest 20% of the water-soluble sulphate test results will be used along with the average of the lowest 20% of the pH results. For the Made Ground, the characteristic water-soluble sulphate value is 1472mg/l and the pH value is 7.63.

Natural Strata
Water soluble sulphate testing was also undertaken on five samples of the natural strata. The range of soluble sulphate (SO_4) recorded is 35.3 mg/l to 98.7 mg/l and associated pH values ranged between 7.89 and 8.79 indicating slightly alkaline conditions.

For a dataset containing five to nine results, the mean of the highest two sulphate test results will be used and the average of the lowest two of the pH results. For the natural strata, the characteristic water-soluble sulphate value is 36.9 mg/l and the pH value is 8.09.

Due to the presence of granular soils underlying the site, groundwater is considered to be mobile.

The results of laboratory pH and sulphate content indicate that ACEC Class AC-3 and sulphate class DS-3 conditions prevail in accordance with BRE Special Digest 1 "Concrete in aggressive ground" 2005. The specific concrete mixes (the Design Concrete Class) to be used on site will be determined by the site-specific concrete requirements in terms of the durability and structural performance. These are assessed in terms of the Structural Performance Level (SPL) and any need for Additional Protective Measures (APM) detailed in Part D of BRE Special Digest 1 with further guidance in Pt E and F.

There is the potential for pyritic ground conditions to be present beneath the site and testing should be undertaken to confirm this.

6.10 Highway / Pavement Design

CBR values of 2% to 5% are likely to be achieved in any shallow undisturbed natural soils for pavement design purposes, unless proven otherwise by in-situ testing at sub-base level by a specialist geotechnical engineer.

As a minimum, the subgrade should be proof rolled prior to construction. Some reengineering of the subgrade is required prior to highway construction to achieve the required design CBR value.

Untreated Made Ground should be assumed to have a CBR value of less than 2.5%, unless proven otherwise. Highways Agency document HD25 'Interim Advice Note 73/06 Revision 1' (2009) states that where a subgrade has a CBR value lower than 2.5%, it is considered unsuitable support for a pavement foundation since it would tend to deform under construction traffic and must be improved.

The soils are considered to be frost susceptible due to the fines content, and highway/pavement construction should be a minimum thickness of 450mm to mitigate the risk.

6.11 Sustainable Urban Drainage System (SuDS)

SuDS drainage is unlikely to be a feasible option at the site due to the presence of deep Made Ground and natural cohesive soils beneath the site which are capable of poor infiltration rates.

Soil percolation testing was attempted however, the sides of the excavations were unstable and natural strata was not encountered in the proposed locations.

7.0 LAND QUALITY

7.1 Geo-Environmental Testing Results - Soils

Samples of Made Ground and natural strata have been tested for a range of relevant Contaminants of Concern (CoCs). In accordance with LCRM, a Generic Quantitative Risk Assessment (GQRA) has been undertaken to determine the significance of the concentrations as derived through Geo-Environmental analysis.

The GQRA process comprises the comparison of the actual concentrations measured on site with Generic Assessment Criteria (GACs) for the protection of human health.

The GACs used for the assessment of soil concentrations have been derived using the CLEA model. The GACs used are listed below:

- *Soil Guideline Values (SGVs) which demonstrate minimal risk.*
- *LQM/CIEH S4ULs which use the same toxicological data as the SGVs but different exposure criteria.*
- *C4SLs which demonstrate low risk.*

In deriving the GACs for use on Brownfield sites, we have assumed a 1% Soil Organic Matter unless the results indicate otherwise.

The proposed end-use for the site is a residential development comprising a redevelopment of the existing mill building into apartments, as well as the construction of two additional apartment blocks in the adjacent land to the south with associated driveways, pavements, access roads, and limited areas of soft landscaping. We have therefore undertaken the GQRA on the basis that the proposed development site falls under the Residential (without Plant Uptake) land-use scenario as defined in SR3 (EA, 2009b).

The strata or sources of contamination targeted by the laboratory testing scheduled is summarised in the table below:

Strata / Source	Number Tested	Locations
Granular Made Ground (Population 1)	*26*	*HP01, HP02, HP03, HP05, HP09, HP10, HP11, HP12, HP13, TP01, TP02, TP03, TP04, TP05, TP06, TP07, WS01A, WS02A, WS04, WS06, WS07A, WS08, WS09, WS10, BH1, BH3*
Cohesive Made Ground (Population 2)	*4*	*HP06, HP07, WS11, BH2*
Natural Clay (Population 3)	*2*	*TP06, WS08*
Former Mills	*32*	*All*
Former Tank	*1*	*HP11*

A summary of the Geo-Environmental Testing results is presented below and the GQRA Screening Values are presented in *Appendix 9*:

Metals				
Contaminant	Range (mg/kg)	Screening Value (mg/kg)	Exceedances	Locations
Arsenic	*7.4 – 71.9*	*40*	*3*	*HP02 at 0.5m* *HP11 at 0.5m* *WS09 at 0.5m*
Cadmium	*<0.1 – 5.5*	*85*	*0*	-
Chromium	*26.0 – 84.1*	*910*	*0*	-
Hexavalent Chromium	*<0.3*	*21*	*0*	-
Copper	*19 – 1477*	*7100*	*0*	-
Lead	*14 – 3285*	*310*	*7*	*HP11 at 0.5m* *TP01 at 1.0m* *TP02 at 0.5m* *TP05 at 1.0m* *TP06 at 0.5m* *WS06 at 0.5m* *WS07A at 1.0m*
Mercury	*<0.1 – 1.2*	*1.2*	*0*	-
Nickel	*9.4 – 65.4*	*180*	*0*	-
Selenium	*<1.0 – 2.0*	*430*	*0*	-
Zinc	*54 – 438*	*40000*	*0*	-
Polycyclic Aromatic Hydrocarbons (PAHs)				
Contaminant	Range (mg/kg)	Screening Value (mg/kg)	Exceedances	Locations
Naphthalene	*<0.04 – 26.86*	*2.3*	*3*	*HP03 at 0.5m* *HP11 at 0.5m* *TP01 at 1.0m*
Acenaphthylene	*<0.03 – 9.21*	*2900*	*0*	-
Acenaphthene	*<0.05 – 54.06*	*3000*	*0*	-
Fluorene	*<0.04 – 33.12*	*2800*	*0*	-
Phenanthrene	*<0.03 – 274.34*	*1300*	*0*	-
Anthracene	*<0.04 – 71.85*	*31000*	*0*	-
Fluoranthene	*<0.03 – 291.31*	*1500*	*0*	-
Pyrene	*<0.03 – 250.97*	*3700*	*0*	-
Benzo(a)anthracene	*<0.06 – 112.94*	*11*	*4*	*HP03 at 0.5m* *TP01 at 1.0m* *WS08 at 0.5m* *WS09 at 0.5m*
Chrysene	*<0.02 – 110.74*	*30*	*2*	*HP03 at 0.5m* *TP01 at 1.0m*
Benzo(b)fluoranthene	*<0.05 – 119.86*	*3.9*	*8*	*HP03 at 0.5m* *HP10 at 0.5m* *TP01 at 1.0m* *TP02 at 0.5m* *TP07 at 1.0m* *WS08 at 0.5m* *WS09 at 0.5m* *BH3 at 1.0m*
Benzo(k)fluoranthene	*<0.02 – 46.61*	*110*	*0*	-
Benzo(a)pyrene	*<0.04 – 107.79*	*3.2*	*8*	*HP03 at 0.5m*

				HP10 at 0.5m TP01 at 1.0m TP02 at 0.5m TP07 at 1.0m WS08 at 0.5m WS09 at 0.5m BH3 at 1.0m
Indeno(123cd)pyrene	<0.04 – 61.48	45	2	HP03 at 0.5m TP01 at 1.0m
Dibenzo(ah)anthracene	<0.04 – 12.07	0.31	8	HP03 at 0.5m HP10 at 0.5m TP01 at 1.0m TP02 at 0.5m TP07 at 1.0m WS08 at 0.5m WS09 at 0.5m BH3 at 1.0m
Benzo(ghi)perylene	<0.04 – 64.20	360	0	-
TPH CWG – Aliphatics				
Contaminant	Range (mg/kg)	Screening Value (mg/kg)	Exceedances	Locations
>C5-C6	<0.1	42	0	-
>C6-C8	<0.1	100	0	-
>C8-C10	<0.1 – 0.3	27	0	-
>C10-C12	1.3 – 185.1	130	1	HP11 at 0.5m
>C12-C16	<4.0 – 2910	1100	1	HP11 at 0.5m
>C16-C35	<7.0 – 4354	65000	0	-
Total aliphatics C5-35	<19 – 10412	-	-	-
TPH CWG - Aromatics				
Contaminant	Range (mg/kg)	Screening Value (mg/kg)	Exceedances	Locations
>C5-EC7	<0.1	370	-	-
>EC7-EC8	<0.1	860	-	-
>EC8-EC10	<0.1	47	-	-
>EC10-EC12	<0.2 – 124.7	250	-	-
>EC12-EC16	<4.0 – 3531	1800	1	HP11 at 0.5m
>EC16-EC21	<7.0 – 6909	1900	1	HP11 at 0.5m
>EC21-EC35	<7.0 – 3542	1900	1	HP11 at 0.5m
Total aromatics C5-35	<19 – 15907	-	-	-
Total aliphatics and aromatics(C5-35)	<38 – 26319	-	-	-
MTBE	<0.005	49	0	-
Benzene	<0.005	0.38	0	-
Toluene	<0.005	880	0	-
Ethylbenzene	<0.005 – 0.007	83	0	-
m/p-Xylene	<0.005 – 0.013	82	0	-
o-Xylene	<0.005 – 0.007	88	0	-
Others				
Moisture Content: 9.4% – 35.7%				

pH: 7.33 – 11.63				
Organic Matter: 1.3% – 25.9%				
Asbestos Screen				
Position	Depth (m bgl)	Result	Asbestos Type	Quantification (mass%)
HP01	*0.50*	*None Detected*	*n/a*	*n/a*
HP02	*0.50*	*None Detected*	*n/a*	*n/a*
HP03	*0.50*	*None Detected*	*n/a*	*n/a*
HP05	*0.50*	*None Detected*	*n/a*	*n/a*
HP06	*0.50*	*None Detected*	*n/a*	*n/a*
HP07	*0.50*	*None Detected*	*n/a*	*n/a*
HP09	*0.50*	*None Detected*	*n/a*	*n/a*
HP10	*0.50*	*None Detected*	*n/a*	*n/a*
HP11	*0.50*	*Chrysotile*	*Cement*	*0.57*
HP12	*0.50*	*None Detected*	*n/a*	*n/a*
HP13	*0.50*	*None Detected*	*n/a*	*n/a*
TP01	*1.00*	*None Detected*	*n/a*	*n/a*
TP02	*0.50*	*None Detected*	*n/a*	*n/a*
TP03	*1.00*	*None Detected*	*n/a*	*n/a*
TP04	*2.00*	*None Detected*	*n/a*	*n/a*
TP05	*1.00*	*None Detected*	*n/a*	*n/a*
TP06	*0.50*	*None Detected*	*n/a*	*n/a*
TP06	*2.70*	*None Detected*	*n/a*	*n/a*
TP07	*1.00*	*Amosite*	*Fibre bundles*	*0.002*
WS01A	*1.00*	*None Detected*	*n/a*	*n/a*
WS02	*0.50*	*None Detected*	*n/a*	*n/a*
WS04	*0.50*	*None Detected*	*n/a*	*n/a*
WS06	*0.50*	*None Detected*	*n/a*	*n/a*
WS07A	*1.00*	*None Detected*	*n/a*	*n/a*
WS08	*0.50*	*None Detected*	*n/a*	*n/a*
WS08	*2.50*	*None Detected*	*n/a*	*n/a*
WS09	*0.50*	*None Detected*	*n/a*	*n/a*
WS10	*1.20*	*None Detected*	*n/a*	*n/a*
WS11	*1.50*	*None Detected*	*n/a*	*n/a*
BH1	*0.50*	*None Detected*	*n/a*	*n/a*
BH2	*2.00*	*None Detected*	*n/a*	*n/a*
BH3	*1.00*	*None Detected*	*n/a*	*n/a*

Generally, all of the VOCs were recorded at concentrations below the laboratory limits of detections with the exception of the following:

- *Chloromethane*
- *Toluene*
- *1,3,5-Trimethylbenzene*
- *1,2,4-Trimethylbenzene*
- *4-Isopropyltoluene*

In addition, the following SVOCs were recorded above the laboratory limits of detection:

- *Carbazole*
- *Dibenzofuran*
- *2-Methylnaphthalene*
- *Bis(2-ethylhexyl) phthalate*
- *Di-n-butyl phthalate*
- *2-Methylphenol*
- *2,4-Dimethylphenol*
- *4-Methylphenol*

7.2 Generic Quantitative Risk Assessment - Soils

Made Ground has been encountered beneath the entire site to a maximum depth of 4.0m bgl during the investigation and the Made Ground soils are predominantly granular with cohesive soils encountered locally.

Ash and slag was observed in The Made Ground soils.

Olfactory evidence of contamination was noted in the Made Ground soils in the form of a faint to strong hydrocarbon odour – this is potentially attributed to the ash and slag content of the Made Ground as well as fuel derived hydrocarbons in the area of the former tank. A strong odour was noted in HP11 where the Made Ground was visibly oily, this was adjacent to an existing above ground tank which is the likely source.

A Contamination Plan is included as *GRO-22462-P06.*

Metals
Elevated levels of arsenic and lead have been detected in samples of granular Made Ground taken from HP02, HP11, TP01, TP02, TP05, TP06, WS06 and WS07A at depths between 0.5m and 1.0m bgl.

Elevated arsenic concentrations were between 43.7 mg/kg and 71.9 mg/kg when compared to the screening value of 40mg/kg. The elevated concentrations of arsenic were recorded around the existing mill building.

Lead was elevated at concentrations were between 319mg/kg and 3285mg/kg in seven locations to the south west of the existing mill at depths between 0.5m and 1.0m bgl, the screening value is 310mg/kg.

The likely source of the elevated arsenic and lead in the granular Made Ground is the former use of the site as a mill and finishing works and could also be linked to dyes used in the textile process. Other sources may include the ash content and traces of hydrocarbons within the shallow Made Ground soils.

Polycyclic Aromatic Hydrocarbons (PAHs)
Several PAHs were recorded above the screening values in the Made Ground in the granular Made Ground soils encountered in HP03, HP10, HP11, TP01, TP02, TP07, WS08, WS09 and BH3 from depths between 0.5m and 1.0m bgl. The contamination has been identified around the existing mill building and also in the land to the south west of the mill, and is considered to be widespread throughout the site.

The elevated PAHs include naphthalene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(a)pyrene, indeno(123cd)pyrene, and dibenzo(ah)anthracene.

The site has historically been used as a mill, which included a chimney. Ash and slag are present within the Made Ground which is the likely source of the elevated speciated PAHs.

The elevated concentrations of Naphthalene are also above the vapour saturation limit based on a S4UL inhalation pathway, Naphthalene is semi-volatile and likely associated with former processes and the slag/ash content in the Made Ground.

Total Petroleum Hydrocarbons (TPH CWG)
A hydrocarbon odour has been detected in HP11 in the vicinity of the former fuel tank. In addition, visual evidence of contamination was noted in HP11, HP12 and TP01 where an oily coating was noted in the Made Ground soils.

Generally, the source of these odours is likely to be the former use of the site as a mill and in the area of HP11, the source will have been from a former above ground fuel storage tank.

Geo-environmental testing has only recorded elevated concentrations of TPH CWG in HP11 at 0.5m bgl which was excavated adjacent to the former fuel storage tank. Interpretation of the hydrocarbon results from this sample indicate that it is linked to degraded diesel, possible lubricating oil and possible tarmac/bitumen.

Volatile Organic Compounds (VOCs) and Semi-Volatile Organic Compounds (SVOCs)
Through the laboratory testing, the majority of the VOCs and SVOCs have been encountered below laboratory limits of detection. However, a number of compounds were recorded above laboratory limits of detection however, none were elevated where screening values are available.

Many of the compounds recorded above the laboratory detection limits, including phenolic and phthalate compounds, are used in coal tar, dyes, solvents, paints, glue, adhesive and insecticide which are all linked to the former use of the site as a mill. The presence of slag is also a major contributor to the presence of the contaminants encountered beneath the site.

Asbestos
Asbestos was generally not identified within the samples of Made Ground that were screened. Chrysotile cement has been detected in HP11 at 0.5m bgl at a concentration of 0.57mass%, and fibre bundles of Amosite have been detected in TP07 at 1.0m bgl at a concentration of 0.002mass%.

The asbestos was detected in the granular Made Ground soils to the south west of the mill building. The source of asbestos will be the demolished buildings that were located on the site, testing indicates that the presence of asbestos is not widespread.

Previous Ground Investigation
Previous investigation works carried out by LK Consulting found similar Contaminants of Concern within the Made Ground soils.

Stockpiles
A number of stockpiles of soil are present across the southern part of the site. TP03 was tested and no elevated Contaminants of Concern were noted.

Additional testing is recommended if the material is to reused or disposed of.

7.3 Geo-Environmental Testing Results - Groundwater

Two samples of groundwater were taken from BH1 and BH3 and were tested for a similar suite of Contaminants of Concern as the soils and the results compared with reference to a selection of guidance

documents as detailed at the rear of this report. The groundwater was taken from the strikes within the natural Sandstone.

The implementation of the Water Framework Directive (WFD) is to protect and enhance the quality of groundwater and groundwater-dependent ecosystems. The objective of the WFD requires all groundwater bodies (GWBs) are of 'good' status in terms of water quality. This status is based on thresholds for the chemical constituents of groundwater and their impact on ecosystems. Preventing pollution is by far the most sustainable and cost-effective way of maintaining good groundwater quality. The EA are committed to the 'prevent or limit' approach reflected in EU and domestic legislation.

Priority is under the Water Framework Directive to protect water supplies intended for human consumption and ensure protection of groundwater quality that supplies dependent ecosystems. After first guidance in 1992 the following significant guidance has been introduced:

- *Water Framework Directive (2000/60/EC) and the Water Act 2003.*
- *The State of Groundwater in England and Wales 2006.*
- *Second phase of the environmental permitting regime in 2010 replacing the Groundwater Regulations (1999, 2009).*
- *Groundwater Daughter Directive.*

Pollutants can be divided into those that break down easily (degradable pollutants) and those that do not (non-degradable pollutants). The Water Framework Directive introduced the concept of 'hazardous substances' and 'non-hazardous pollutants', which replaced the previous List I and List II of substances considered to pose the greatest threat to the environment.

- *Hazardous substances* are the most toxic and must be prevented from entering groundwater. Substances in this list may be disposed of to the ground, under a permit, but must not reach groundwater. They include pesticides, sheep dip, solvents, hydrocarbons, mercury, cadmium and cyanide.

- *Non-hazardous pollutants* are less dangerous and can be discharged to groundwater under a permit but must not cause pollution. Examples include sewage, trade effluent and most wastes. Non-hazardous pollutants include any substance capable of causing pollution and the list is much wider than the previous List II of substances. For example, nitrate is now a non-hazardous pollutant whereas before it was not a List II substance.

Polluting substances in groundwater can occur as a gas (gaseous phase) or dissolved in water (aqueous phase), or as a non-aqueous phase liquid (NAPL). Some pollutants include substances that dissolve readily in water. These are said to have high solubility; an example is MTBE. Substances that have low solubility (such as oil) are referred to as non-aqueous phase liquids (NAPLs). NAPLs behave differently in groundwater depending on whether they are lighter or heavier than water. Light non-aqueous phase liquids (LNAPLs) may float on the water table whereas dense non-aqueous phase liquids (DNAPLs) may sink through the aquifer until they reach an impermeable layer. They may then generate plumes of contamination. In both cases, the slowly dissolving pollutant may form a plume of dissolved contamination which moves with the groundwater flow.

A table summarising the groundwater testing results is presented below:

Metals				
Contaminant	Range (ug/l)	EQS (ug/l)	Exceedances	Locations
Dissolved Arsenic	*<2.5 – 2.7*	*50*	-	-
Dissolved Cadmium	*<0.5 – 0.5*	*0.08 - 0.25*	-	-
Dissolved Chromium	*<1.5*	*4.7*	-	-
Hexavalent Chromium	*<0.006*	*3.4*	-	-
Dissolved Copper	*<7*	*10*	-	-
Dissolved Lead	*<5*	*7.2*	-	-
Dissolved Mercury	*<1*	*1*	-	-
Dissolved Nickel	*10*	*4*	*2*	*BH01 and BH03*
Dissolved Selenium	*<3*	*10**	-	-
Dissolved Zinc	*5 - 14562*	*75*	*1*	*BH03*
Polycyclic Aromatic Hydrocarbons (PAHs)				
Contaminant	Range (ug/l)	EQS (ug/l)	Exceedances	Locations
Naphthalene	*<0.1*	*2*	-	-
Benzo(a)pyrene	*0.402*	*0.00017*	*1*	*BH01*
Indeno(123cd)pyrene	*0.233*	*0.00017*	*1*	*BH01*
Benzo(ghi)perylene	*0.259*	*0.00017*	*1*	*BH01*
Benzo(b)fluoranthene	*0.505*	*0.00017*	*1*	*BH01*
Benzo(k)fluoranthene	*0.197*	*0.00017*	*1*	*BH01*
TPH CWG – Aliphatics				
Contaminant	Range (ug/l)	EQS (ug/l)	Exceedances	Locations
>C5-C6	*<10*	*15,000*	-	-
>C6-C8	*<10*	*15,000*	-	-
>C8-C10	*<10*	*300*	-	-
>C10-C12	*<5*	*300*	-	-
>C12-C16	*<10*	*300*	-	-
>C16-C35	*940*	-	-	-
Total aliphatics C5-35	*<10*	-	-	-
TPH CWG - Aromatics				
Contaminant	Range (ug/l)	EQS (ug/l)	Exceedances	Locations
>C5-EC7	*<10*	-	-	-
>EC7-EC8	*<10*	-	-	-
>EC8-EC10	*<10*	-	-	-
>EC10-EC12	*<5*	*90*	-	-
>EC12-EC16	*<10*	*90*	-	-
>EC16-EC21	*<10*	*90*	-	-
>EC21-EC35	*<10*	*90*	-	-
Total aromatics C5-35	*<10*	-	-	-
Total aliphatics and aromatics(C5-35)	*<10*	-	-	-

MTBE	*<0.1*	*2600*	-	-
Benzene	*<0.5*	*10*	-	-
Toluene	*<5*	*50*	-	-
Ethylbenzene	*<1*	*20*	-	-
m/p-Xylene	*<2*	*30*	-	-
o-Xylene	*<1*	*30*	-	-
Others				
Total Hardness	*198 – 480mg/l*			

All of the VOCs tested for were recorded at concentrations below the laboratory limits of detection.

Minor concentrations of the 2,4-Dichlorophenol and 1,2-Dichlorobenzene (SVOCs) were recorded above the laboratory limits of detection in the two groundwater samples that were tested.

7.4 Generic Quantitative Risk Assessment - Groundwater

Strata underlying the site comprised Made Ground soils to a maximum depth of 4.0m bgl over Glacial Till consisting of firm to stiff Clay with bands of sand and gravel which in turn overlies Sandstone bedrock deposits encountered at depths of between 15.5m and 17.8m bgl.

Groundwater was encountered within natural bedrock deposits at a depth of 20.0m bgl. The site is not within a Source Protection Zone.

The superficial bedrock deposits have been classified as a Secondary Undifferentiated Aquifer and the bedrock deposits have been classified as a Secondary A Aquifer.

The installations were installed within the rotary boreholes to target the groundwater encountered during the Ground Investigation. These locations were installed to obtain water samples to determine if the potential onsite sources identified in the Preliminary Risk Assessment and the Ground Investigation have migrated to the underlying groundwater.

The contaminants tested for have been compared to EQS screening levels. The nearest named surface water body is the Ashton Canal located to the immediate south east. Generally, all of the Contaminants of Concern which includes metals and TPHs have been recorded at concentrations below the relevant EQS screening values.

Slightly elevated concentrations of nickel were recorded in BH01 and BH03 and zinc was significantly elevated in BH03. Speciated PAHs were elevated in BH01 when compared against the stringent PAH screening values.

Historically, the site has been used as a mill. In addition, there are a number of offsite sources that could potentially impact the underlying groundwater at the site and include other mills, boiler works, engineering works, glass works, gas works, chemical works, landfills and printing works. The minor elevations of PAHs encountered within the groundwater of BH01 are not considered to be related to the elevated concentrations of PAHs recorded in the Made Ground soils as a significant thickness of natural Clay of between 14m and 17m is present beneath the site acting as an aquitard and protecting the underlying groundwater in the underlying Sandstone. In addition, no elevated concentrations of nickel or zinc were recorded in the Made Ground soils beneath the site.

There was a minor oily sheen present on some of the Made Ground soils however, no evidence of contamination was present within the underlying groundwater samples obtained from the site.

The deeper groundwater table is at circa 20m below ground level and is not considered to be in hydraulic continuity or providing base flow to the Ashton Canal.

Naphthalene is an indicator of potential contamination as it is associated with the slag contamination identified at the site. Within the groundwater testing, naphthalene has been encountered at levels below the laboratory limit of detection which is a good indication that potential contamination from slag has not impacted the underlying groundwater.

The groundwater testing results have proven that the underlying groundwaters have not been impacted by the sources of contamination identified at the site.

7.5 Permanent Ground Gases

Two gas monitoring visits have been carried out between the dates of 13th June and 19th June 2023.

A maximum carbon dioxide concentration of 9.2% v/v was recorded in WS05 on the second monitoring visit. Carbon dioxide was also above 5% v/v in BH1 during both monitoring visits. In the other standpipes, carbon dioxide was recorded at a maximum level of 3.4% v/v.

No methane has been detected in the standpipes and a depleted oxygen level of 0.8% v/v was encountered in BH01 on the first visit.

A positive gas flow rate of 6.3 l/hr was detected in BH1 during the first monitoring visit, which was completed during a period of steady barometric pressure.

The atmospheric pressure ranged between 1000mb and 1008mb during both visits which were carried during periods of steady barometric pressure.

Groundwater was recorded in the deeper standpipes installed in BH1 to BH3 at depths of between 17.26m and 18.73m bgl. Groundwater was also present in WS08 during the second monitoring visit at a depth of 2.31m bgl.

Characterisation of the Gas Screening Value (GSV)

Based upon the results recorded, in accordance with CIRIA Report C665, the risk to the site from ground gases has been assessed by converting the results to gas screening values (GSVs), calculated by multiplying the typical maximum gas concentrations with the recorded maximum positive flow rates. In addition, individual "hazardous gas flow rates" (Qhg) have been derived for each monitoring point.

GSV (l/hr) = max borehole flow rate (l/hr) x max gas concentration (%)

For this assessment, the maximum recorded concentration of carbon dioxide of 9.2% v/v has been used. As a positive gas flow rate has been detected, a value of 6.3 l/hr has been adopted to calculate the GSV.

As no methane was detected, a GSV for methane cannot be calculated.

Carbon Dioxide GSV = 0.092 (9.2%) x 6.3 = 0.5796 l/hr

In order to assess the ground gas regime beneath the site and the need to incorporate ground gas precautions, guidance was taken from CIRIA C665 'Assessing risks posed by hazardous ground gases to buildings'. Based on the site being developed with residential apartments, the Wilson and Card method has been used to carry out the assessment.

When considering the results in accordance with CIRIA C665 (Section A Development and Table 8.5 – Modified Wilson and Card Classification) it can be seen that the GSV value for carbon dioxide is are below the assessment GSV of less than 0.7 l/hr and based on the GSV the site falls within Characteristic Situation 2.

Characteristic Situation 2

In accordance with CIRIA C665 and the site being placed in CS2, gas protection measures will be required comprising the following:

- *Reinforced concrete cast in situ floor slab (suspended, non-suspended or raft) with at least 1200 gauge DPM and underfloor venting.*
- *Beam and block or pre-cast concrete and 2000 gauge DPM/reinforced gas membrane and underfloor venting.*

All joints and penetrations sealed.

The proposed development is classified as a Building Type A in accordance with BS 8485:2015. The site falls into CS2 in accordance with Table 2 of the above guidance and 3.5 points of protection will be required comprising a combination of the following:

Structural Barrier / Floor Slab

- *Cast in situ monolithic reinforced ground bearing raft or reinforced cast in situ suspended floor slab with minimal penetrations – 1.5 points.*

Ventilation Protection Measures

- *Passive sub floor dispersal layer of good performance – 1.5 points.*

Gas Resistant Membrane

- *Gas resistant membrane (including carbon dioxide) meeting the criteria outlined in Table 7 of BS 8485:2015 – 2 points.*

Radon
The site is indicated to be situated in an area requiring basic radon precautions within foundations.

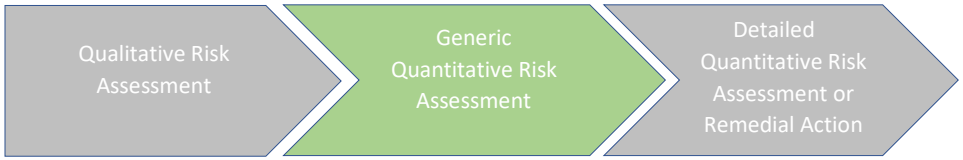
Volatile Vapours

The geo-environmental testing has recorded high concentrations of PAHs across the site and also localised areas of hydrocarbons. Naphthalene has been recorded significantly above the vapour saturation limit of the Made Ground in HP03, HP11 and TP01. It is recommended that a vapour resistant membrane is included within the proposed commercial units as source removal will be difficult as the PAH contamination is widespread and the Made Ground soils are similar in nature. Alternatively vapour intrusion modelling can be undertaken to determine if the requirements for a vapour resistant membrane can be removed.

7.6 Revised Pollution Linkage Assessment

A pollution linkage assessment has been undertaken based on the results of the Ground Investigation and the testing in accordance with LCRM and CIRIA C552 to identify any realistic pollution linkages in order to quantify the risks to human health and controlled waters. An Illustrative CSM is presented as Plan No. *GRO-22462-P06* and the risk classification has been estimated in accordance with the CIRIA C552 assessment criteria outlined in *Appendix 10.*

Human Health Pollution Linkage Assessment



- The table below represents the second stage in the land quality risk assessment process - **the Generic Quantitative Risk Assessment**.
- In order for a development site to be deemed 'suitable for use' the level of risk needs to be reduced to an acceptable level - low to negligible risk. The purpose of each stage of risk assessment is to establish if there is a requirement for additional stages of assessment in order to have sufficient confidence to support a risk characterisation or remedial action.

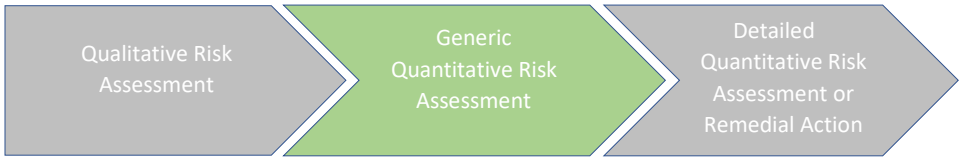
Conceptual Site Model					*Generic Quantitative Risk Assessment*	
PL	Potential Source	Pollution Linkage	Likelihood	Consequence/ Severity	Risk Rating	*Rationale and Action*
PL1	Contaminated Soils	Ingestion of soil and dust. Dermal contact with soil.	Likely	Medium	Moderate	*Pollution Linkage 1 refers to proposed site users coming into contact with contaminated soils on the site.* *The site currently consists of Brunswick Mill in the north east, and land formerly containing India Mills and a methodist chapel in the south west.* *Made Ground has been encountered in all exploratory holes to a maximum depth of 4.0m bgl, and generally comprised ashy variably gravelly clayey sand with a high cobble content of brick and minor constituents of concrete, ceramics, plastic, fabric, sandstone, wood, slate, ash, tarmac, slag and glass.* *Based on the site being developed with apartments, elevated concentrations of arsenic, lead, PAHs and TPH CWG have been recorded.* *Additionally, asbestos was detected within two of the screened samples in the Made Ground soils at a maximum concentration of 0.57mass%. The combined hazard,*

Conceptual Site Model						*Generic Quantitative Risk Assessment*
PL	Potential Source	Pollution Linkage	Likelihood	Consequence/ Severity	Risk Rating	*Rationale and Action*
						exposure and receptor ranking in accordance with the Joint Industry Working Group is Low. *The proposed development is for refurbishing the existing mill into residential apartments, as well as the construction of two new apartment blocks on the adjacent land to the south west which will include areas of soft landscaping. An asbestos survey of the existing mill will be required.* *Where hardsurfacing or the proposed buildings are present, there is not considered to be a risk as the surfacing will break the pathway to potentially contaminated soils. However, as significant elevations of CoCs have been recorded, a pollution linkage is considered to exist in the areas of soft landscaping.*
PL2	Contaminated Soils	Inhalation of vapour.	Low Likelihood to Likely	Medium to Severe	Moderate to High	*This pollution linkage refers to volatile vapours migrating into confined spaces within the proposed development. Potential sources of volatile contamination were identified through the PRA with former mills and a tank being present onsite.* *Significantly elevated concentrations of PAHs have been recorded across the majority of the site including naphthalene which is considered to be a semi-volatile substance which has been encountered above vapour saturation limits.* *As a potential source of volatile contamination has been encountered, a pollution linkage has been identified.*

Conceptual Site Model						*Generic Quantitative Risk Assessment*
PL	Potential Source	Pollution Linkage	Likelihood	Consequence/ Severity	Risk Rating	*Rationale and Action*
PL3	Contaminated Soils	Inhalation of soil dust by adjacent site users.	Unlikely to Low Likelihood	Medium	Moderate to Low	*Pollution Linkage 3 relates to contamination on the subject site affecting adjacent site users. Potential sources of mobile contamination have been identified through the PRA including the former mills. Residential properties are located close to the northern site boundary and there is potential for migration of mobile contamination off site from the tank which was located close to the northern boundary.* *Significant mobile contamination has not been identified through the ground investigation and lateral migration may have been restricted by the superficial Glacial Till deposits.* *A minor pollution linkage is currently considered to exist.*
PL4	Contaminated Soils	Attacking potable water supply pipe.	Likely	Medium	Moderate to High	*Pollution Linkage 4 refers to the possible contaminants permeating potable water pipes and consumption by the future site end users of the tainted water supply. Made Ground has been encountered to 4.0m bgl and is present at installation depth.* *Made Ground has been identified as being contaminated with a range of Contaminants of Concern including organics associated with the former tank and Mills.* *Potable water supply pipes will be included as part of the development and a local water company risk assessment should be carried out prior to construction to advise on the level of protection required for the potable water supply.*

Conceptual Site Model						*Generic Quantitative Risk Assessment*
PL	Potential Source	Pollution Linkage	Likelihood	Consequence/ Severity	Risk Rating	*Rationale and Action*
PL5	Ground Gas	Migration and accumulation of ground gas in internal spaces.	Likely	Medium to Severe	Moderate to High	*Deep Made Ground was encountered beneath the sites up to a maximum depth of 4.0m bgl during the investigation.* *Interim gas monitoring results currently place the site into CS2 and gas protection measures will be required. This will be confirmed upon completion of the monitoring.* *The site is also located in an area requiring basic radon precautions within foundations. In addition, allowance should be made for the membrane to be resistant to vapours as well.* *Therefore, a pollution linkage has been identified.*

Controlled Waters Pollution Linkage Assessment



- The table below represents the second stage in the land quality risk assessment process – **Generic Quantitative Risk Assessment**.
- In order for a development site to be deemed 'suitable for use' the level of risk needs to be reduced to an acceptable level - low to negligible risk. The purpose of each stage of risk assessment is to establish if there is a requirement for additional stages of assessment in order to have sufficient confidence to support a risk characterisation or remedial action.

Conceptual Site Model					*Generic Quantitative Risk Assessment*	
PL	Potential source	Pollution linkage	Likelihood	Severity	Level of risk	*Rationale*
PL6	Contaminated Soils	Impaction of groundwater from soil contamination (diffuse and point). Impaction of groundwater from groundwater plume.	Unlikely to Low Likelihood	Medium	Moderate to Low	*Made Ground has been encountered to a maximum depth of 4.0m bgl and generally comprised dark brown, grey or black ashy variably clayey to gravelly sand, with localised areas of brown grey gravelly sandy clay and dark grey to black slightly sandy slightly clayey gravel. Visual evidence of contamination was recorded in the form of ash and slag in the Made Ground soils, as well as an oily coating in the Made Ground of HP11 which was dug close to an above ground fuel storage tank. Olfactory evidence of contamination was noted in the Made Ground across the site and was generally linked to an ashy organic odour. A hydrocarbon odour was noted in the soils from around the former fuel storage tank adjacent to WS11.* *Geological maps indicate that the site is underlain by superficial Glacial Till (Secondary (Undifferentiated Aquifer) and the bedrock is the Etruria Formation (Secondary A Aquifer). A significant Clay aquitard was encountered during the investigation.* *Groundwater testing has indicated that slightly elevated concentrations of Nickel and PAHs have been encountered and a significantly elevated concentration of zinc was recorded.*

Conceptual Site Model						*Generic Quantitative Risk Assessment*
PL	Potential source	Pollution linkage	Likelihood	Severity	Level of risk	*Rationale*
						However, the Made Ground beneath the site is underlain by a significant thickness of natural Clay which will have acted as an aquitard protecting the underlying Secondary A Aquifer. *Historically, the site has been surrounded by numerous industrial uses and therefore it is likely that groundwater contamination is indicative of the general area and is not related to the presence of mills on the subject site.* *As a minimum, any free-phase contamination identified beneath the site will need to be remove to prevent it from entering the groundwater.* *The site will be predominantly covered with hardsurfacing and a new drainage system installed which will restrict the infiltration of water through the underlying soils.* *The risk to groundwater from contaminated soils is considered Moderate to Low. Laboratory testing has been undertaken on samples of groundwater obtained from the site and the only significantly elevated contaminant was zinc, however a source has not been identified onsite. A second round of groundwater testing is recommended for EA compliance.*
PL7	Contaminated Soils	Migration of soil and groundwater contamination impacting surface waters.	Unlikely	Medium	Low	*Pollution Linkage 7 refers to the impaction of the Ashton Canal from contaminated soils and groundwater.* *The canal is a closed system and will not be affected by any contamination on the subject site. In addition, the canal will not be in hydraulic continuity with the groundwater as it is present within the sandstone bedrock at circa 20m bgl.* *A pollution linkage is not considered to exist.*

7.7 Outline Remedial Strategy

Soils

Historically, the site has been occupied by former Mills. Made Ground has been encountered beneath the entire site to depths of up to 4.0m bgl. Visual and olfactory evidence of contamination has been encountered across much of the site and geo-environmental testing has recorded elevated concentrations of arsenic, lead, PAHs and TPH CWG. In addition, asbestos was detected in two samples screened at a maximum concentration of 0.57mass%.

The development will be largely covered with hardsurfacing or the proposed residential properties, effectively acting as a cover system which would break the pathway to the underlying contaminated soils. Where soft landscaped areas are proposed, it is recommended that a clean cover layer is installed to mitigate the risk from metals, speciated PAHs, TPH and asbestos.

A 600mm thick, clean cover system overlying a contamination warning membrane or a 100mm hard dig layer will be required in any areas of soft landscaping.

The imported topsoil and subsoil used in the cover system will need to be tested to ensure it is suitably clean for the proposed residential without plant uptake end use. In addition, the depth of cover placed will also need to be validated.

Above Ground Storage Tanks

Elevated concentrations of hydrocarbons have been recorded in HP11 in the area of a former above ground fuel storage tank. These soils will need to be excavated out and removed off site. If any free phase hydrocarbon contamination is identified, this will also need to removed and the resulting excavation will need to be validated to ensure that the soils remaining onsite are suitably clean for the proposed residential end use.

The above ground fuel storage tank will need to be decommissioned in accordance with current guidance and removed offsite in an appropriate manner.

Controlled Waters

Significant contamination has not been encountered within the underlying groundwater beneath the site with the exception of a significantly elevated concentration of zinc being recorded in BH3. An onsite source of zinc has not been identified and is likely to be associated with an offsite source. At this stage, no further action is required in regard to controlled waters, a further monitoring visit is recommended to satisfy the EA subject to findings.

Ground Gas

Interim gas monitoring has indicated that the site falls into CS2 conditions and gas protection measures will be required with regards to ground gases. This will be confirmed on completion of the monitoring.

The site is located in an area requiring basic radon precautions.

In addition, due to the vapour risk generated from the presence of naphthalene contamination at the site, a vapour resistant membrane will also be required unless modelling determines a membrane is not required.

Further Investigation

Further environmental testing of the 6F2 stockpile on site should be undertaken if it is wished to be utilised as a piling mat during the construction works. Testing to date indicates no elevated Contaminants of Concern.

Obstructions as part of the historic land use, such as the brick walls and concrete slab structures, will require grubbing up as part of the enabling works.

Waste and Fly Tipped Material

Care should be taken when removing the waste and fly tipped material as several LPG gas cannisters have been identified. Further dangerous objects may also be present.

Watching Brief and Regulatory Compliance

A watching brief should be in place during ground works and construction. If previously unidentified contamination is encountered, work should cease in that area and Groundtech Consulting contacted for advice.

Regulatory compliance should be obtained pre-commencement to avoid delays during the construction phase which will have cost implications.

7.8 Asbestos in Soils

Asbestos has been encountered in only two of the thirty-two samples that were screen in HP11 at 0.5m and TP07 at 1.0m bgl within the granular Made Ground in the form of Chrysotile cement and Amosite fibre bundles respectively. The asbestos quantification results indicate the Chrysotile mass is 0.57%. and the Amosite mass is 0.002%. It is recommended that where possible, the asbestos impacted soils remain undisturbed. The cover system implemented in the soft landscaped areas of the proposed development will break the pollution linkage to this material.

Where soils will be disturbed as part of the ground works, in accordance with the Joint Industry Working Group (JIWG) decision support tool for CAR2012 work categories, the combined hazard and exposure ranking is *Low* for the asbestos detected at trace levels. The work is classified as non-licenced, and CAR does not apply. RPE, dust suppression and decontamination are not required.

The JIWG tables are presented in *Appendix 11*. This should be used as an aid to classify risk and recommend the level of protection required, the final decision on how asbestos within the soils should be managed should be made by the contractor.

7.9 Health and Safety - Construction and Ground Workers

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

PL Ref	Potential Source	Pollution Linkage	Likelihood	Severity	Level of Risk
PL8	*Made Ground Soils*	*Ingestion, direct contact, inhalation of dusts.*	*Likely*	*Medium*	***Moderate to High***
PL8	*Asbestos*	*Ingestion, direct contact, inhalation of dusts.*	*Likely*	*Medium to High*	***Moderate to High***

Elevated concentrations of metals, PAHs and TPH CWG have been recorded across much of the site in the underlying Made Ground soils. In addition, asbestos has been detected at two locations in the granular Made Ground. The risk to ground workers should be communicated through a site induction and through information on noticeboards.

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

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

7.10 Waste Classification by Assessment

We have reviewed the testing results and inputted them into the HazWasteOnline model which allows users to code and classify waste as defined in the EWC (European Waste Catalogue 2002) based on EC Regulation 1272/2008 on the Classification, labelling and packaging of substances and mixtures (CLP) and latest Environment Agency guidance (WM3 "Guidance on the classification and assessment of waste (1st edition 2015)-Technical Guidance").

This is a useful tool as waste producers have the legal responsibility to classify any waste they produce.

Thirty samples were tested to assess whether they contained any contaminants in the hazardous range when screened against assessment criteria within WM3. The results are in the Waste Classification Report presented in *Appendix 12*.

Based on the assessment tool the Made Ground soils have generally been classified as *Non-Hazardous*. However, three samples of the granular Made Ground have been classified as being Hazardous as follows:

- *HP03 at 0.5m - Ecotoxic hazardous properties associated with the copper content.*
- *WS07A at 1.0m - Ecotoxic hazardous properties associated with the lead content.*
- *BH1 at 0.5m bgl - Corrosive hazardous properties associated with the pH concentration.*

Total testing was undertaken on two samples of the natural soils in TP06 at 2.7m bgl and WS08 at 2.5m bgl and have these have been classified as *Non-Hazardous* for waste disposal purposes.

7.11 Waste Acceptance Criteria (WAC) Results

The Landfill Directive (Directive 1999/31/EC on the landfilling of waste) led to the establishment of a methodology for classifying wastes. Wastes can only be accepted at a landfill if they meet the relevant Waste Acceptance Criteria (WAC) for that type of landfill. There are three different WAC, these are for:

- *Inert waste*
- *Non-Hazardous waste*
- *Hazardous waste*

Wastes should first be classified based on their total concentrations as detailed in the previous section. WAC testing is then required if the end disposal route is a landfill.

Waste Acceptance Criteria (WAC) testing was outside the scope of this investigation and the guidance given below is general.

The possibility of automatic inert classification of the natural soils should be explored in accordance with Section 4.3 of the EA guidance document. The Council Decision includes a list of wastes in Section 2.1.1 of the document that are assumed to be inert and therefore acceptable at a landfill for inert waste without testing, this is the case if:

- *They are single stream waste of a single waste type (although different waste types from the list may be accepted together if they are from a single source)*
  and
- *There is no suspicion of material or substances such as metals, asbestos, plastics, chemicals, etc to an extent which increases the risk associated with the waste sufficiently to justify contamination and they do not contain other their disposal in other classes of landfill.*

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

Materials should be segregated and where necessary, sufficient time is allowed to further classify the material properly, including discussion with landfill sites and waste transfer stations to find the best disposal route. It is recommended that where possible, the soils could be recycled at a suitable local waste treatment plant or transfer station rather than a landfill disposal route.

The reuse of soils on the site this should be done in accordance with the CL:AIRE "Development Industry Code of Practice for the Definition of Waste" (CL:AIRE CoP). Any re-use scheme should be designed to minimise disposal costs.

After a cut and fill balance plan/volume calculation has been carried out, a U1 and T5 exemption could be registered. This will allow the use of the following soils without a waste permit or under Dow CoP MMP:

- *1,000 tonnes (c.600m^3) of non-hazardous soil*
- *5,000 tonnes (c.3,000m^3) of natural sand and gravels.*
- *50,000 tonnes (c.25,000m^3) of bituminous material to be used in roadways.*
- *5,000 tonnes (c.3,000m^3) of crushed concrete / stone.*

8.0 FINAL APPRAISAL

8.1 Land Quality

The site has historically been occupied by Mills and a chapel. The mill on the northern half of the site still exists whereas the buildings on the southern area have been demolished.

Made Ground has been encountered to a maximum depth of 4.0m bgl and was underlain by firm and firm to stiff Clay interbedded with bands of sand. Sandstone bedrock was encountered from depths of between 15.5m and 17.8m bgl.

Geo-environmental testing has recorded elevated concentrations of metals and PAHs within the granular Made Ground soils. In addition, elevated concentrations of hydrocarbons were recorded in HP11 which was excavated adject to an above ground tank. Asbestos was detected in two of thirty-two samples that were screened.

It is proposed to develop the site with apartments which will include areas of soft landscaping therefore the risk to human health is considered to be *Moderate.*

Potential sources of volatiles have been identified and the risk from vapours is considered to be *Moderate to High.*

Interim gas monitoring results currently place the site into CS2 and gas protection measures will be required. This will be confirmed upon completion of the monitoring. The site is also located in an area requiring basic radon precautions within foundations. In addition, allowance should be made for the membrane to be resistant to vapours as well. The risk from permanent ground gases is *Moderate to High.*

Groundwater testing indicates that elevated concentrations of Nickel, Zinc and PAHs are present in the samples that were taken from beneath the site. The site has historically been surrounded by industrial premises which are indicated to be the source of the contamination. In addition, the site is underlain by natural cohesive deposits which will have prevented the downward migration of potential contaminants. At present, the risk to groundwater is *Moderate to Low* and a second round of groundwater monitoring is required. The risk to nearby surface water is *Low.*

Based on the assessment tool the granular Made Ground soils have generally been classified as *Non-Hazardous*. However, three samples of the granular Made Ground have been classified as being *Hazardous* as follows:

- *HP03 at 0.5m - Ecotoxic hazardous properties associated with the copper content.*
- *WS07A at 1.0m - Ecotoxic hazardous properties associated with the lead content.*
- *BH1 at 0.5m bgl - Corrosive hazardous properties associated with the pH concentration.*

8.2 Ground Engineering

The most suitable solution for the proposed apartment development is considered to be piled foundations transferring loads through the underlying Made Ground and natural Clay and Sand strata to the very weak Sandstone which has been encountered between 15.5m and 17.8m bgl. The most suitable type of pile for the development is considered to be Continuous Flight Auger (CFA) bored pile, this should be discussed with the preferred piling contractor.

The results of laboratory pH and sulphate content indicate that ACEC Class AC-3 and sulphate class DS-3 conditions prevail in accordance with BRE Special Digest 1 "Concrete in aggressive ground" 2005.

CBR values of 2% to 5% are likely to be achieved in any shallow undisturbed natural soils for pavement design purposes. Untreated Made Ground should be assumed to have a CBR value of less than 2.5%, unless proven otherwise.

SuDS drainage is not considered to be a feasible option at the site due to the presence of deep Made Ground and natural cohesive soils beneath the site which are capable of poor infiltration rates.

There are archaeological restrictions on the site that require consideration.

8.3 Required Further Work

The following further work is considered necessary to progress the site to construction phase:

Completion of gas monitoring programme
Issue gas assessment
Second round of groundwater testing
Further environmental testing of 6F2 stockpile if utilised
Removal of piles of waste and fly tipping in the external area
Demolition and Refurbishment Asbestos survey
Production of Remedial Specification
Vapour modelling, if required
Tree survey by qualified arboriculturist
Detailed foundation design
Confirmation of the recommendations made within this report with the Regulators

9.0 RELEVANT INDUSTRY REFERENCES

British Standards Institution. *Investigation of Potentially Contaminated sites - code of practice*. BS 10175:2017.

British Standards Institution '*Code of Practice for Site Investigations*' BS 5930:2020

British Standards Institution "*Geotechnical investigation and testing – Identification and classification of soil*" BS EN ISO 14688:2002.

British Standards Institution "*Geotechnical investigation and testing – Identification and classification of rock*" BS EN ISO 14689:2002.

BRE Report BR211 '*Radon – Guidance on protective measures for new buildings'* 2015 Edition.

BRE Special Digest 1: "*Concrete in Aggressive Ground*" 3rd Ed 2005.

CIRIA 552 "Contaminated Land Risk Assessment – A guide to good practice" 2001.

CIRIA C665 "Assessing Risks Posed by Hazardous Ground Gases to Buildings" 2007.

Wilson & Card "*Proposed method classifying gassing sites*" Ground Engineering 1999.

Card & Steve Wilson in *"A pragmatic approach to ground gas risk assessment for the 21st Century"* - CIRIA/Environmental Protection UK Ground gas seminar 2011

BS 8576:2013 '*Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs)'*

BS 8485:2015 '*Code of practise for the design of protective measures for methane and carbon dioxide ground gases for new buildings'*

The Hazardous Waste (England) Regulations 2005.

Environment Agency Hazardous Waste: "*Guidance on the classification and assessment of waste"* WM3 ver 1 May 2015.

The National Planning Policy Framework (NPPF) March 2012

DETR. Circular 02/2000 Contaminated Land.

Environment Agency, 2009 'Using Soil Guideline Values'.

Environment Agency, 2009 'Updated Technical Background to the CLEA model'.

Environment Agency, 2009 'Human health toxicological assessment of contaminants in soil'.

Department of the Environment, 1994, CLR Report No 1 'A framework for assessing the impact of contaminated land on groundwater and surface water'.

Department of the Environment, 1994, CLR Report No 2 'Guidance on Preliminary Site Inspection of Contaminated Land'.

Department of the Environment, 1994, CLR Report No 3 'Documentary research on Industrial Sites'.

Department of the Environment, 1994, CLR Report No 4 'Sampling Strategies for Contaminated Land'.

DEFRA and the Environment Agency, 2002-2004, CLR10 'Soil Guideline Value Reports for Individual Soil Contaminants'.

Land Contamination Risk Management (LCRM), April 2021.

Nathanail, C. P., McCaffrey, C., Gillett, A., Ogden, R. C. and Nathanail, J.F. 2015. The LQM/CIEH S4ULs for Human Health Risk Assessment. Land Quality Press, Nottingham.

CL:AIRE, 2014 'Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination'.

Water Framework Directive.

Environmental Quality Standards.

UK Drinking Water Standards: Water Supply (Water Quality) Regulations 1989 (SI 1989/1147) and Water Supply (Water Quality) Regulations

UKWIR Report 10/WM/03/21 2010 "Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites"

Health & Safety Executive, 1991. 'Protection of Workers & the General Public during the Development of Contaminated Land'.

Environment Agency & NHBC, 2000. R&D Publication 66. Guidance for the Safe Development of Housing on Land Affected by Contamination.

Environment Agency "Guidance on the classification and assessment of waste (1st edition 2015) Technical Guidance WM3"

NHBC Standards 2023

CL:AIRE "*The Definition of Waste: Development Industry Code of Practice*" Version 2 March 2011.

CIRIA "*Asbestos in soil and made ground: a guide to understanding and managing risks*" C733 2014

Control of Asbestos Regulations (CAR) 2012

Harris, M R, Herbert, S. M, Smith, M A 'Remedial Treatment for Contaminated Land' (twelve volumes), special publications 101-112, CIRIA 1996.

Department of the Environment. 1995. Industry Profiles - 48 separate publications available from The Stationery Office, London

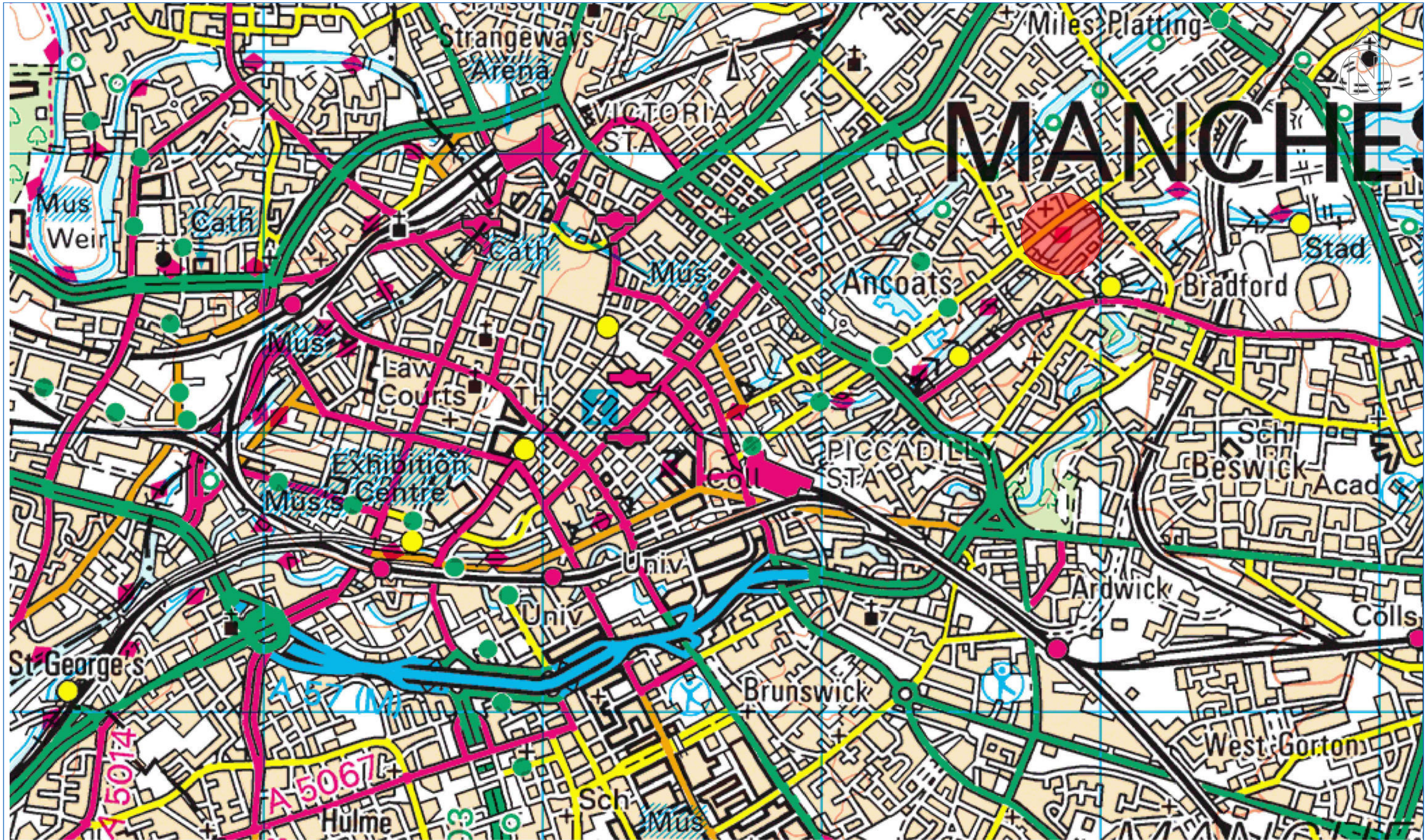
BRE Digest 365 "Soakaway Design" 2015.

Environment Agency. R&D Publication 20. Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources. 1999.

Environment Agency Technical Guidance Note 01. Hydrogeological Risk Assessment for Landfills.

Specification for Highways Works – Series 600 Earthworks November 2017.

APPENDIX 1 - Plans



GROUNDTECH CONSULTING

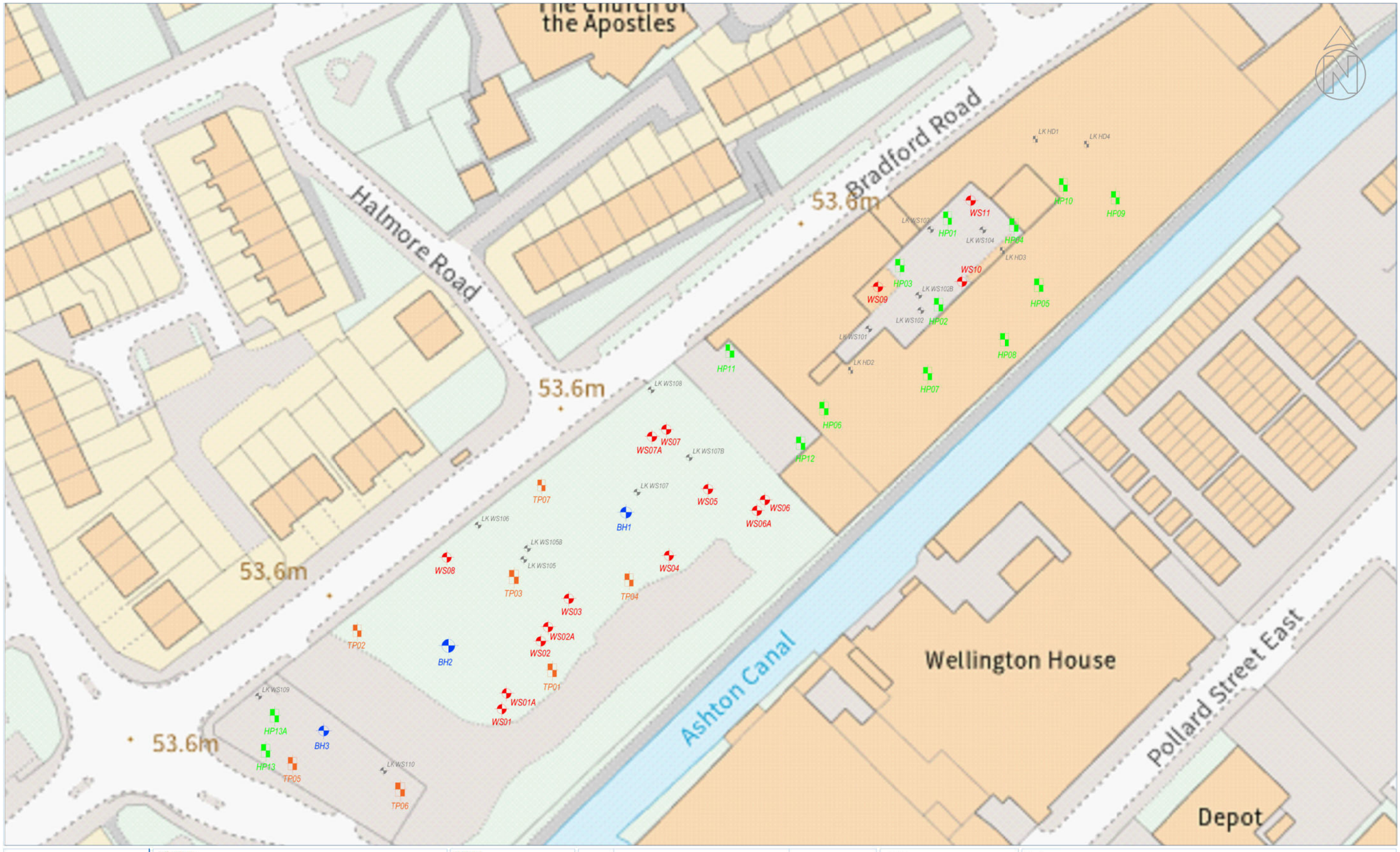
CLIENT	ARROWSMITH INVESTMENT LIMITED
PROJECT TITLE	BRUNSWICK MILL
PLAN TITLE	PROJECT LOCATION PLAN
DATE	JUNE 2023
SCALE	NTS
PLAN NUMBER	GRO-22462-P01

Rev.	Details	Date

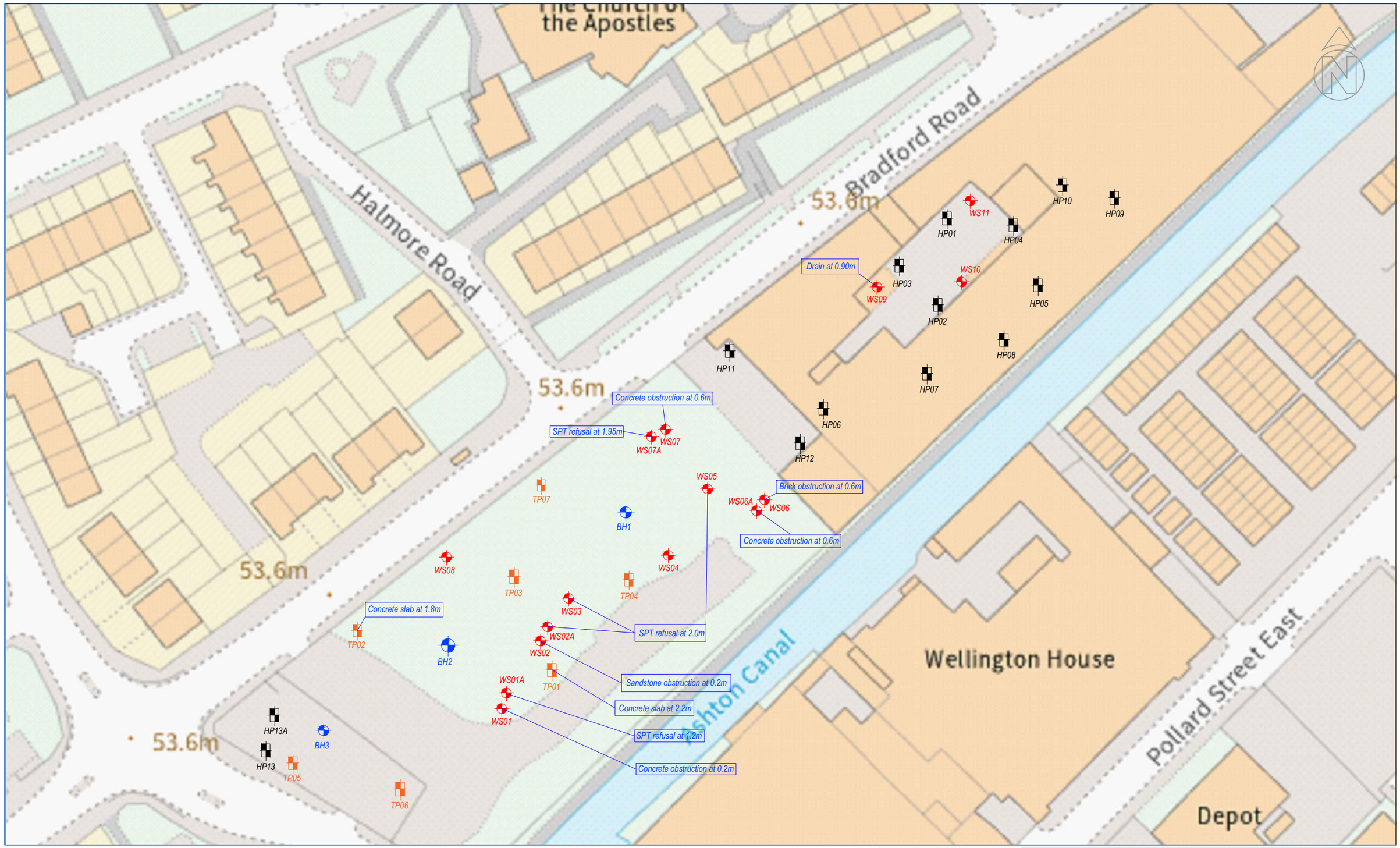
Status	
Preliminary	
Draft	
Issued	●
For Comment	
Approved	

Notes

SITE LOCATION



GROUNDTECH CONSULTING	CLIENT: ARROWSMITH INVESTMENT LIMITED	DATE: JUNE 2023			Status: Preliminary / Draft / Issued ● / For Comment / Approved
	PROJECT TITLE: BRUNSWICK MILL	SCALE: NTS			Notes: GROUNDTECH HAND DUG PIT LOCATION; GROUNDTECH TRIAL PIT LOCATION; GROUNDTECH CABLE PERCUSSION AND ROTARY BOREHOLE LOCATION; GROUNDTECH WINDOWLESS SAMPLE BOREHOLE LOCATION; LK WINDOWLESS SAMPLE BOREHOLE LOCATION; LK HAND DUG PIT LOCATION
	PLAN TITLE: EXPLORATORY HOLE LOCATION PLAN	PLAN NUMBER: GRO-22462-P02	Rev.	Details / Date	



GROUNDTECH CONSULTING	CLIENT: ARROWSMITH INVESTMENT LIMITED	DATE: JUNE 2023
	PROJECT TITLE: BRUNSWICK MILL	SCALE: NTS
	PLAN TITLE: OBSRTUCTIONS PLAN	PLAN NUMBER: GRO-22462-P03

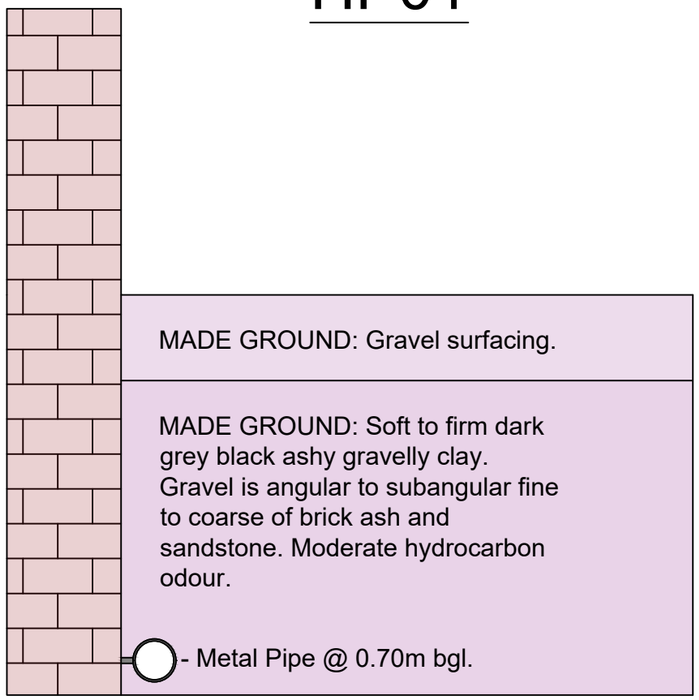
Rev.	Details	Date

Status	
Preliminary	
Draft	
Issued	●
For Comment	
Approved	

Notes

- HAND DUG PIT LOCATION
- TRIAL PIT LOCATION
- CABLE PERCUSSION AND ROTARY BOREHOLE LOCATION
- WINDOWLESS SAMPLE BOREHOLE LOCATION

HP01



Ground Level

0.15m

0.70m



GROUNDTECH CONSULTING

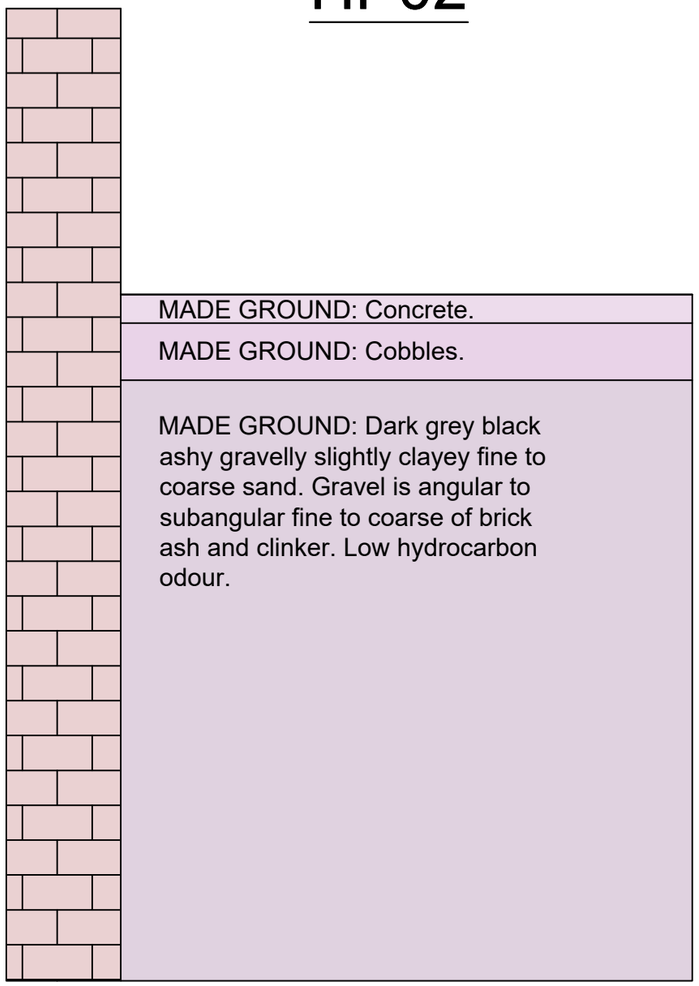
CLIENT	ARROWSMITH INVESTMENT LIMITED
PROJECT TITLE	BRUNSWICK MILL
PLAN TITLE	HP01 FOUNDATION CROSS SECTION
DATE	JULY 2023
SCALE	NTS
PLAN NUMBER	GRO-22462-P04A

Rev.	Details	Date

Status	
Preliminary	
Draft	
Issued	●
For Comment	
Approved	

Notes

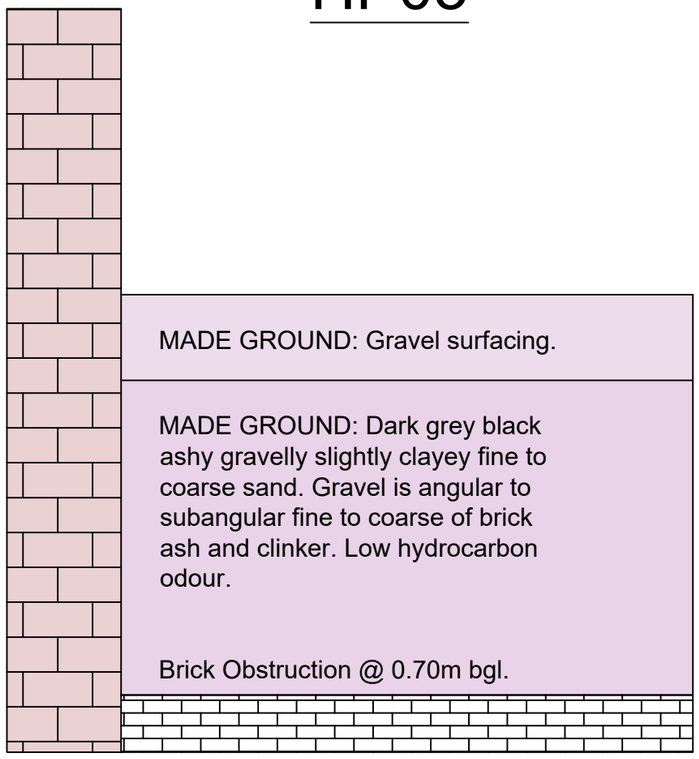
HP02





GROUNDTECH CONSULTING	CLIENT: ARROWSMITH INVESTMENT LIMITED	DATE: JULY 2023			Status: Preliminary / Draft / Issued ● / For Comment / Approved
	PROJECT TITLE: BRUNSWICK MILL	SCALE: NTS			Notes
	PLAN TITLE: HP02 FOUNDATION CROSS SECTION	PLAN NUMBER: GRO-22462-P04B	Rev. / Details / Date		

HP03



Ground Level

0.15m

0.70m
Unknown



GROUNDTECH CONSULTING

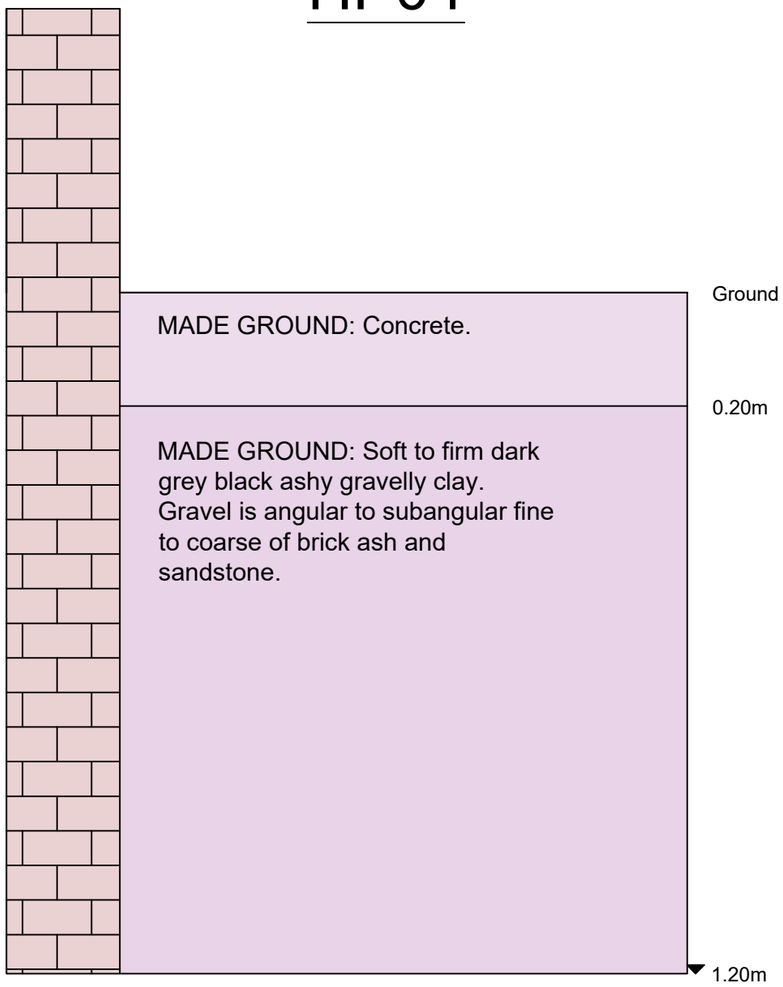
CLIENT	ARROWSMITH INVESTMENT LIMITED
PROJECT TITLE	BRUNSWICK MILL
PLAN TITLE	HP03 FOUNDATION CROSS SECTION
DATE	JULY 2023
SCALE	NTS
PLAN NUMBER	GRO-22462-P04C

Rev.	Details	Date

Status	
Preliminary	
Draft	
Issued	●
For Comment	
Approved	

Notes

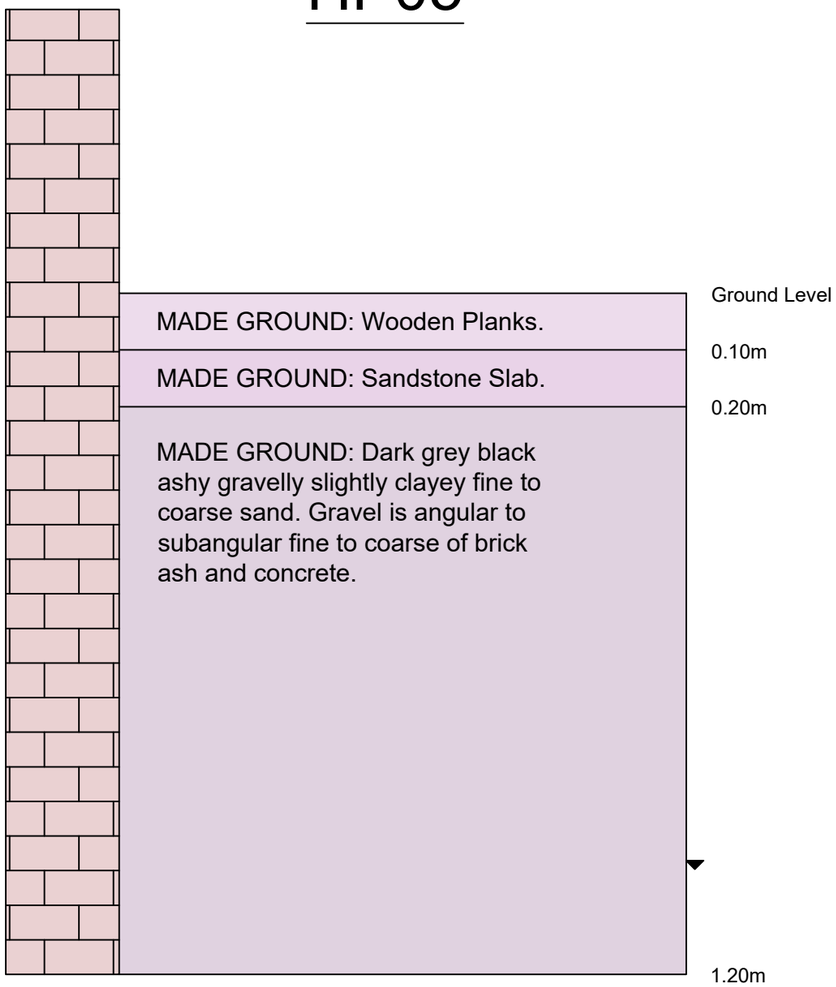
HP04





GROUNDTECH CONSULTING	CLIENT: ARROWSMITH INVESTMENT LIMITED	DATE: JULY 2023				Status: Preliminary ☐ Draft ☐ Issued ● For Comment ☐ Approved ☐
	PROJECT TITLE: BRUNSWICK MILL	SCALE: NTS				Notes
	PLAN TITLE: HP04 FOUNDATION CROSS SECTION	PLAN NUMBER: GRO-22462-P04D	Rev.	Details	Date	

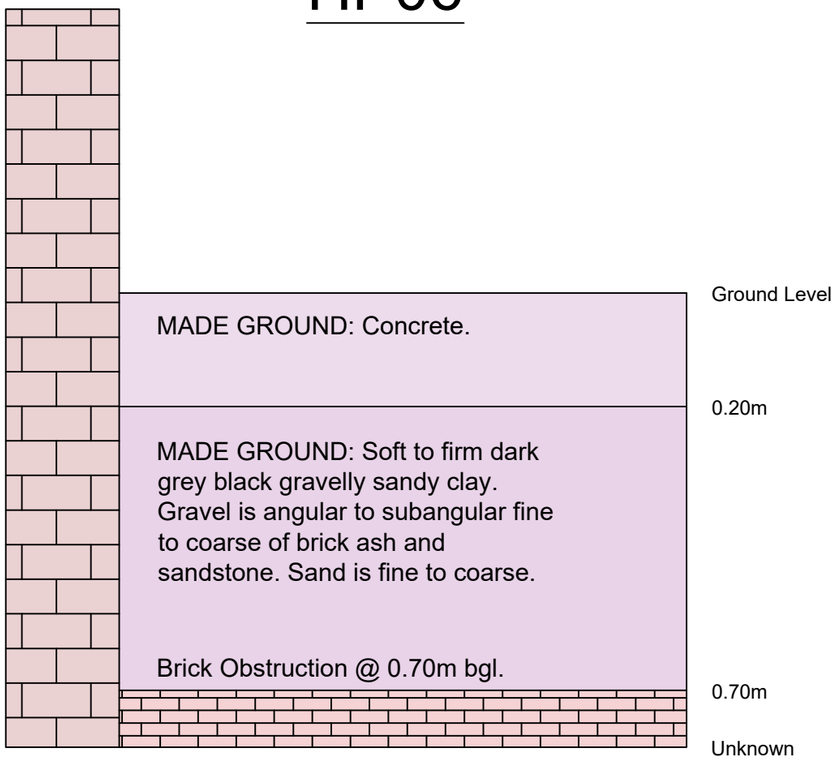
HP05





GROUNDTECH CONSULTING	CLIENT: ARROWSMITH INVESTMENT LIMITED	DATE: JULY 2023			Status: Preliminary ☐ Draft ☐ Issued ● For Comment ☐ Approved ☐
	PROJECT TITLE: BRUNSWICK MILL	SCALE: NTS			Notes
	PLAN TITLE: HP05 FOUNDATION CROSS SECTION	PLAN NUMBER: GRO-22462-P04E	Rev.	Details / Date	

HP06





GROUNDTECH CONSULTING

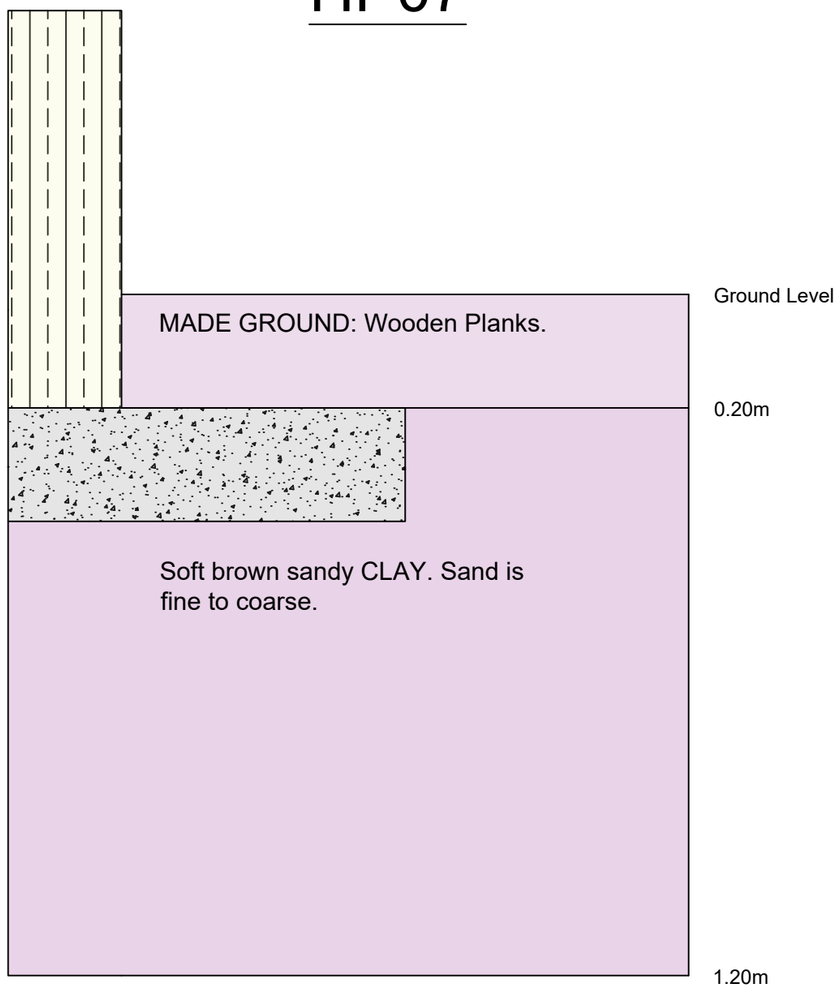
CLIENT	ARROWSMITH INVESTMENT LIMITED
PROJECT TITLE	BRUNSWICK MILL
PLAN TITLE	HP06 FOUNDATION CROSS SECTION
DATE	JULY 2023
SCALE	NTS
PLAN NUMBER	GRO-22462-P04F

Rev.	Details	Date

Status	
Preliminary	
Draft	
Issued	●
For Comment	
Approved	

Notes

HP07





GROUNDTECH CONSULTING

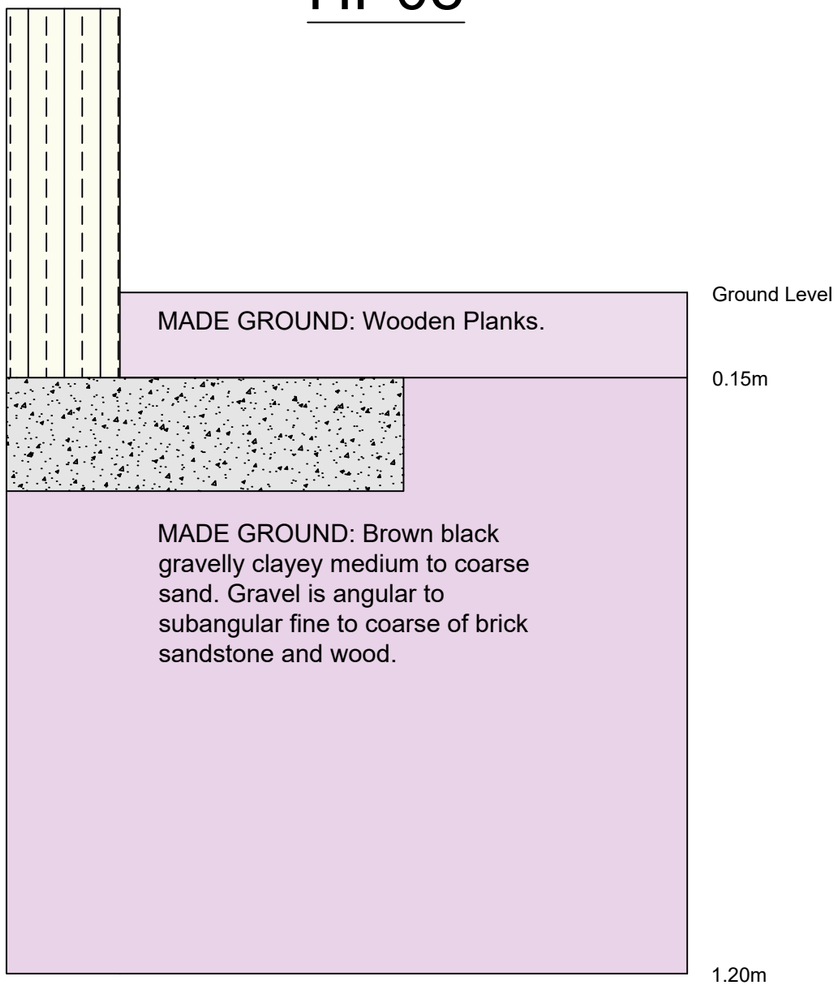
CLIENT	ARROWSMITH INVESTMENT LIMITED
PROJECT TITLE	BRUNSWICK MILL
PLAN TITLE	HP07 FOUNDATION CROSS SECTION
DATE	JULY 2023
SCALE	NTS
PLAN NUMBER	GRO-22462-P04G

Rev.	Details	Date

Status	
Preliminary	
Draft	
Issued	●
For Comment	
Approved	

Notes

HP08

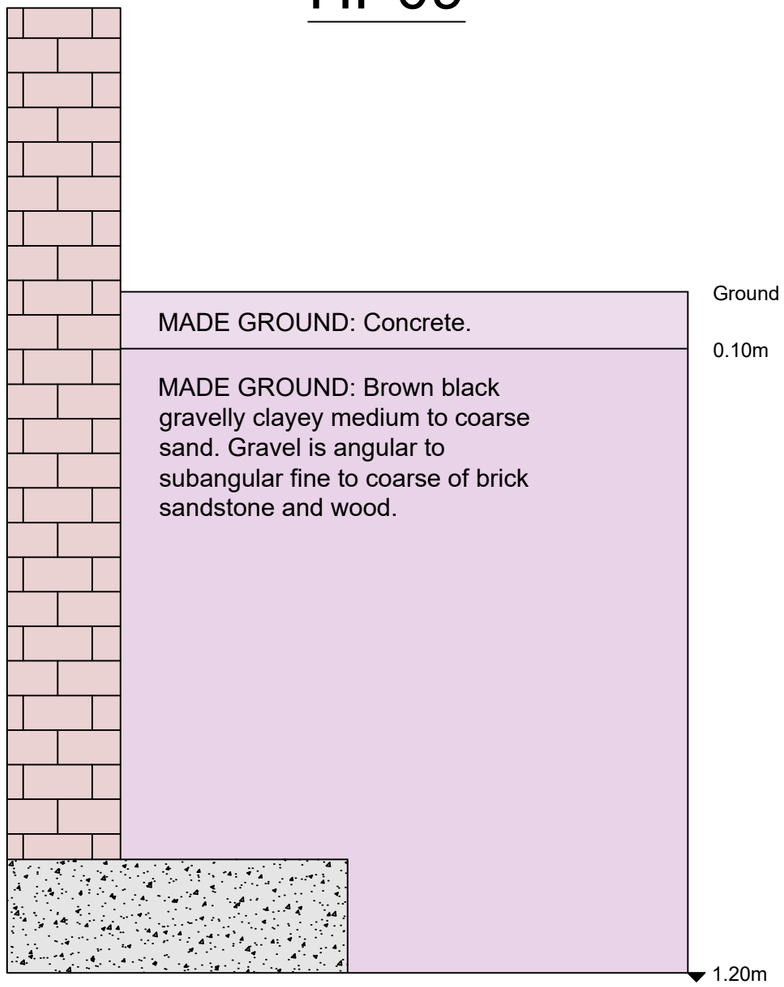




GROUNDTECH CONSULTING	CLIENT: ARROWSMITH INVESTMENT LIMITED	DATE: JULY 2023				Status	
	PROJECT TITLE: BRUNSWICK MILL	SCALE: NTS				Preliminary	
						Draft	
	PLAN TITLE: HP08 FOUNDATION CROSS SECTION	PLAN NUMBER: GRO-22462-P04H				Issued	●
						For Comment	
			Rev.	Details	Date	Approved	

Notes

HP09





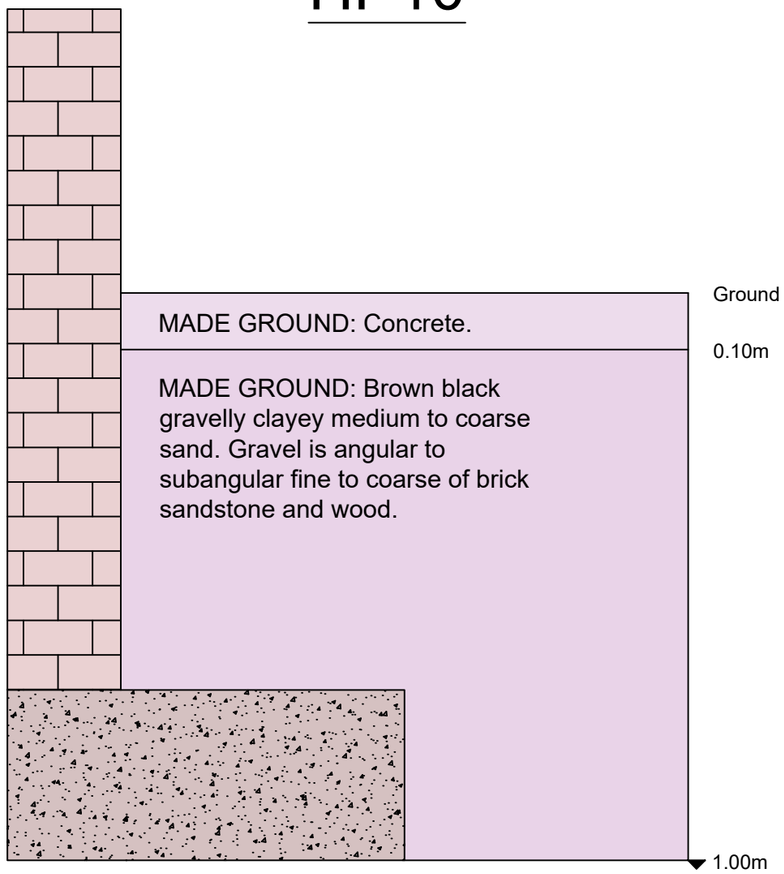
CLIENT	ARROWSMITH INVESTMENT LIMITED
PROJECT TITLE	BRUNSWICK MILL
PLAN TITLE	HP09 FOUNDATION CROSS SECTION
DATE	JULY 2023
SCALE	NTS
PLAN NUMBER	GRO-22462-P04I

Rev.	Details	Date

Status	
Preliminary	
Draft	
Issued	●
For Comment	
Approved	

Notes

HP10





GROUNDTECH CONSULTING

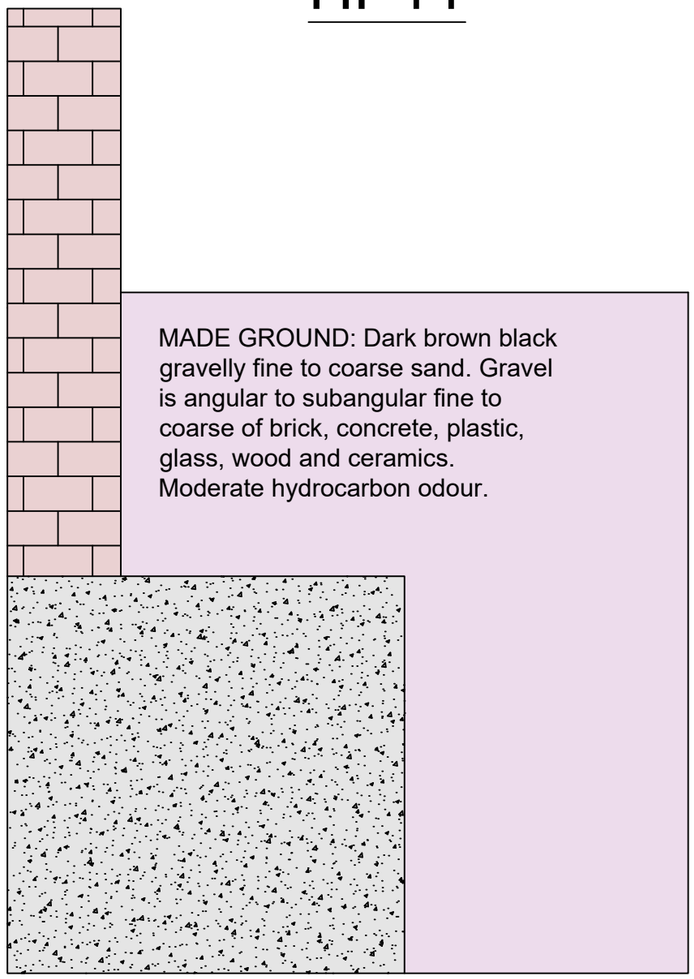
CLIENT	ARROWSMITH INVESTMENT LIMITED
PROJECT TITLE	BRUNSWICK MILL
PLAN TITLE	HP10 FOUNDATION CROSS SECTION
DATE	JULY 2023
SCALE	NTS
PLAN NUMBER	GRO-22462-P04J

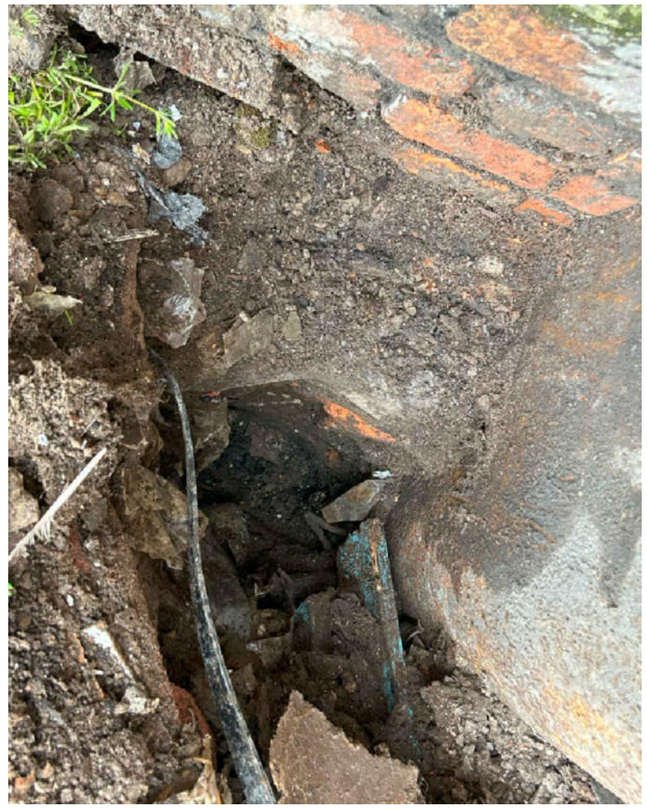
Rev.	Details	Date

Status	
Preliminary	
Draft	
Issued	●
For Comment	
Approved	

Notes

HP11





GROUNDTECH CONSULTING

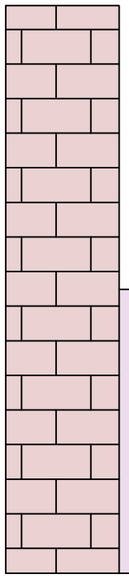
CLIENT	ARROWSMITH INVESTMENT LIMITED
PROJECT TITLE	BRUNSWICK MILL
PLAN TITLE	HP11 FOUNDATION CROSS SECTION
DATE	JULY 2023
SCALE	NTS
PLAN NUMBER	GRO-22462-P04K

Rev.	Details	Date

Status	
Preliminary	
Draft	
Issued	●
For Comment	
Approved	

Notes

HP12



Ground Level

MADE GROUND: Dark brown black gravelly fine to coarse sand. Gravel is angular to subangular fine to coarse of brick, concrete, plastic, glass, wood and ceramics.
Moderate hydrocarbon odour.

Terminated at 0.50m bgl due to collapse.

0.50m



GROUNDTECH CONSULTING

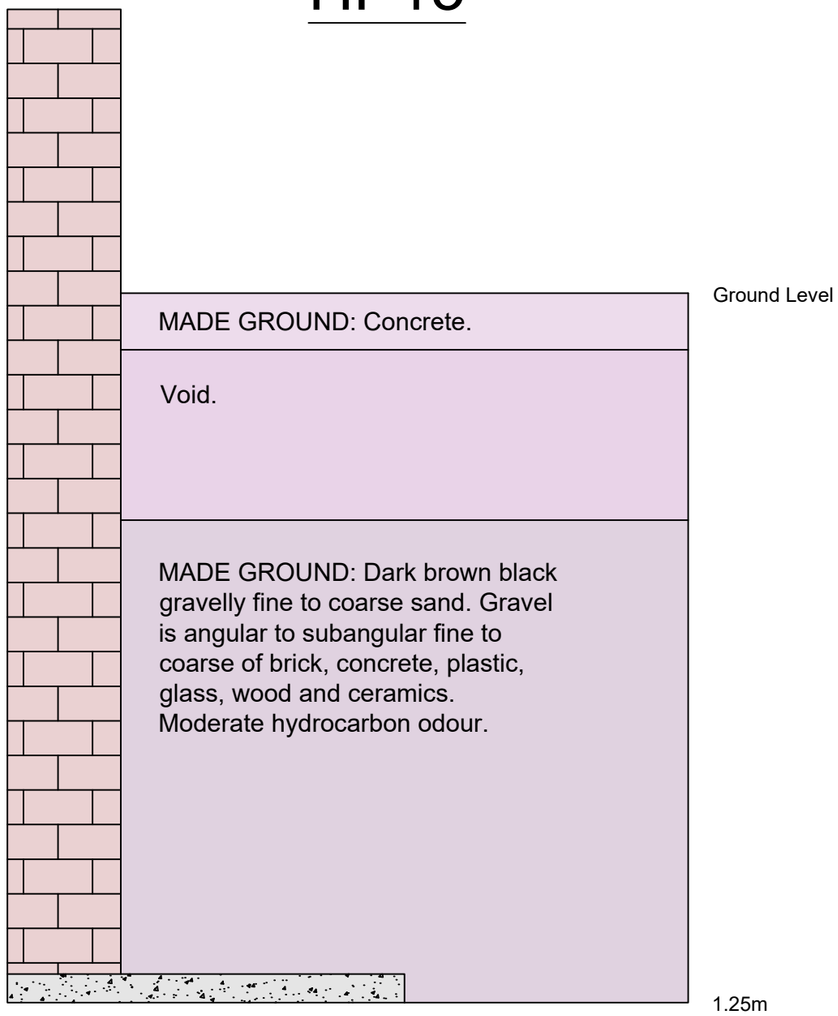
CLIENT	ARROWSMITH INVESTMENT LIMITED
PROJECT TITLE	BRUNSWICK MILL
PLAN TITLE	HP12 FOUNDATION CROSS SECTION
DATE	JULY 2023
SCALE	NTS
PLAN NUMBER	GRO-22462-P04L

Rev.	Details	Date

Status	
Preliminary	
Draft	
Issued	●
For Comment	
Approved	

Notes

HP13





GROUNDTECH CONSULTING

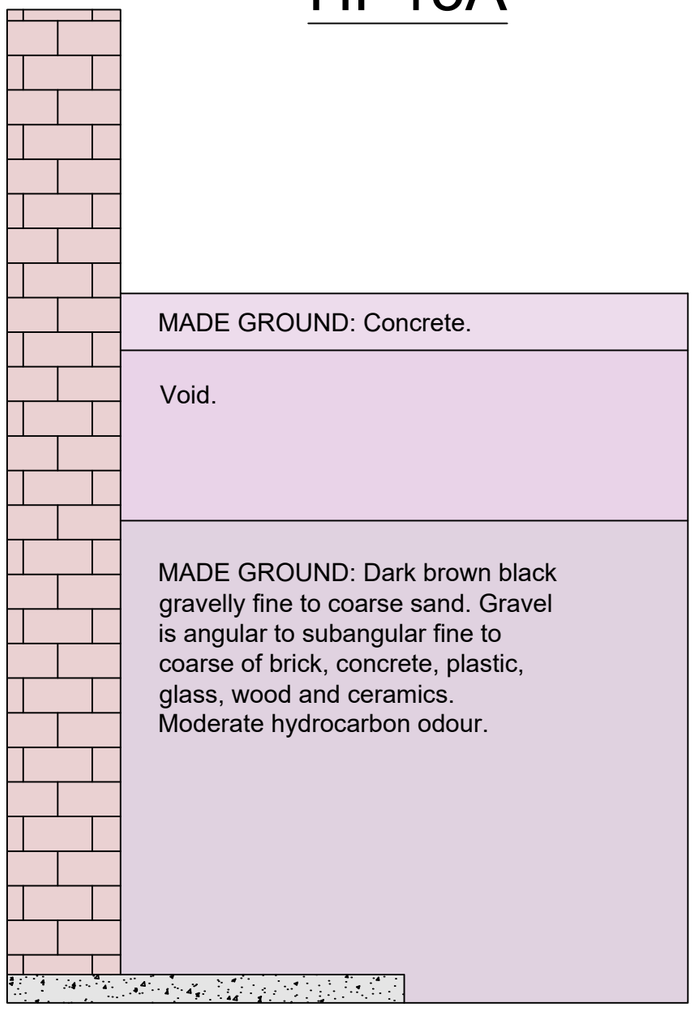
CLIENT	ARROWSMITH INVESTMENT LIMITED
PROJECT TITLE	BRUNSWICK MILL
PLAN TITLE	HP13 FOUNDATION CROSS SECTION
DATE	JULY 2023
SCALE	NTS
PLAN NUMBER	GRO-22462-P04M

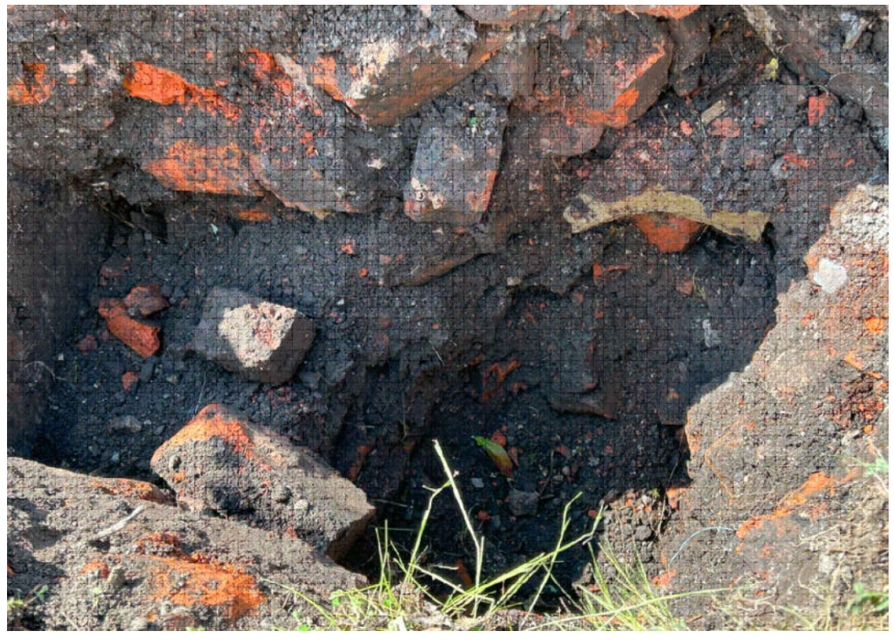
Rev.	Details	Date

Status	
Preliminary	
Draft	
Issued	●
For Comment	
Approved	

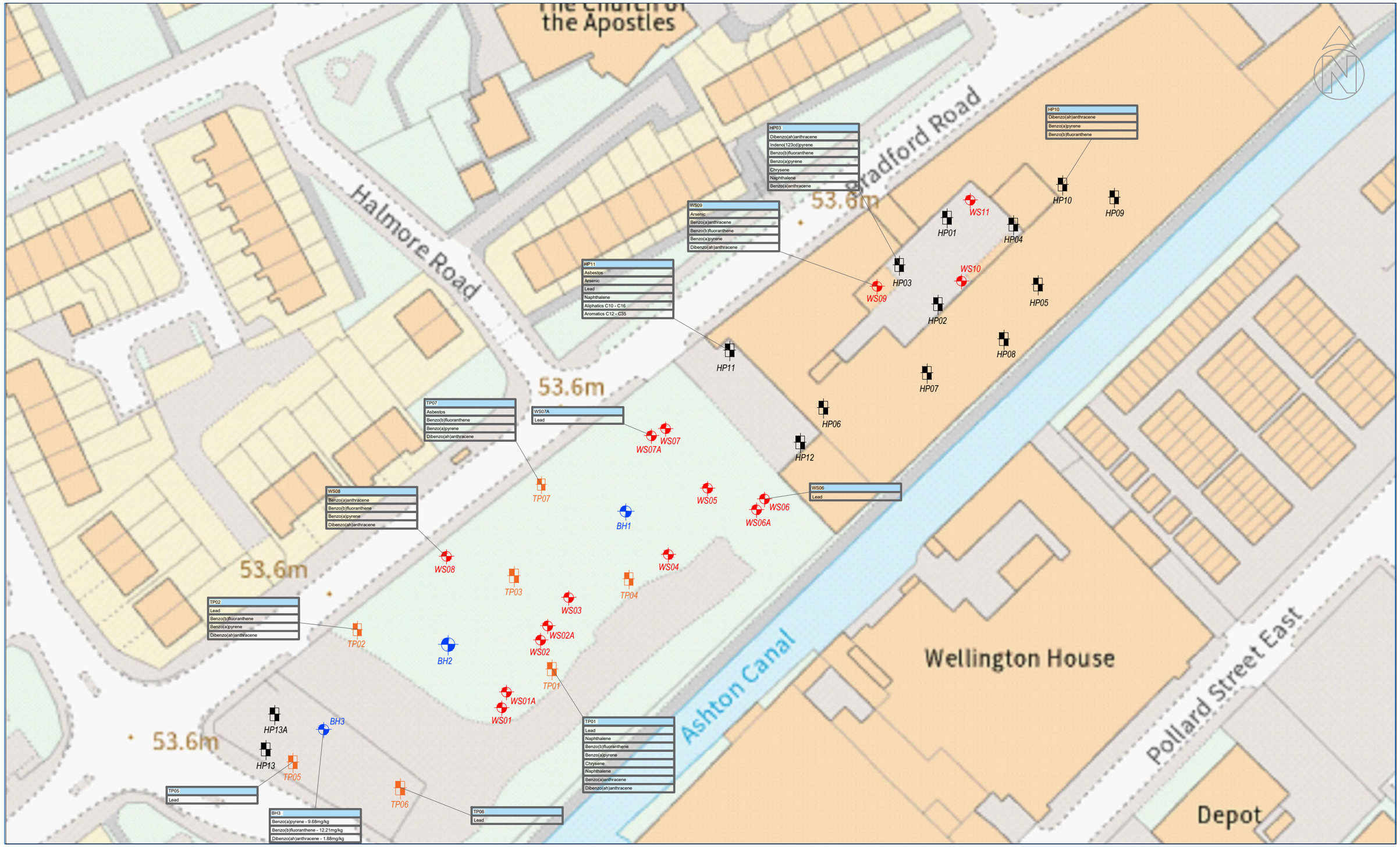
Notes

HP13A





GROUNDTECH CONSULTING	CLIENT: ARROWSMITH INVESTMENT LIMITED	DATE: JULY 2023			Status: Preliminary / Draft / Issued / For Comment / Approved
	PROJECT TITLE: BRUNSWICK MILL	SCALE: NTS			Notes
	PLAN TITLE: HAND DUG FOUNDATION PIT	PLAN NUMBER: GRO-22462-HP13A	Rev. / Details / Date		



GROUNDTECH CONSULTING	CLIENT: ARROWSMITH INVESTMENT LIMITED	DATE: JUNE 2023	
	PROJECT TITLE: BRUNSWICK MILL	SCALE: NTS	
	PLAN TITLE: CONTAMINATION PLAN	PLAN NUMBER: GRO-22462-P06	

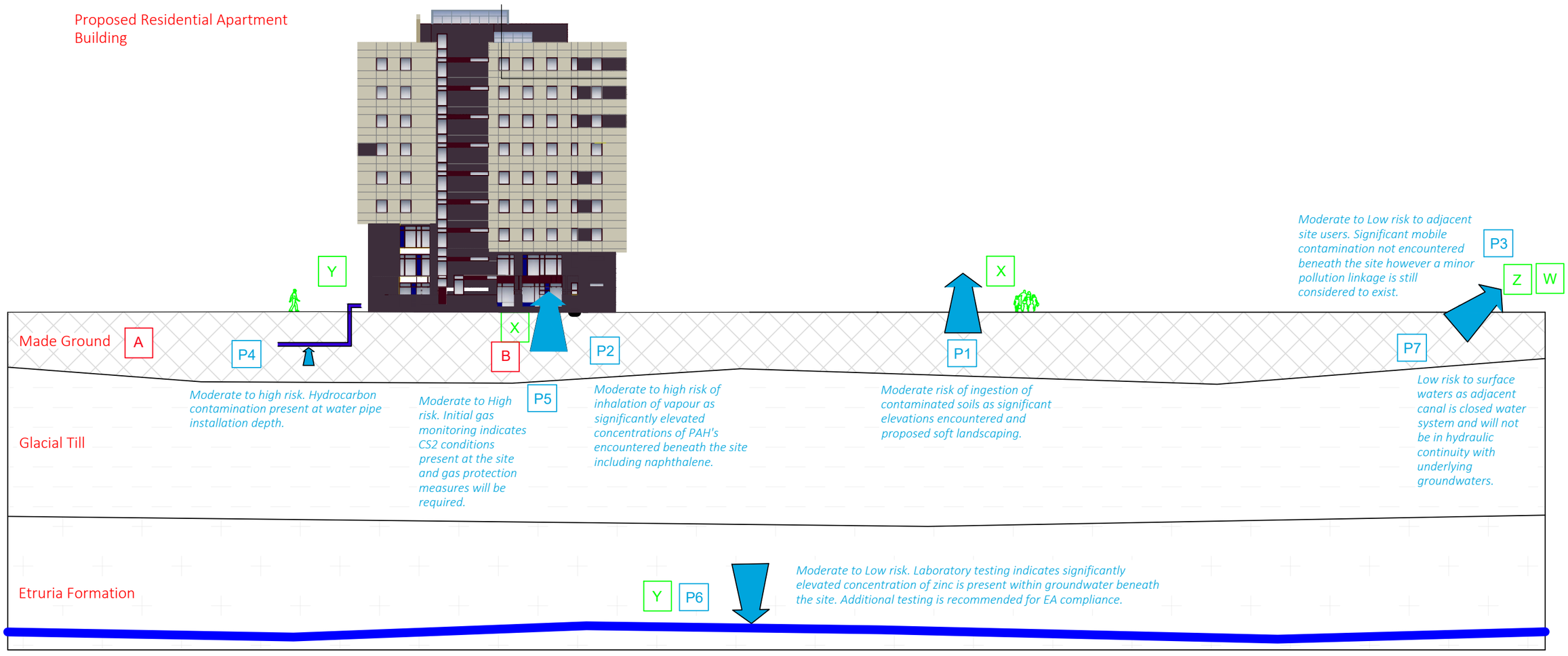
Rev.	Details	Date

Status	
Preliminary	
Draft	
Issued	●
For Comment	
Approved	

Notes

- HAND DUG PIT LOCATION
- TRIAL PIT LOCATION
- CABLE PERCUSSION AND ROTARY BOREHOLE LOCATION
- WINDOWLESS SAMPLE BOREHOLE LOCATION

SOURCES	POLLUTION LINKAGES	RECEPTORS
A. Contaminated soils / Made Ground. B. Ground gas.	P1. Ingestion of soil and dust. P2. Inhalation of vapour. P3. Inhalation of soil dust by adjacent site users. P4. Attacking of potable water supply pipe. P5. Migration and accumulation of ground gas in internal places. P6. Impaction of groundwater from soil contamination. P7. Migration of soil and groundwater contamination impacting surface waters.	W. Ashton Canal adjacent to the south of the site. X. Site end users. Y. Groundwater within the underlying Secondary A Undifferentiated superficial and Secondary A bedrock Aquifers. Z. Adjacent site users.



GROUNDTECH CONSULTING

CLIENT	ARROWSMITH INVESTMENT LIMITED
PROJECT TITLE	BRUNSWICK MILL
PLAN TITLE	ILLUSTRATIVE REVISED CSM
DATE	JULY 2023
SCALE	NTS
PLAN NUMBER	GRO-22462-P07

Rev.	Details	Date

Status	
Preliminary	
Draft	
Issued	●
For Comment	
Approved	

Notes

APPENDIX 2 - Site Photographs



Photograph 1 – Brunswick Mill courtyard in the north.



Photograph 2 – External site area with 6F2 stockpile on the right.



Photograph 3 – Entrance to the south west corner of the site.



Photograph 4 – Pile of waste against the external mill walls.



Photograph 5 – LPG gas cannisters located on site.



Photograph 6 – Tank currently situated adjacent to the existing mill building.