Phase II Geoenvironmental Site Assessment
Vine Street, Gorton

Reference:14-944-R1-3
Date: October 2023

PHASE II GEOENVIRONMENTAL SITE ASSESSMENT

Land off Vine Street
Gorton
Manchester
M18 8SR

Prepared for:

Ridge and Partners LLP
&
Kirkland Developments Ltd

Report Ref: 14-944-R1-3
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EXECUTIVE SUMMARY

Site Address	Land off Vine Street, Gorton, Manchester M18 8SR	
Grid Reference	E389261 N396959	
Site Area	0.95 Ha.	
Proposed Development	E3P understands that Ridge and Partners LLP, acting on behalf of their client, are involved with respect to a proposed residential development on a parcel of land at Vine Street, Gorton. The proposed scheme will comprise the construction of circa 25 No. new dwellings.	
Current Site Use	The site is an irregular shaped vacant plot of land occupied by rough shrub vegetation, trees are present to the west and east of site and adjacent to the northern boundary. The site is relatively flat in topographically at 81m AOD. A significant slope is present adjacent to the northern boundary, where a railway track is present at a lower level of 72.5m AOD.	
Site History	A review of the pertinent Ordnance Survey mapping suggests pre 1892 a railway line was present adjacent to the western boundary with an associated signal box located within the northwest corner. The site sloped from southeast to northwest towards the railway lines. Pre 1949 more earth works have occurred in the centre of site. Pre 1957 two small buildings and one larger building have been erected in the central western area of site (thought to be associated with brick works). Pre 2003 the railway lines along the western boundary are no longer present The large building and one smaller building to the west have also been demolished. The last buildings to the southwest of site were demolished between 2003 and present day. The land has since been topographically levelled with a 8.5 m tall slope present along the northern boundary.	
Environmental Setting	**Drift Geology**	Glacial Till – Clay, Sand and Gravels
	Bedrock Geology	Manchester Marls Formation – Mudstone (Central and East) Chester Formation – Sandstone (West)
	Faults	No faults are present within 1 km of site.
	Hydrogeology	Glacial Till – Secondary Undifferentiated; Manchester Marl – Secondary B Aquifer; Chester Formation – Principal Aquifer There are no groundwater abstraction boreholes recorded within 1km of site.
	Hydrology	No surface water features are within close proximity. The nearest surface water feature is Gorton Reservoir located 720 m south.
	Flood Risk	Unaffected by flooding from rivers.

Natural Landform and Geomorphology	The subject site is underlain by Glacial Till – these are deposits laid down by the deposition of melting ice shelf in the most recent glaciation. The underlying rock formations are associated with the Manchester Marl Formation to the central and east and Chester Formation to the west. Historical maps, as well as previous investigations, indicate extensive Made Ground deposits due to numerous earthwork processes. The site has artificially been levelled within recent years. A significant slope is present adjacent to the northern boundary with levels falling approximately 8.5 m to the railway line.
Previous Reports	The following previous reports have been completed for the site: • Desk Study Report, Vine Street, Gorton, Applied Geology (Report Ref: AG3211-20-AL43, Dated December 2020) This report includes a summary of previous intrusive ground investigation works at the site and a full summary of is provided in Section 2.1.
Utility Locations	A formal drainage survey has not been completed, however, online records indicate a distribution main and surface water public sewer is present within Vine Street. A gas main and electricity are also present throughout Vine Street. A 33kV and low voltage cable are present throughout site, roughly transecting east-west.
Landfill Sites and Ground Gases	The subject site is known to have been landfilled to infill a railway cutting. Another historical landfill site is present within 250 m of site; Stockport Branch located 180 m southwest receiving inert materials and liquid sludge. A material recycling treatment facility was located 185 m west receiving an annual tonnage of 75000. The license was suspended September 2000.
Radon	The Envirocheck report indicates the site is situated in an area where less than 1% of homes are above the “Action Level”. The BGS reports that full radon protective measures are not necessary in the construction of new dwellings or extensions.
Coal Mining / Land Stability	The site is in a coal mining reporting area but not in a development high-risk area. A review of the geology and coal authority records has identified no coal seams, mine entries or records of past underground workings within or within proximity of the site. The risks associated with coal mining beneath the site are therefore considered to be low and no further assessment is considered necessary.
Brine Workings	The site is not situated within the Cheshire Salt Field; therefore, is not effected by brine workings.
Hazardous Installations	No hazardous installations that could potentially prejudice the proposed construction of highly sensitive residential dwellings have been identified within influencing distance of the subject site.

GROUND INVESTIGATION

Ground Investigation Works	E3P has completed a supplementary ground investigation comprising: • 4 No. Cable Percussive borehole; • 8 No. Mechanically Excavatrd Trial Pits; • 6 No. Window Sample Boreholes; and • Installation of four environmental monitoring wells.
Ground Conditions	**MADE GROUND – Ground Level to between 7.50m and 11.00mbgl** Made Ground deposits were recorded to a proven depths of between 7.50m and 9.50m bgl. The full depth of Made Ground was not penetrated with window sample boreholes or trial pits due to the depth and presence of buried obstructions. Made Ground deposits comprise a reworked topsoil of dark brown slightly sandy clay overlying a brown clayey, sandy gravel (CP101 and CP103-CP104) and gravelly clay (CP102) with occasional cobbles. Gravel is fine to coarse angular to subangular of brick, plastic, timber, concrete and ceramic. Cobbles are angular of brick and concrete. The Made Ground is understood to be associated with historic fill material used to infill a railway cutting to current levels.
	DRIFT – 7.50mbgl to 15.50mbgl The drift deposits were recorded from depths of between 7.50m and 9.70m bgl to a proven depth of 15.50m bgl. The superficial deposits were are varied, comprising a medium dense to dense brown silty fine to coarse SAND, which was typically interbedded and underlain by a stiff to very stiff, high to very high strength, brown sandy CLAY with occasional boulders. The SAND deposits contained traces of coal fragments from 9.70 – 11.50m bgl within CP103. The cohesive deposits were not recorded in CP101, however, BGS records would indicate the likely presence of deeper cohesive deposits beyond the termination depth of this borehole.
	SOLID GEOLOGY No solid geology was encountered during the intrusive site investigation.
	GROUNDWATER Groundwater strikes and seepages were noted within the shallow Made Ground at depths of between 1.20m and 2.50m bgl however, these likely represent perched water within the landfilled waste. Deeper water strikes were noted within the cable percussive boreholes at 7.50 to 8.50m bgl. No shallow groundwater (<3.50m bgl) has been recorded in the monitoring to date.

CONTAMINATED LAND ASSESSMENT

Human Health	The preliminary Tier I human health risk assessment has identified the presence of heavy metals, non-volatile TPH and PAHs, volatile TPH compounds and asbestos within the sub-surface at a number of locations within the shallow Made Ground. Asbestos has been identified within the shallow Made Ground, and as such it will be necessary to carefully manage these impacted soils and place them in a legislatively compliant manner that will negate any possibility of future exposure. In respect to the non-volatile PAHs, TPH and heavy metals, external areas will be covered by hard-standing or a chemically suitable cover system within all private garden and soft landscaped areas thereby removing the exposure pathway to future site users. Volatile TPH C12-16 and naphthalene has been encountered at the site, which poses a potential vapour inhalation risk. Due to the nature of the fill material, the presence of such volatile compounds throughout the Made Ground cannot be discounted. Due to the presence of volatile compounds within the Made Ground, a vapour risk assessment is required and if a unacceptable level of risk is identified, local hotspot removal or installation of a suitable vapour membrane will be required for new structures to prevent vapour ingress. It is possible that as yet unidentified contaminant impact is present within localised hotspots at the site. It is considered that any such contamination could be addressed by the delineation, excavation and treatment of impacted soils.
Controlled Waters	Elevated concentrations of chromium and lead were recorded in the leachate samples from the Made Ground soils. However, the site is underlain by cohesive deposits which will serve to prevent vertical migration towards the underlying Principal Aquifer. Furthermore, there are no surface watercourses within influencing distance of the site, as such, the site is considered to pose a very low risk to controlled waters.
Ground Gas	Based on a review of historic site investigation information, the site falls into classification Characteristic Situation 3; as such protection measures are required. However, due to elevated methane concentrations recorded by Cooper Associates, E3P would also suggest that post enabling works monitoring is undertaken to confirm the final gas regime. This could be completed using continuous monitoring installations to expedite the monitoring period.
Potable Water Infrastructure	The site was historically landfilled and therefore will require PE Barrier Pipe Type A for potable water supply infrastructure.

GEOTECHNICAL ASSESSMENT

Underground Obstructions	Significant concrete and brick obstructions have been encountered within the shallow Made Ground across the site. During a phase of cut-and-fill enabling works to create a suitable developable platform, shallow below-ground obstructions will require grubbing out to facilitate the installation of piled foundations.
Allowable Bearing Pressure	The very stiff very high strength sandy CLAY soils and dense SAND at a depth of >11.50 m bgl typically offer an ABP of 100 kN/m² which generally increases with depth.
Preliminary Slope Stability Assessment	A preliminary slope stability assessment has been completed based on the proposed development scheme provided to date. The assessment indicates that the proposed structural (and infrastructure) loads induced by the construction of dwellings adjacent to the northern boundary have the potential to cause failure of the embankment. For the avoidance of any doubt proposed levels have not yet been provided, therefore this interim analysis is based on existing topographical information with the proposed loadings applied to assess the stability for initial design considerations only. Based on the current assessment, in the absence of any retainment features, E3P recommend that piled foundations will be required for those plots adjacent to the northern boundary which are considered to be within influencing distance of the embankment, Any surcharge associate with the construction of residential plots within the locality of the embankment may pose a risk of slope failure and therefore E3P recommend mitigation measures are required to ensure long term stability as part of the development. E3P understand the client intend to construct a retaining feature to stabilise the slope, however, no designs are available at this stage. Upon receipt of the final proposed development scheme, retainment feature designs, finished floor levels (FFLs) and structural loadings are confirmed a final slope stability model will be required. If further negative impacts on the slope are recorded (such as the potential for shallow failure) based on the revised assessment, additional mitigation measures will need to be considered, such as regrading of the slope, reinforcement or greater structural retainment.
Foundation Options	In respect of the proposed scheme; E3P consider it feasible to construct the proposed residential units utilising piled foundations set within the dense SAND or very stiff very high strength sandy CLAY soils. Pre-boring of piles would likely be required due to the presence of obstructions within the upfilled Made Ground. Based on the assessment of the relative undrained shear strength, relative in-situ densities and corresponding safe net allowable bearing pressure, the suitable target founding stratum for the plots adjacent to the slope has been identified as the underlying very stiff very high strength sandy CLAY. While a detailed assessment of pile depths and bearing capacity is beyond the scope of this report, piles would likely achieve a 'set' within either the dense SAND or very stiff very high strength sandy CLAY soils at a depth of >11.50 m bgl where an ABP of 100 kN/m² can be achieved.

Foundation Options Continued...	Consideration of the effects of negative skin friction due to variability on the Made Ground and natural drift strata will be required. A specialist piling contractor should be contacted to obtain detailed designs and costs for a specialist piling technique and to allow them to reduce the factor of safety based on their extensive pile testing data. However, for the remaining plots across the southern portion of the site, the use of ground improvement through installation of vibro stone columns (VSC) could also be utilised. Due to the depth of Made Ground, partial depth treatment (within the Made Ground) could be completed to facilitate the construction of raft foundations, however, settlement analysis would be required to confirm if a partial depth VSC treatment is possible to support a raft on the stone columns. If site levels are reduced, it may be feasible to achieve full depth VSC treatment. Alternatively, the upper 3.00m of the site could be subject to a programme of reprocessing and re-engineering of the Made Ground at each plot to create a development platform for raft foundations. However, due to the depth of Made Ground across the site, settlement analysis will be required with respect to plots foundation and external areas to appraise the long term settlement and differential induced. Should a raft be adopted zone load assessments will be required to understand the settlement over the 60 year design life of the proposed dwellings. A detailed Geotechnical Enabling Works Specification will be required for the site upon completion of detailed design levels. The final foundation solution will be dependent on the structural loadings, elevation and should be designed by a suitably qualified structural engineer with detailed designs from a specialist piling contractor.
Building Floor Slabs	Ground-bearing floor slabs are unlikely to be viable given the anticipated depths or reworked Made Ground > 600 mm and shallow cohesive soils.
Heave Precautions	The clay soils are of a medium volume change potential and heave precautions will be required and designed by a suitably qualified engineer.
Soakaway Drainage	The presence of deep Made Ground and underlying cohesive deposits would preclude the use of soakaway drainage systems in this instance.
Sulphate Assessment	Concrete classification will be DS1 AC1s.
CBR Design %	It is considered the shallow Made Ground can be re-engineered in accordance with Class 1 (a-c) material under favourable climatic conditions to achieve a CBR of 5% for the proposed access road and car park to the east of the structure. Where any compressible ground is present beneath proposed roads, adopted drainage infrastructure and hardstand consideration must be given to the potential for consolidation which will induce unacceptable degrees of total and differential settlement at the surface.
Cut / Fill	It is assumed that site levels will remain close to present for the proposed new dwellings, as such a major cut /fill earthworks is not envisaged. However, a programme of enabling works will be required to remove any obstructions within the shallow Made Ground.

Civil Engineering Excavations	The presence of obstructions within the Made Ground may impede excavations. Furthermore, a slope stability assessment is currently pending and the findings will be issued as an addendum to this report.
Waste Characterisation	Any landfilled waste that is to be disposed off-site should undergo assessment using Technical Guidance WM3: *Waste Classification – Guidance on the classification and assessment of waste*.

RECOMMENDATIONS

Based on the findings of the intrusive site investigation, the following additional works are recommended to be completed in due course:

- Final Slope Stability Assessment (upon receipt of further information);
- Post enabling works monitoring to confirm the final gas regime;
- Arboricultural Survey (for off-site trees within the embankment);
- Geotechnical Earthworks Strategy (Infrastructure);
- Remediation and Enabling Works Strategy; and
- Construction Phase Surface Water Management Plan.

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DRAWING LIST

14-944-001	Site Location Plan
14-944-002	Proposed Development Plan
14-944-003	Historical Features Plan
14-944-004	Site Features Plan
14-944-005	Exploratory Hole Location Plan
14-944-006	Depth of Made Ground Plan
14-944-010	Conceptual Site Model

1. INTRODUCTION

1.1. BACKGROUND

E3P has been commissioned by Ridge and Partners LLP, on behalf of their client (Kirkland Developments Ltd) to undertake a detailed Phase I and II Geoenvironmental Site Assessment for a parcel of land located off Vine Street, Gorton, Manchester; herein referred to as the site.

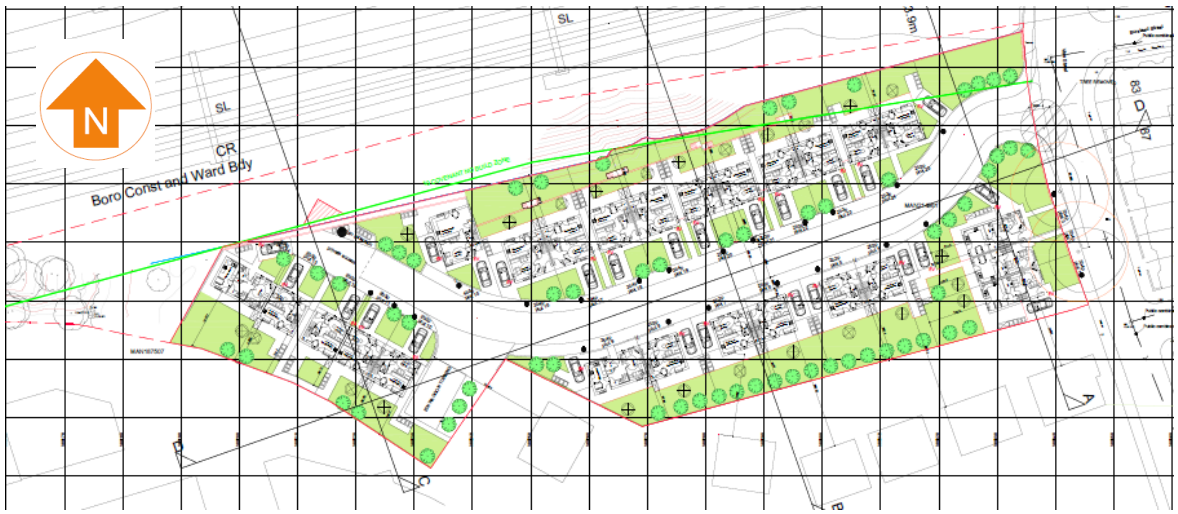
This report is required to determine potential contaminated land liabilities, remediation requirements and geotechnical engineering works that will be required as part of the proposed development for a proposed low-rise residential development.

1.2. PROPOSED DEVELOPMENT

E3P understands the client intends to develop the site with the construction of a low-rise residential development comprising c. 25 No. residential dwellings with associated gardens, estate roads and adopted utility infrastructure.

The Proposed Development Scheme is presented in Figure 1.1 (below) and Drawing 14-944-002 (Appendix III).

FIGURE 1.1 SNAPSHOT OF PROPOSED DEVELOPMENT



1.3. OBJECTIVES

The objectives of the geoenvironmental assessment are as follows:

- Review historical plans, geology, hydrogeology, site sensitivity, floodplain issues, mining records and any local authority information available in order to complete a desk study in line with Environment Agency (EA) document *Land Contamination:Risk Management (LCRM) (2019).*
- Undertake a preliminary stage of sampling and analysis to provide an overview of environmental issues identified.
- Assess the implications of any potential environmental risks, liabilities and development constraints associated with the site in relation to the future use of the site and in relation to off-site receptors.
- Assess the geotechnical information and provide preliminary recommendations in relation to foundations, pavement construction and floor slabs.
- Provide recommendations regarding future works required.

1.4. SCOPE OF WORKS

The scope of work includes the following elements:

- Detailed review of historic information;
- Design of suitable intrusive ground investigation;
- Window sample probeholes with, and construction of, environmental monitoring installations;
- Deep cable percussive boreholes;
- Mechanically excavated trial pits;
- In-situ geotechnical testing;
- Chemical and geotechnical laboratory analysis;
- Groundwater monitoring and sampling;
- Ground gas monitoring;
- Contamination risk assessment and conceptual site model;
- Geotechnical assessment and interpretation; and
- Factual and interpretive reporting.

1.5. LIMITATIONS

The limitations of this report are presented in Appendix I.

1.6. CONFIDENTIALITY

E3P has prepared this report solely for the use of the client and those parties with whom a warranty agreement has been executed, or with whom an assignment has been agreed. Should any third party wish to use or rely upon the contents of the report, written approval must be sought from E3P; a charge may be levied against such approval.

2. GROUND INVESTIGATION

2.1. PREVIOUS REPORTS AND SITE INVESTIGATIONS

The following previous site investigation reports have been provided to E3P for review:

- Desk Study Report, Vine Street, Gorton, Applied Geology (Report Ref: AG3211-20-AL43) dated December 2020.

This report should be read in conjunction with this document. However, the pertinent points of the previous report are summarised below and where necessary data used to support the E3P Geoenvironmental Site Assessment.

- *From the earliest map edition (1948), the site is shown to have been largely undeveloped and part of an open field, until a railway line is shown in the western portion from the 1890s. Cutting of the site appears to have taken place at several stages, associated with the development of the railway line and in the 1940s/50s, likely relating to adjacent infrastructure / developments. Unknown structures were present during the 1950s, likely relating to the railway, and remaining until c. 2000;*

- *Filling of the railway cutting is understood to have taken place following dismantling of the railway in c. 2000, which is also collaborated by available aerial imagery at this time;*

- *From 1848, a railway line has been present immediately to the north of the site and surrounding area largely comprised open fields and sporadic residential properties. Residential development in the general vicinity was beginning to develop in the 1890s, associated with the development of Gorton Foundry and Gorton Locomotive Works (and other industry), which were located roughly 500m to the west. A 'Brick Works' was present immediately east and 50m south in the early 1900's, and 'Works' have been present 50m southwest since the 1930's. Other than these, the surrounding area has largely comprised residential areas;*

- *There are no coal seams shown to sub-crop close to the surface beneath or within close proximity to the site. There are no recorded mine entries shown within 100m of the site boundary (nearest recorded approximately 2.1km to the west). In view of the above, the site is not considered at risk of surface instability due to historic underground coal workings;*

- *There are no recorded natural cavities within 500m of the site boundary;*

- *There are no surface watercourses within 250m of the site;*

- *The site currently comprises a plot of vacant land with mounded material to the west. It is understood that unauthorised access had recently taken place on site, resulting in deposition of the mounded material. The mounded material measured 50 m by 10 m, tapering to 5 m in width towards the eastern boundary. The material comprised black clayey very gravelly sand with ceramic fragments, glass, fabric, brick, concrete, plastic and wood;*

- *Fly tipping had also occurred to the west of site including unlabelled plastic drums, plastic car parts, tyres, mattresses and unknown bagged waste;*

- *The slope to the north of site is roughly 60-70 degrees; and*

- *An open excavation contaminated with yellowish-brown oil substance on the water surface was observed.*

PREVIOUS GROUND INVESTIGATIONS

Two previous investigations have been produced for the application site by Cooper Associates (2006) and REC Ltd (2013). E3P have produced a Remediation Strategy for a parcel of land to the south (2017).

These reports were reviewed by Applied Geology and a summary of all three is included below;

Basic Site Investigation Report, Coopers Associates (Report Ref 3927br2, dated December 2006)

- *Eleven trial pits and nine cable percussive boreholes were conducted across site;*
- *Made Ground was encountered between 4.8 m and 10.2 m bgl generally comprising black gravelly sand with brick, concrete, slag, plastic, metal and timber with some areas encountering concrete obstructions. A hydrocarbon odour was generally present within the upper 2.0 m bgl;*
- *Drift deposits were encountered between 3.4 m and 10.2 m bgl, comprising a gravelly silty sand and gravelly silty clay;*
- *Ground water was recorded as seepages between 1.3 m and 15.4 m bgl;*
- *Only benzo(a)pyrene was noted to exceed threshold values for residential development with plant uptake; however limited testing was noted;*
- *Elevated carbon dioxide (maximum 11.8%) and methane (maximum 57.7%) were noted within monitoring wells. The site was therefore classed as Characteristic Situation 3; and*
- *A Piled solution was recommended due to deep made ground deposits.*

Phase I & II Geoenvironmental Site Investigation, Resource & Environmental Consultants (REC) Ltd (Report ref: 44766pr0, dated March 2013)

- *Similar findings of ground conditions to Coopers Associate report were identified;*
- *REC recommended a 600 m thick inert cover layer in private gardens, considering the lack of clean topsoil on site;*
- *Ground gas protection in line with Characteristic Situation 3 was recommended, based on the previous findings by Cooper Associates; and*
- *A Soil vapour survey was recommended to quantify naphthalene vapour concentrations in respect to indoor inhalation and a hydrocarbon membrane was to be installed.*

Remediation & Enabling Works Strategy, E3P (report ref 10-019-R3 dated March 2017)

- *Similar ground conditions were identified as in the Coopers Associate and REC reports;*
- *Japanese Knotweed was identified in the central eastern area of site;*
- *Heavy metals, non-volatile PAHs and trace asbestos fibres within shallow Made Ground were identified. Localised naphthalene and TPH C_{10}-C_{16} 'hotspot' was identified in one location to the south of site;*
- *No significant risk to controlled waters was identified;*
- *The site was classified as Characteristic Situation 2 based on additional monitoring visits; and*
- *Foundation solution comprised a programme of reprocessing and re-engineering of the upper 3.0 m of Made Ground at each plot to create a development platform for raft foundations.*

2.2. GENERAL OVERVIEW

A ground investigation has been designed based on the findings of the desk study, with exploratory holes advanced to target specific potential contaminant sources identified within the previous site investigations and Phase I report made available to E3P. The investigation has also been used to collect geotechnical information to assist in the design and construction of the proposed development.

Trial pitting and window sampling was completed on 31st of August 2021. Cable percussive boreholes were completed between the 20th to 25th October 2021. The works are summarised in Table 2.1 below.

2.3. SCOPE OF INVESTIGATION

TABLE 2.1 SUMMARY OF FIELDWORK

POTENTIAL SOURCE / RATIONALE	LOCATION HOLE	TYPE	MAXIMUM DEPTH (m bgl)	MONITORING WELLS RESPONSE ZONE (m bgl)
Investigate and sample Made Ground including the Presence / Nature of Obstructions. Collection of geotechnical data.	WS101	Window Sample Probehole	0.81	N/A
	WS101A		0.78	
	WS102		0.58	
	WS102A		3.30	1.00–3.00
	WS103		0.20	N/A
	WS103A		0.48	
	WS104		3.30	1.00–2.50
	WS105		1.22	N/A
	WS105A		0.68	
	WS106		0.31	
	WS106A		0.77	
Investigate and sample Made Ground including the Presence / Nature of Obstructions.	TP101	Mechanically excavated trial pit	2.9	N/A
	TP102		0.7	
	TP103		2.7	
	TP104		1.8	1.00 – 2.00
	TP105		2.3	N/A
	TP106		1.9	
	TP107		2.1	
	TP108		1.2	
Prove depth of Made Ground and investigate underlying natural ground conditions. Collection of geotechnical data.	CP101	Cable Percussive Boreholes	15.45	N/A
	CP102		15.45	
	CP103		15.45	
	CP104		15.45	
Investigate Suspected Culvert	TT101	Trial Trench	6.50	N/A

Mechanically excavated trial pits were advanced to investigate ground conditions and to retrieve environmental samples, spatially distributed to offer the maximum site coverage whilst also being advanced to target specific contaminant sources.

Window sample probeholes were advanced to undertake in-situ detailed geotechnical testing, obtain environmental samples and install groundwater and ground gas monitoring wells.

The series of cable percussive boreholes were advanced to prove the depth of Made Ground , investigate the underlying natural strata and obtain geotechnical samples.

The sampling locations are illustrated in Drawing 14-944-005 (Appendix III). The ground conditions encountered are indicated on the logs, which are provided in Appendix V.

Return visits were made to monitor installations for groundwater level and gas concentrations. In addition, selected wells were purged and samples of groundwater recovered for chemical analysis.

2.4. IN-SITU STANDARD PENETRATION TESTING (SPT)

In-situ geotechnical testing was conducted using the standard penetration test (SPT) and, where the ground is granular, a 60° cone (SPT(C)) was used instead of the sampling tube.

The results are shown in the probehole logs in Appendix V and presented in Table 3.5 and discussed in Section 5.

2.5. LABORATORY ANALYSIS

Selected soil samples were submitted for a range of chemical analysis comprising:

- Metals.
- pH, total sulphate, water-soluble sulphate (2:1 extract).
- Sulphide.
- Cyanide.
- Phenols.
- Total and speciated polycyclic aromatic hydrocarbons (PAHs).
- Semi Volatile Organic Compounds (SVOC).
- Asbestos identification and quantification.
- Speciated and banded total petroleum hydrocarbon (TPH).

I2 Analytical undertook the analytical work and the testing results are included in Appendix VI and discussed in Section 4.2.

Selected samples were submitted to PSL Laboratory where the following geotechnical tests were undertaken:

- Atterberg limits determinations;
- Particle size distribution classification;
- Consolidated shear box testing; and
- Single-stage triaxial tests.

Laboratory analysis sheets are included in Appendix VIII and are summarised in Section 5.

3. GROUND AND GROUNDWATER CONDITIONS

3.1. SUMMARY OF GROUND CONDITIONS

The ground investigation generally confirms the published geology and identifies the strata set out in Table 3.1.

TABLE 3.1 SUMMARY OF STRATA

HOLE	DEPTH TO STRATUM (m bgl)			
	MADE GROUND	OBSTRUCTION	MEDIUM DENSE TO DENSE SAND	STIFF TO VERY STIFF CLAY
WS101	0.00 - 0.81	0.81 (Refusal)	–	–
WS101A	0.00 - 0.78	0.78 (Refusal)	–	–
WS102	0.00 - 0.58	0.58 (Refusal)	–	–
WS102A	0.00 - 3.30	3.30 (Refusal)	–	–
WS103	0.00 - 0.20	0.20 (Refusal)	–	–
WS103A	0.00 - 0.48	0.48 (Refusal)	–	–
WS104	0.00 - 3.30	3.30 (Refusal)	–	–
WS105	0.00 - 1.22	1.22 (Refusal)	–	–
WS105A	0.00 - 0.68	0.68 (Refusal)	–	–
WS106	0.00 - 0.31	0.31 (Refusal)	–	–
WS106A	0.00 - 0.77	0.77 (Refusal)	–	–
TP101	0.00 - 2.90		–	–
TP102	0.00 - 0.70	0.70 (Concrete)	–	–
TP103	0.00 - 2.70		–	–
TP104	0.00 - 1.80	1.80 (Concrete)	–	–
TP105	0.00 - 2.30	2.30 (Concrete)	–	–
TP106	0.00 - 1.90	1.90 (Concrete)	–	–
TP107	0.00 - 2.10	2.10 (Concrete)	–	–
TP108	0.00 - 1.20	1.20 (Concrete)	–	–
TT101	0.00 – 6.50	-		
CP101	0.00 - 8.80		8.80 - 15.45	–
CP102	0.00 – 11.00		14.45 - 15.45	11.00 - 14.45
CP103	0.00 - 9.70		9.70 - 11.50 14.00 - 15.45	11.50 - 14.00
CP104	0.00 - 7.50		8.50 - 11.00	7.50 - 8.50 11.00 - 15.45

3.2. MADE GROUND

Made Ground deposits were encountered within all exploratory hole locations from ground level to proven depths of between 7.50 m and 11.00 m bgl (CP102).

Made Ground deposits comprise a reworked topsoil of dark brown slightly sandy clay overlying a brown clayey, sandy gravel or gravelly clay (CP102) with occasional cobbles. Gravel is fine to coarse angular to subangular of brick, plastic, timber, concrete and ceramic. Cobbles are angular of brick and concrete.

The Made Ground is understood to be associated with landfilled material used to upfill a historic railway cutting to bring the site to current levels, equivalent to the adjacent plot to the south.

The Made Ground was not fully penetrated in a number of the exploratory locations due to the presence of obstructions within the landfilled waste. Many of the window sample boreholes refused at depths of <3.30m bgl, as noted in Table 3.1 above.

A Depth of Made Ground Plan is presented as Drawing 14-944-006 in Appendix III. This plan has been based on the information from the deeper cable percussive boreholes, all of which fully penetrated the landfilled material into natural stratum.

3.3. DRIFT DEPOSITS

Drift deposits were encountered within the four cable percussive boreholes where the full depth of Made Ground could be proven.

The drift deposits are varied, comprising a medium dense to dense brown silty fine to coarse SAND, which was typically interbedded and underlain by a stiff to very stiff, high to very high strength, brown sandy CLAY with occasional boulders to a proven depth of 15.50m bgl.

The cohesive deposits were not recorded within CP101. The SAND deposits contained traces of coal fragments from 9.70 – 11.50 m bgl within CP103.

3.4. SOLID GEOLOGY

The solid bedrock geology was not encountered during the site investigation works.

However, BGS records indicate the site is underlain by Manchester Marl (Mudstone) within the central and eastern portion and Chester Formation (Sandstone) within the western sector.

There are no BGS borehole records within 1.00km of the site which encountered bedrock, to confirm the published geology.

The nearest BGS borehole is located c. 1.40km southwest of the site, which recorded sandstone at 34.50m bgl.

3.5. GROUNDWATER

Groundwater strikes were encountered as both strikes (boreholes) and seepages (trial pits).

The depth of the strikes / seepages are shown on the exploratory hole records in Appendix V and are summarised in Table 3.2 below.

TABLE 3.2 SUMMARY GROUNDWATER STRIKES

LOCATION	DEPTH TO STRIKE (m)	NOTES
TP104	1.20	Seepage
TP105	1.80	Seepage
WS102A	2.40	Strike
WS104	2.50	Strike
CP102	7.50	Strike
CP103	8.00	Strike
CP104	8.50	Strike

Monitoring was undertaken using an electronic dip meter and interface probe to record the depth to groundwater and the thickness of any free-phase hydrocarbon product, if present. These results are summarised in Table 4.7.

3.6. VISUAL AND OLFACTORY EVIDENCE OF CONTAMINATION

Visual and olfactory evidence of potential contamination has been identified during the site investigation and these are summarised in Table 3.3 below.

TABLE 3.3 SUMMARY VISUAL AND OLFACTORY EVIDENCE OF CONTAMINATION

LOCATION	DEPTH (m)	STRATUM	NOTES
TP101	0.00 – 2.90	Made Ground	Sweet hydrocarbon odour
TP103	1.60 – 2.70		Strong hydrocarbon odour
TP105	0.15 – 2.30		Sweet hydrocarbon odour
TP106	1.00 – 1.90		Hydrocarbon odour
TP108	0.10 – 1.20		Clinker and ash
WS104	0.10 – 2.40		Clinker and ash

3.7. SOIL CONSISTENCY

Undrained shear strength values were measured using laboratory undrained triaxial tests in one sample. Results of the test are presented in Table 3.4 below, which indicate the clay soil to be firm at 11.00m bgl.

Strength test data is generally consistent with the field descriptions of the aforementioned soils.

TABLE 3.4 SUMMARY OF UNDRAINED SHEAR STRENGTH TEST RESULTS

LOCATION	SAMPLE DEPTH (m)	LAB DESCRIPTION	UNDRAINED SHEAR STRENGTH (kN/m^2)	CONSISTENCY
CP104	11.00 - 11.45	Firm, brown, slightly gravelly, sandy CLAY	59	Firm

Results of the standard penetration tests, including undrained shear strengths derived from SPTs are included in Table 3.5 overleaf.

The window sample boreholes have been omitted from this table as all locations refused on obstructions within the shallow Made Ground deposits, as such, the results are not considered reliable or representative of the wider site conditions.

TABLE 3.5 STANDARD/CONE PENETRATION TEST RESULTS

BOREHOLES	DEPTH (m bgl)	MATERIAL FIELD DESCRIPTION	CPT/SPT "N" VALUE	CORRECTED "N" VALUE $(N_1)_{60}$	TERZAGHI & PECK RELATIVE DENSITY (SANDS)	EUROCODE SOIL STRENGTH	CONSISTENCY (BS 5930)	TERZAGHI & PECK APPROXIMATE UNDRAINED SHEAR STRENGTH (kN/m^2)	ALLOWABLE BEARING PRESSURE (kN/m^2)*
CP101	1.0	MG: Gravel	12	12.10	Medium Dense	N/A	N/A	N/A	**120.97**
	2.0	MG: Gravel	12	10.96	Medium Dense	N/A	N/A	N/A	**109.62**
	3.0	MG: Gravel	8	6.96	Loose	N/A	N/A	N/A	**69.57**
	4.0	MG: Gravel	13	10.98	Medium Dense	N/A	N/A	N/A	**109.83**
	5.0	MG: Gravel	16	13.27	Medium Dense	N/A	N/A	N/A	**132.73**
	6.5	MG: Gravel	15	12.25	Medium Dense	N/A	N/A	N/A	**122.45**
	8.0	MG: Gravel	30	24.28	Medium Dense	N/A	N/A	N/A	**242.83**
	9.5	Clayey SAND	54	43.52	Dense	N/A	N/A	N/A	**435.20**
	11.0	Clayey SAND	26	20.11	Medium Dense	N/A	N/A	N/A	**201.07**
	12.5	Clayey SAND	26	19.00	Medium Dense	N/A	N/A	N/A	**189.95**
	14.0	Clayey SAND	50	34.64	Dense	N/A	N/A	N/A	**346.35**
	15.5	SAND	50	32.93	Dense	N/A	N/A	N/A	**329.33**

BOREHOLES	DEPTH (m bgl)	MATERIAL FIELD DESCRIPTION	CPT/SPT "N" VALUE	CORRECTED "N" VALUE $(N_1)_{60}$	TERZAGHI & PECK RELATIVE DENSITY (SANDS)	EUROCODE SOIL STRENGTH	CONSISTENCY (BS 5930)	TERZAGHI & PECK APPROXIMATE UNDRAINED SHEAR STRENGTH (kN/m^2)	ALLOWABLE BEARING PRESSURE (kN/m^2)*
CP102	1.0	Reworked Clay	50	50.41	N/A	Very High Strength	Very Stiff	252.04	**518.19**
	2.0	Reworked Clay	50	45.68	N/A	Very High Strength	Very Stiff	228.38	**469.56**
	3.0	Reworked Clay	29	25.22	N/A	High Strength	Very Stiff	126.10	**259.26**
	4.0	Reworked Clay	42	35.48	N/A	Very High Strength	Very Stiff	177.42	**364.77**
	5.0	Reworked Clay	35	29.04	N/A	High Strength	Very Stiff	145.18	**298.50**
	6.5	Reworked Clay	11	8.98	N/A	Medium Strength	Stiff	44.90	**92.32**
	8.0	Reworked Clay	25	20.24	N/A	High Strength	Very Stiff	101.18	**208.03**
	9.5	Silty SAND	14	11.28	Medium Dense	N/A	N/A	N/A	**112.83**
	11.0	CLAY	31	23.97	N/A	High Strength	Very Stiff	119.87	**246.45**
	12.5	CLAY	23	16.80	N/A	High Strength	Very Stiff	84.02	**172.75**
	14.0	CLAY	50	34.64	N/A	Very High Strength	Very Stiff	173.18	**356.06**
	15.5	SAND	50	32.93	Dense	N/A	N/A	N/A	**329.33**

BOREHOLES	DEPTH (m bgl)	MATERIAL FIELD DESCRIPTION	CPT/SPT "N" VALUE	CORRECTED "N" VALUE $(N_1)_{60}$	TERZAGHI & PECK RELATIVE DENSITY (SANDS)	EUROCODE SOIL STRENGTH	CONSISTENCY (BS 5930)	TERZAGHI & PECK APPROXIMATE UNDRAINED SHEAR STRENGTH (kN/m^2)	ALLOWABLE BEARING PRESSURE (kN/m^2)*
CP103	1.0	MG: Gravel	45	45.37	45.37	Dense	N/A	N/A	**453.66**
	2.0	MG: Gravel	28	25.58	25.58	Medium Dense	N/A	N/A	**255.79**
	3.0	MG: Gravel	50	43.48	43.48	Dense	N/A	N/A	**434.82**
	4.0	MG: Gravel	28	23.66	23.66	Medium Dense	N/A	N/A	**236.55**
	5.0	MG: Gravel	30	24.89	24.89	Medium Dense	N/A	N/A	**248.88**
	6.5	MG: Gravel	31	25.31	25.31	Medium Dense	N/A	N/A	**253.08**
	8.0	MG: Gravel	23	18.62	18.62	Medium Dense	N/A	N/A	**186.17**
	9.5	SAND	13	10.48	Medium Dense	N/A	N/A	N/A	**104.77**
	11.0	SAND	21	16.24	Medium Dense	N/A	N/A	N/A	**162.40**
	12.5	CLAY	33	24.11	N/A	High Strength	Very Stiff	120.55	**247.85**
	14.0	SAND	50	34.64	Dense	N/A	N/A	N/A	**346.35**
	15.5	SAND	50	32.93	Dense	N/A	N/A	N/A	**329.33**

BOREHOLES	DEPTH (m bgl)	MATERIAL FIELD DESCRIPTION	CPT/SPT "N" VALUE	CORRECTED "N" VALUE $(N_1)_{60}$	TERZAGHI & PECK RELATIVE DENSITY (SANDS)	EUROCODE SOIL STRENGTH	CONSISTENCY (BS 5930)	TERZAGHI & PECK APPROXIMATE UNDRAINED SHEAR STRENGTH (kN/m^2)	ALLOWABLE BEARING PRESSURE (kN/m^2)*
CP104	1.0	MG: Gravel	44	44.36	44.36	Dense	N/A	N/A	**443.58**
	2.0	MG: Gravel	26	23.75	23.75	Medium Dense	N/A	N/A	**237.52**
	3.0	MG: Gravel	12	10.44	10.44	Medium Dense	N/A	N/A	**104.35**
	4.0	MG: Gravel	50	42.24	42.24	Dense	N/A	N/A	**422.42**
	5.0	MG: Gravel	50	41.48	41.48	Dense	N/A	N/A	**414.81**
	6.5	MG: Gravel	39	31.84	31.84	Dense	N/A	N/A	**318.39**
	8.0	CLAY	17	13.76	N/A	Medium Strength	Stiff	68.80	**249.64**
	9.5	Silty SAND	19	15.31	Medium Dense	N/A	N/A	N/A	**153.12**
	12.5	CLAY	50	36.53	N/A	Very High Strength	Very Stiff	182.65	**375.53**
	14.0	CLAY	50	34.64	N/A	Very High Strength	Very Stiff	173.18	**356.06**
	15.5	CLAY	50	32.93	N/A	Very High Strength	Very Stiff	164.67	**338.56**

NOTES
* The Allowable Bearing Pressure (ABP) should be considered indicative.
The interpretation of in situ mass undrained shear strength (cu) data from SPT Blow Count (N) results and the influence of the Plasticity Index (PI) was reported in Standard Penetration Test in Insensitive Clays and Soft Rocks. Stroud (1974). The standard penetration test and the engineering properties of glacial materials subsequently. Stroud and Butler (1975) and (1989).
Allowable bearing pressure on sands. Soil Mechanics in Engineering Practice Terzaghi, K. & Peck, R.B. 1996.

3.8. SIDE STABILITY AND EASE OF EXCAVATION

The sides of the exploratory trial pit excavations appeared to be generally stable during excavation with the exception of TP106, where sidewall collapse was observed and the excavation terminated on a concrete obstruction.

The presence of brick and concrete cobbles within the Made Ground deposits across much of the site meant that in certain places, excavation was slow through the Made Ground and in some places could not be fully penetrated. Significant obstructions were noted within the upper 3.00m of the Made Ground.

3.9. PARTICLE SIZE DISTRIBUTION

Particle Size Distribution Tests have been undertaken on selected samples of granular material via wet sieve to obtain information on the soil fractions.

The results are included in Table 3.6. The full results are presented in Appendix VIII.

TABLE 3.6 SUMMARY OF PARTICLE SIZE DISTRIBUTION TEST RESULTS

LOCATION	DEPTH (m)	SOIL FRACTION (%)			
		COBBLES	GRAVEL	SAND	SILT / CLAY
CP101	2.00 – 2.45 (Made Ground)	0	49	36	25
CP101	12.50 – 12.95 (Natural)	0	1	65	34
CP102	9.50 – 9.95 (Natural)	0	6	27	67
CP103	3.00 – 3.45 (Made Ground)	11	55	21	13
CP104	3.00 – 3.45 (Made Ground)	0	52	27	21

3.10. SOIL PLASTICITY

The Atterberg limits determinations, summarised in Table 3.7, show the clay to be of predominantly low plasticity with areas of moderate plasticity clay.

TABLE 3.7 SUMMARY OF PLASTICITY INDEX TEST RESULTS

LOCATION	DEPTH (m)	NATURAL MOISTURE CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	PASSING 425 µm SIEVE (%)	MODIFIED PLASTICITY INDEX	NHBC VOLUME CHANGE POTENTIAL
CP102	12.50	19	20	42	22	97	21.34	Medium
CP103	12.50	12	13	28	15	94	14.10	Low
CP104	8.00	22	19	37	18	95	17.10	Low

For assessment purposes, the results of the Atterberg limits testing confirmed that the soils would be deemed to be "Medium Volume Change Potential" in accordance with the classification system utilised by the LABC/NHBC industry guidance.

3.11. pH AND SULPHATE

Chemical analyses for pH and soluble sulphate content contained in Appendix VI (summarised in Table 3.8), shows that the MADE GROUND soils at the site meet Class DS-1, Aggressive Chemical Environment for Concrete Classification (ACEC) AC-1s in accordance with BRE *Special Digest 1* (2005).

TABLE 3.8 SUMMARY OF pH AND SULPHATE DATA

LOCATION	DEPTH (m)	SO_4 IN 2:1 WATER/SOIL (g/l)	pH VALUE	CLASSIFICATION
TP101	2.10	0.13	8.3	DS-1, AC-1s
TP103	2.00	0.11	8.4	DS-1, AC-1s
TP104	1.30	0.081	8.4	DS-1, AC-1s
TP105	1.60	0.19	8.9	DS-1, AC-1s
TP106	1.50	0.023	8.7	DS-1, AC-1s
WS101	0.40	0.044	8.8	DS-1, AC-1s
WS106	0.30	<0.01	8.6	DS-1, AC-1s
WS102B	2.60	0.11	9.2	DS-1, AC-1s

4. TIER I QUALITATIVE CONTAMINATED LAND RISK ASSESSMENT

E3P has undertaken a Tier 1 qualitative risk assessment to determine if any potential contaminants within the underlying soils and groundwater pose an unacceptable level of risk to the identified receptors.

4.1. DEVIATING SAMPLES

Deviating samples were to be avoided during the ground investigation by using best practice sampling procedures including use of appropriate sampling containers and adhering to the laboratory holding times for each contaminant analysis undertaken. The following is noted regarding sample deviations:

Deviations were identified within some of the soil samples used for leachate testing (TP102, TP106 and WS105). The samples did not exceed holding times. Deviations relate to the use of a non Chemtest (the environmental testing laboratory undertaking chemical analysis) plastic tubs under the charge code C. It is not deemed that these results will be deviating as the use of plastic tubs is standard for conducting leachate testing.

All other results are not identified as deviating.

4.2. HUMAN HEALTH RISK ASSESSMENT

At Tier 1 stage, the long term (chronic) human health toxicity of the soil has been assessed by comparing the on-site concentrations of organic and inorganic compounds with reference values published in LQM/CIEH S4UL (S4UL3267).

Where Tier 1 screening values are not provided by LQM, other screening values have been used and these are referenced in Table 4.1.

The results of this comparison have been summarised within Table 4.1.

TABLE 4.1 SUMMARY OF INORGANIC AND HYDROCARBON TOXICITY ASSESSMENT FOR A RESIDENTIAL END USE

DETERMINANT	UNIT	GAC	N	MC	LOC. OF EX	PATH-WAY	ASSESSMENT
Arsenic	mg/kg	37	8	820 600 590 220	TP104 1.30m TP103 2.00m TP101 2.10m TP106 1.50m	1	Further Action
Cadmium	mg/kg	11	8	2.6	N/A	1	No Further Action
Chromium (VI)	mg/kg	6.0	8	<0.5	N/A	1	No Further Action
Lead	mg/kg	200	8	700	WS101 0.40m	1	Further Action
Mercury	mg/kg	1.2	8	4.7	WS101 0.40m	4	Further Action
Nickel	mg/kg	130	8	470 200	WS101 0.40m TP104 1.30m	1	Further Action
Selenium	mg/kg	250	8	4.4	N/A	1	No Further Action
Copper	mg/kg	2400	8	140	N/A	1	No Further Action
Zinc	mg/kg	3700	8	440	N/A	1	No Further Action
Cyanide – Total	mg/kg	791	8	1.1	N/A	1	No Further Action
Phenols – Total	mg/kg	120	8	0.17	N/A	1	No Further Action
Asbestos	Fibres	NFD	8	N.D	N/A	3	No Further Action
Naphthalene	mg/kg	2.3	8	24 4.7 3.2	WS101 0.40m TP101 2.10m TP103 2.00m	4	Further Action
Acenaphthylene	mg/kg	170	8	2.3	N/A	2	No Further Action
Acenaphthene	mg/kg	210	8	22	N/A	1	No Further Action
Fluorene	mg/kg	170	8	18	N/A	1	No Further Action
Phenanthrene	mg/kg	95	8	130	WS101 0.40m	2	Further Action
Anthracene	mg/kg	2400	8	25	N/A	2	No Further Action
Fluoranthene	mg/kg	280	8	110	N/A	2	No Further Action
Pyrene	mg/kg	620	8	87	N/A	2	No Further Action
Benzo(a)Anthracene	mg/kg	7.2	8	48 31 21 12	WS101 0.40m TP101 2.10m TP103 2.00m WS102B 2.60m	2	Further Action
Chrysene	mg/kg	15	8	43 31 10	WS101 0.40m TP101 2.10m TP103 2.00m	2	Further Action
Benzo(b)Fluoranthene	mg/kg	2.6	8	49 33 25 16 14 6.4 6.4	WS101 0.40m TP101 2.10m TP103 2.00m TP106 1.50m WS102B 2.60m WS106 0.30m TP104 1.30m	2	Further Action

DETERMINANT	UNIT	GAC	N	MC	LOC. OF EX	PATH-WAY	ASSESSMENT
Benzo(k)Fluoranthene	mg/kg	77	8	16	N/A	2	No Further Action
Benzo(a)Pyrene	mg/kg	2.2	8	39 26 22 13 12 5.3 5	WS101 0.40m TP101 2.10m TP103 2.00m TP106 1.50m WS102B 2.60m WS106 0.30m TP104 1.30m	2	Further Action
Indeno(123-cd)Pyrene	mg/kg	27	8	27	N/A	2	No Further Action
Dibenzo(a,h)Anthracene	mg/kg	0.24	8	6 5.6 5.3 2.6 2.5 1.1 0.98 0.85	WS106 0.30m TP101 2.10m WS101 0.40m TP106 1.50m TP103 2.00m TP105 1.60m WS102B 2.60m TP104 1.30m	2	Further Action
Benzo(ghi)Perylene	mg/kg	320	8	18	N/A	2	No Further Action
TPH C5-C6 (aliphatic)*	mg/kg	42	3	<1	N/A	4	No Further Action
TPH C6-C8 (aliphatic)*	mg/kg	100	3	<1	N/A	4	No Further Action
TPH C8-C10 (aliphatic)*	mg/kg	27	3	<1	N/A	4	No Further Action
TPH C10-C12 (aromatic)*	mg/kg	74	3	16	N/A	4	No Further Action
TPH C12-C16 (aromatic)*	mg/kg	140	8	180	TP101 2.10m	4	Further Action
TPH C16-C21 (aromatic)*	mg/kg	260	8	460 430	TP101 2.10m WS101 0.40m	1	Further Action
TPH C21-C35 (aromatic)*	mg/kg	1100	3	4200 1900	TP101 2.10m WS101 0.40m	1	Further Action

Notes
PL1 = soil ingestion, PL2 = dermal contact and ingestion, PL3 = dust inhalation; PL4 = Vapour/Gas Inhalation; PL5 = Vertical / Lateral Migration; PL6 = Corrosion of concrete; PL7=Tainting of water supply; PL8 = Uptake by plants

Abbreviations: GAC = general assessment criteria, n = number of samples, MC = maximum concentration; Loc of Ex = location of exceedance; NFD = no fibres detected.

* The Tier 1 GAC for the hydrocarbon fraction is derived from the CIEH assessment for petroleum hydrocarbons Criteria Working Group (CWG) for both aliphatic and aromatic compounds. E3P has utilised the Tier 1 values for aliphatic compounds for the volatile and semi volatile fractions (C5-C12) and the Tier 1 values for aromatic compound for the non-volatile fractions (C12-C35). The comparison of a total (aliphatic/aromatic) compounds to an individual fraction is considered to be a conservative approach and satisfactory for the protection of human health.

Referring to Table 4.1, the results of this direct comparison indicates that the data exceeds the screening criteria for a residential end use for the following contaminants:

- Arsenic;
- Lead;
- Mercury;
- Nickel;
- Naphthalene;
- Phenanthrene;
- Benzo(a)Anthracene;
- Chrysene;
- Benzo(b)Fluoranthene;
- Benzo(k)Fluoranthene;
- Benzo(a)Pyrene;
- Dibenzo(a,h)Anthracene; and
- Hydrocarbon Fractions C12-C35 (aromatic).

Naphthalene and TPH C12-16 was identified at three locations within the shallow (<2.50m bgl) Made Ground soils.

In relation to these exceedances, the following can be determined:

- The main exposure pathways based on the Tier I exceedances are:
  - Soil Ingestion;
  - Vapour Inhalation (indoor);
  - Dermal Contact and Ingestion;
  - Consumption of Homegrown Vegetables; and
  - Fibre / Dust Inhalation

The exceedances for the majority of deteminands were recorded within the shallow Made Ground soils (<3.00 m bgl).

4.3. HUMAN HEALTH RISK ASSESSMENT AND MITIGATION

4.3.1. NON-VOLATILE TPH, PAH AND HEAVY METALS

The risk to chronic human health associated with the elevated concentrations of inorganic heavy metals, non-volatile TPHs and non-volatile PAH compounds can be mitigated through the installation of a suitable cover system in all proposed private gardens, soft landscaping areas and public open space to remove any potential for direct exposure to impacted soils.

The specific design and installation process for the appropriate cover systems will be clearly defined within the site remediation and enabling works strategy.

4.3.2. VOLATILE TPH AND NAPHTHALENE

In respect to elevated naphthalene, this has been detected in three exploratory locations within the shallow Made Ground and it can be reasonably assumed that naphthalene may be present throughout the Made Ground.

Naphthalene and TPH C12-16 poses a potential volatilisation to indoor air risk, as such, a vapour risk assessment should be undertaken to assess if the volatile compounds within the landfilled material pose a potential risk to future site users.

If any hotspots are identified, local removal should be undertaken where soils may be chemically validated to assess chemical suitability for retention on site in an area of no future sensitivity.

4.3.3. ASBESTOS

Asbestos was not identified in any of the eight samples submitted for analysis. However, the presence of asbestos within the Made Ground deposits was recorded during previous investigations and therefore cannot be entirely discounted.

In consideration of the proposed development scheme; the asbestos impacted soils identified will likely underlie the proposed dwellings, areas of hard-standing (such as the site roads and driveways) or the cover system with private gardens and landscaped areas; thereby removing the exposure pathway and ensuring no risk to future site users.

The asbestos impacted Made Ground should be managed in accordance with CIRIA 733 (Asbestos in soil and made ground: a guide to understanding and managing risks) and placed in accordance with the Asbestos Risk Mitigation Conceptual Site Model shown in Figure 4.1 below.

FIGURE 4.1 ASBESTOS RISK MITIGATION CONCEPTUAL SITE MODEL

Notes
ND None Detect
0.001% Soils may contain ≤ 0.001% asbestos using composite testing to ensure there is no potential risk to human health. This value is present within areas where there may be a short term low level exposure of soils containing trace asbestos fibres by construction workers where an appropriate level of asbestos management is employed (dust suppression)
0.1% Soils at a depth of >1.00m bgl may contain <0.1% asbestos using composite testing where they will not be likely to be disturbed in the future and will therefore be in an area of low sensitivity. Risk assessment completed in accordance with Asbestos JIWG risk assessment tools.
Undefined- this will be dependent upon soils encountered during earthworks, which may be placed at these depths to ensure no potential risk to human health.

There are no topsoil deposits at the site suitable for re-use with the cover system.

Furthermore, the natural cohesive soils are at such a depth that it would not be economically viable to recover this material for use within the cover system.

Any landfilled waste that is to be disposed off-site should undergo assessment using Technical Guidance WM3: *Waste Classification – Guidance on the classification and assessment of waste*.

4.4. WM3 ASSESSMENT OF STOCKPILE

A series of stockpiles are understood to have been fly tipped in the western portion of the site prior to May 2021. These stockpiles mainly comprised reworked Made Ground and demolition materials.

A total of ten samples were collected, three (SP101 to SP103 – June 2021) of which were analysed for a full suite of contaminants including heavy metals, PAHs, TPHs and asbestos. A further seven samples were collected in July 2021 specifically to test for asbestos screening.

No asbestos was recorded in any of the ten samples analysed by E3P.

To confirm the waste classification of the Made Ground soils within these stockpiles, RJT Consulting (Specialist Waste Consultant) completed a WM3 assessment on three selected samples.

The samples were formally assessed in line with the requirements of the Environment Agency Technical Guidance WM3: Waste Classification – Guidance on the Classification & Assessment of Waste. This assessment was done through the use of the One Touch Data Ltd 'HazWaste Online' waste assessment software by suitably trained staff.

The software identifies if any of the results obtained would be classed as hazardous in nature due to their properties and concentrations.

The three sample results were inputted into the HazWaste Online software to determine whether the material samples can be classed as hazardous or non-hazardous in line with the requirements of the EA Technical Guidance WM3. This assessment is essential for the application of the correct List of Waste Code (European Waste Catalogue) for the future haulage, treatment, recovery or disposal of waste material. Based on the excavated material analysis results and ground conditions observed during the field sampling, the waste classification assessment considered whether the samples are either:

- 17 – Construction & Demolition Waste
- 17 05 – Soil (including excavated soil from contaminated sites), stones and dredging spoil
- 170503 – Soil and stone containing hazardous substances. (Mirror Hazardous)
- 170504 – Soil and stone other than those mentioned in 170503. (Mirror Non-hazardous)

On completion of the WM3 (Haz Waste Online) assessment, E3P can confirm that three samples were determined as being non-hazardous and therefore the waste code 170504 can be applied.

A copy of the WM3 Assessment is presented in Appendix XI.

E3P was later provided with a Ground Investigation Report (Ref: M0485 MS (GSI1552) GI Report JF PG 280921) dated October 2021, completed by GeoCon Site Investigations Ltd. This report details that in a total of 58 No. further samples were collected (in September 2021) from the stockpiles for asbestos screening.

A total of 11 No. samples recorded asbestos and subsequent quantification confirmed the asbestos in soil % was between >0.001% and 0.005%.

Based on these results, the material within the stockpiles can be removed as non-hazardous.

4.5. CONTROLLED WATERS RISK ASSESSMENT

E3P has undertaken a controlled waters risk assessment for the site based on the consideration of the conceptual site model and the sensitive receptors which are summarised in Table 4.2 below.

TABLE 4.2 CONTROLLED WATERS CONCEPTUAL MODEL AND SENSITIVITY PROFILE

DISCUSSION		SENSITIVITY RATING
Contaminant Source		
Made Ground The site is understood to have been historically landfilled, as such, the presence of heavy metals, TPH and PAH contamination cannot be discounted.		**High**
Pathway		
Vertical Migration The Made Ground soils are underlain by substantial (>2m thick where encountered) cohesive deposits which will serve as an aquitard and prevent the downward migration of any mobile contaminants towards the underlying Principal Aquifer.		**Low**
Lateral migration There are no surface water courses within influencing distance of the site.		**Low**
Receptor		
Aquifer Classification in Superficial Drift Deposits	Secondary B Aquifer	**Low**
Aquifer Classification in Bedrock	Principal Aquifer	**High**
Groundwater Source Protection Zone or Drinking Water Safeguard Zone	The site is not located within a GSPZ or Drinking Water Safeguard Zone.	**Low**
Distance to the Closest Groundwater Abstraction Point	There are no potable groundwater abstraction boreholes located within a 1km radius.	**Low**
Is the Site Located Within 50 m of a Surface Watercourse?	There are no surface watercourses located within influencing distance of the site.	**Low**
The ICSM developed within the context of the site has identified not a viable pollutant linkage. The site has historically been landfilled and mobile contaminants have been recorded within the Made Ground deposits, however, the underlying cohesive deposits will serve to prevent the vertical migration of any mobile contaminants towards the underlying Principal Aquifer within the Chester Formation. Furthermore, there are no surface watercourses within influencing distance of the site and therefore the site is considered to pose a very low risk to controlled waters.		

To ensure a robust appraisal of the identified risk to controlled waters, E3P has identified the sources of potential contamination that represent a risk to controlled waters from the initial CSM, we have then assessed the availability of ground investigation data in the form of analysis of the solid phase (soil).

The results of this assessment are presented in Table 4.3.

TABLE 4.3 QUALITATIVE RISK TO CONTROLLED WATERS FROM SOIL ANALYTICAL RESULTS

CONTAMINANT	ASSESSMENT RATING	DISCUSSION
BTEX > 1 mg/kg	The soil data analysis has not identified any detectable concentrations of VOCs above 1mg/kg or TPH C5 to C6 that might otherwise be indicative of VOC impact.	None
Total VOC > 1 mg/kg		
Total SVOC > 1 mg/kg	N/A	N/A
C5-C10 > 5 mg/kg	All concentrations are below the laboratory LOD, other than in WS101 at 0.40m bgl.	None
C10-C12 > 10 mg/kg	Concentrations of C10-C12 have been recorded above 10mg/kg within WS101 at 0.40 m bgl (32mg/kg) and TP101 at 2.10m bgl (16mg/kg).	Further Discussion
C12-C16 > 50 mg/kg	Concentrations of C12-C16 have been recorded above 50 mg/kg within four locations.	Further Discussion
Phenols > 2 mg/kg	All concentrations are below the laboratory LOD.	None
Naphthalene > 2 mg/kg	Naphthalene above 2 mg/kg has been recorded in three locations.	Further Discussion
Total PAH > 10 mg/kg	Total PAH concentrations above 10 mg/kg have been recorded in the Made Ground soils across the site.	Further Discussion
PCB > 1 mg/kg	N/A	N/A
Heavy metals > 500 mg/kg	Concentrations of chromium and lead above 500 mg/kg have been recorded in the Made Ground soils.	Further Discussion

Due to the lack of viable surface water receptors within influencing distance of the site the primary receptor has been identified as the underlying the principal bedrock aquifer through vertical migration of contaminants.

During return monitoring visits, groundwater was not encountered within the shallow monitoring wells, therefore no groundwater samples were collected. As such the Tier I assessment has included a comparison of leachate analysis from samples of the Made Ground to drinking water standards (DWS).

The Tier I controlled waters assessment is presented in Table 4.4 overleaf.

TABLE 4.4 COMPARISON OF GROUNDWATER AND LEACHATE ANALYSIS WITH TIER 1 SCREENING LEVELS

DETERMINAND	UNIT	EQS [1, 2, 3] AA	DWS [3,4,5]	NO. OF LEACHATE SAMPLES	MAX CONC. IN LEACHATE	LOCATION OF EXCEEDANCE	ASSESSMENT
Heavy Metals							
Arsenic	µg/l	50	10	3	7.4	N/A	No Further Action
Cadmium	µg/l	0.08-0.25	5	3	<0.11	N/A	No Further Action
Chromium (VI)	µg/l	3.4	–	3	<20	N/A	No Further Action
Chromium (III)	µg/l	4.7	50	3	160 160 150	TP102 0.50m TP106 0.60m WS105 0.70m	Further Action
Copper	µg/l	1	2000	3	360	N/A	No Further Action
Total Cyanide	µg/l	1	50	3	<0.005	N/A	No Further Action
Lead	µg/l	1.2	10	3	1.6	N/A	No Further Action
Mercury	µg/l	–	1.0	3	<0.05	N/A	No Further Action
Nickel	µg/l	4	20	3	90 75 67	TP102 0.50m TP106 0.60m WS105 0.70m	Further Action
Selenium	µg/l	–	10	3	2.6	N/A	No Further Action
Zinc	µg/l	10.9	–	3	1	N/A	No Further Action
pH	6–9			3	10.5	TP102 0.50m	No Further Action
Polycyclic Aromatic Hydrocarbons							
Naphthalene	µg/l	2	10*	3	84	TP102 0.50m	Further Action
Anthracene	µg/l	0.1	10*	3	7.3	N/A	No Further Action
Benzo[b]fluoranthene	µg/l	0.00017*	10*	3	12 11	WS105 0.70m TP106 0.60m	Further Action
Benzo[k]fluoranthene	µg/l	0.00017*	10*	3	4.3	N/A	No Further Action
Benzo(a)pyrene	µg/l	0.00017*	10*	3	9.2	N/A	No Further Action
Indeno(123-cd)pyrene	µg/l	0.00017*	10*	3	8.4	N/A	No Further Action
Fluoranthene	µg/l	0.0063	10*	3	30 30	TP106 0.60m WS105 0.70m	Further Action
Benzo(ghi)perylene	µg/l	1.7–4	10*	3	6.0	N/A	No Further Action
Aromatic Hydrocarbon [5]							
TPH C5-C6 (benzene)	µg/l	10	1	3	<1	N/A	No Further Action
TPH C6-C8 (toluene)	µg/l	74	700	3	<1	N/A	No Further Action

DETERMINAND	UNIT	EQS [1, 2, 3] AA	DWS [3,4,5]	NO. OF LEACHATE SAMPLES	MAX CONC. IN LEACHATE	LOCATION OF EXCEEDANCE	ASSESSMENT
TPH C8-C10 (ethyl benzene)	µg/l	20	300	3	<1	N/A	No Further Action
TPH C10-C12 (xylene)	µg/l	30	500	3	<1	N/A	No Further Action
TPH C10-C12 (xylene)	µg/l	30	500	3	<1	N/A	No Further Action
TPH C12-C16	µg/l	2	905	3	610	N/A	No Further Action
TPH C16-C35	µg/l	50#	905	3	<0.1	N/A	No Further Action
Aliphatic Hydrocarbon 5							
TPH C5-C6	µg/l	–	15000	3	<0.1	N/A	No Further Action
TPH C6-C8	µg/l	–	15000	3	<0.1	N/A	No Further Action
TPH C8-C10	µg/l	–	300	3	<0.1	N/A	No Further Action
TPH C10-C12	µg/l	–	300	3	<0.1	N/A	No Further Action
TPH C12-C16	µg/l	–	300	3	<0.1	N/A	No Further Action
TPH C16-C21	µg/l	–	300**	3	<0.1	N/A	No Further Action
TPH C21-C35	µg/l	–	300**	3	<0.1	N/A	No Further Action

Notes

Solubility <0.01µg/l
AA – Annual Average
MAC- Maximum Admissible Concentration
* Polyaromatic hydrocarbons (PAH) - Benzo(a)pyrene (BaP), Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(g,h,i)-perylene and Indeno(1,2,3-cd)-pyrene. Benzo(a)pyrene can be considered as a marker for the other PAHs, hence only benzo(a)pyrene needs to be monitored for comparison with the biota EQS or the corresponding AA-EQS in water
** There are no WHO Guideline Values for aliphatic fractions C16-C21 and C21-C35, therefore the guideline value for aliphatic fractions inclusive of C8-C16 (300µg/l) has been applied.

1. The Water Environment (Water Framework Directive) (England and Wales) (Amendment) Regulations (2015)
2. Directive establishing a framework for Community action in the field of water policy (Water Framework Directive)
3. Council Directive on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community (Dangerous Substances Directive) - List II substances
4. Council Directive on the quality of water intended for human consumption (Drinking Water Directive)
5. WHO Guidelines for Drinking Water Quality. Third edition (2004)

4.5.1. CONTROLLED WATER RISK ASSESSMENT AND MITIGATION

This comparison indicates that the data exceeds the DWS values for the following inorganic compounds:

- Chromium (III);
- Nickel;
- Naphthalene;
- Benzo[b]fluoranthene; and
- Fluoranthene.

Cooper Associates completed chemical testing of groundwater on a number of samples, which recorded slightly elevated concentrations of copper and benzo[a]pyrene. No measurable hydrocarbons were recorded in any of the samples tested.

REC concluded that no further groundwater testing was considered necessary following the Copper Associates' assessment.

4.5.2. DISCUSSION OF CONTROLLED WATERS RISK ASSESSMENT

The presence of heavy metals and PAHs compounds have been identified in the soil (E3P results), that were observed from chemical analysis to be elevated for a conservative assessment.

No water was present within the monitoring installations so leachate analysis was utilised for the assessment, this is an aggressive test that may overstate the risk, therefore providing a conservative assessment given the lack of water within the monitoring installations.

Due to the site having been landfilled to rase levels within the former railway cutting, the source of the contaminants cannot be attributed to one area or point source and the majority of the contamination is likely to be present site-wide within the landfilled waste.

As the site is currently open, uncapped public space, rainfall is not being intercepted and subsequently infiltrates freely into the underlying Made Ground, potentially mobilising the identified contaminants.

However, the proposed development will upfill and largely encapsulate the site thus limiting the potential for infiltration and therefore leaching potential of any contaminants.

The landfilled waste is proven to be underlain by cohesive deposits in CP102-CP104. No cohesive deposits were recorded in CP101, however clay deposits are likely to be present beneath the granular drift soils at depths beyond the borehole termination depths; when reviewed against wider BGS records.

Therefore, despite potentially mobile contaminant being present within the landfilled waste, there is not considered to be a complete pollutant linkage and the site is unlikely to impact the Principal Aquifer within the Chester Sandstone Formation. Furthermore, the overall sensitivity of this aquifer is reduced given the absence of any potable groundwater abstraction boreholes within a 1km radius of the site.

4.6. GROUND GAS

The potential impact on the development from ground gases has been assessed with reference to standards and guidelines published in CIRIA Report 665 – *Assessing risks posed by hazardous ground gases to buildings* (2007). However, it is recommended that the full ground gas assessment and recommended protection measures are agreed with the local authority prior to their adoption on site. Furthermore, all protection measures adopted should be validated by a suitably qualified engineer.

4.6.1. INVESTIGATION RATIONALE

The ICSM identified that the underlying Made Ground (landfilled material) represent a potentially significant source of ground gas generation. Based on the identification of these sources, E3P has determined that the site represents a high ground gas source generation potential.

Within the context of the proposed residential end use and ground gas generation potential, the gas assessment requires that 12 visits are required over 6 months, with at least two sets of readings at low or falling atmospheric pressure as set out within CIRIA 665 Tables 5.5a and 5.5b.

The spacing requirements for monitoring wells are detailed within CIRIA 665 Table 4.2, which indicates that for high gas hazard sites (domestic landfills) a high sensitivity development, nominal well spacing should be between >25m.

Due to the presence of obstructions within the shallow Made Ground, only two locations were installed within the window sample boreholes by E3P. Therefore, reliance on previous phases of investigation by Cooper Associates and REC Ltd has been considered as part of the ground gas risk assessment.

TABLE 4.5 GROUND GAS MONITORING LOCATION RATIONALE

LOCATION	GROUND GAS SOURCE	DEPTH OF MONITORING WELL (m)
WS102	Made Ground	1.00–3.00
WS104	Made Ground	1.00–3.50

4.6.2. MONITORING METHODOLOGY

Concentrations of methane (CH_4), carbon dioxide (CO_2) and oxygen (O_2) were measured using a calibrated infra-red gas analyser (GFM435) with gas flow rates were measured using an integrated flow meter.

Gas measurements were recorded for a minimum of 300 seconds at each location, at which point the maximum concentration of CH_4 and CO_2, together with the lowest concentration of O_2 were recorded.

The results of the preliminary ground gas monitoring are presented in Table 4.7.

CIRIA C665 and NHBC Report No 10627-R01 provide assessments for carbon dioxide and methane based upon gas screening values (GSVs) utilising flow rates and concentrations. The site-based GSVs for steady state methane and carbon dioxide are based upon the following equation:

$$GSV = \frac{concentration\ (by\ vol)}{100} \times flowrate\ (1\ /\ hr)$$

The GSVs within CIRIA C665 are based upon all buildings other than standard residential houses. The NHBC GSVs are based upon standard residential houses with precast concrete floors (block and beam). The CIRIA 665 report author (Steve Wilson) since provided further clarification regarding which guidance should be adopted for residential houses that have suspended cast in-situ concrete floor slab: for the avoidance of doubt, it was confirmed that the GSVs within the CIRIA 665 guidance should be adopted.

The thresholds for GSVs based upon NHBC and CIRIA guidance are provided within Table 4.6.

TABLE 4.6 RESIDENTIAL THRESHOLDS FOR GAS SCREENING VALUES (GSV) IN ACCORDANCE WITH CIRIA C665 AND NHBS REPORT NO 10627-R01 – RESIDENTIAL END USE

CIRIA – NO SUBFLOOR VOID		NHBC – SUBFLOOR VOID		
CLASSIFICATION	**GSV (METHANE AND CARBON DIOXIDE)**	**CLASSIFICATION**	**GSV (METHANE)**	**GSV (CARBON DIOXIDE)**
CS1	< 0.07	Green	< 0.13	< 0.76
CS2	< 0.70	Amber 1	< 0.63	< 1.60
CS3	< 3.5	Amber 2	< 1.60	< 3.10
CS4	< 15	Red	> 1.60	> 3.10
CS5	< 70	N/A	N/A	N/A
CS6	> 70	N/A	N/A	N/A

4.6.3. SUMMARY OF MONTIORING RESULTS

Table 4.7 presents the ground gas and groundwater monitoring results to date.

The ground gas monitoring is ongoing and an addendum will be issued on completion of the monitoring program.

TABLE 4.7 SUMMARY OF GROUND GAS MONITORING RESULTS

WELL	DATE	CH_4 INITIAL (%V/V)	CH_4 STEADY (%V/V)	CH_4 GSV (l/hr)	CO_2 INITIAL (%V/V)	CO_2 STEADY (%V/V)	CO_2 GSV (l/hr)	O_2 (%V/V)	ATMOS (mb)	ATMOS. DYNAMIC	FLOW (l/hr)	RESPONSE ZONE (m bgl)	DEPTH TO BASE (m bgl)	DEPTH TO WATER (m bgl)
WS102	29/10/21	5.40	5.40	0.0054	0.20	0.20	0.0002	8.30	982	Falling	0.10	1.00–3.00	2.70	Dry
	11/11/21	4.20	4.20	0.0042	0.10	0.10	0.0001	8.70	989	Falling	0.10		2.70	Dry
	16/11/21	0.10	0.10	0.0001	1.80	0.90	0.0009	18.70	1006	Rising	0.10		2.70	Dry
	09/12/21	0.10	0.10	0.0001	0.10	0.10	0.0001	19.40	993	Falling	0.10		2.70	Dry
	23/12/21	0.10	0.10	0.0001	0.10	0.10	0.0001	19.40	997	Steady	0.10		2.70	Dry
	05/01/21	0.10	0.10	0.0001	0.10	0.10	0.0001	19.50	1006	Steady	0.10		2.70	Dry
	18/01/22	0.10	0.10	0.0001	0.10	0.10	0.0001	19.70	1015	Steady	0.10		2.70	Dry
	02/02/22	0.10	0.10	0.0001	0.10	0.10	0.0001	19.90	1013	Steady	0.10		2.70	Dry
	15/02/22	0.10	0.10	0.0001	0.10	0.10	0.0001	19.60	993	Falling	0.10		2.70	Dry
	01/03/22	0.10	0.10	0.0001	0.10	0.10	0.0001	19.70	1023	Falling	0.10		2.70	Dry
	10/03/22	0.10	0.10	0.0001	0.10	0.10	0.0001	20.00	1005	Steady	0.10		2.70	Dry
	01/04/22	0.10	0.10	0.0001	0.10	0.10	0.0001	19.60	1016	Falling	0.10		2.70	Dry
WS104	29/10/21	7.50	7.40	0.0074	1.00	1.00	0.001	0.70	979	Falling	0.10	1.00-3.50	3.30	Dry
	11/11/21	6.70	6.40	0.0064	0.80	0.70	0.0007	2.90	989	Falling	0.10		3.30	Dry
	16/11/21	0.10	0.10	0.0001	2.40	1.50	0.0015	17.20	1006	Rising	0.10		3.30	Dry

WELL	DATE	CH_4 INITIAL (%V/V)	CH_4 STEADY (%V/V)	CH_4 GSV (l/hr)	CO_2 INITIAL (%V/V)	CO_2 STEADY (%V/V)	CO_2 GSV (l/hr)	O_2 (%V/V)	ATMOS (mb)	ATMOS. DYNAMIC	FLOW (l/hr)	RESPONSE ZONE (m bgl)	DEPTH TO BASE (m bgl)	DEPTH TO WATER (m bgl)
WS104	09/12/21	0.10	0.10	0.0001	0.10	0.10	0.0001	19.50	989	Falling	0.10	1.00-3.50	3.30	Dry
	23/12/21	0.10	0.10	0.0001	0.10	0.10	0.0001	19.50	996	Steady	0.10		3.30	Dry
	05/01/21	0.10	0.10	0.0001	0.10	0.10	0.0001	19.60	1006	Steady	0.10		3.30	Dry
	18/01/22	0.10	0.10	0.0001	0.10	0.10	0.0001	19.80	1015	Steady	0.10		3.30	Dry
	02/02/22	0.10	0.10	0.0001	0.10	0.10	0.0001	19.80	1013	Steady	0.10		3.30	Dry
	15/02/22	0.10	0.10	0.0001	0.10	0.10	0.0001	19.70	992	Falling	0.10		3.30	Dry
	01/03/22	0.10	0.10	0.0001	0.10	0.10	0.0001	18.60	1022	Falling	0.10		3.30	Dry
	10/03/22	0.10	0.10	0.0001	0.10	0.10	0.0001	20.0	1005	Steady	0.10		3.30	Dry
	01/04/22	0.10	0.10	0.0001	0.10	0.10	0.0001	19.60	1014	Falling	0.10		3.30	Dry

NOTES

NHBC Traffic Light System	Typical Max CH4 Concentration	GSV CH4	Typical Max CO2 Concentration	GSV CO2
Amber 1	1	0.16-0.63	5	0.78-1.56
Amber 2	5	0.63-1.56	10	1.56-3.13
Red	20	1.56+	30	3.13+

Values in **BOLD** exceed Amber 1 Thresholds
Values in BLUE denote water above monitoring well

4.6.4. SOURCES OF GROUND GAS

The ground investigation has identified the following potential sources of ground gas:

- Made Ground (historic fill) to a proven depth of 11.00 m bgl.

4.6.5. GROUNDWATER

No groundwater was recorded in either of the shallow wells installed.

4.6.6. GAS FLOW

Very limited has flow has been recorded to date at 0.10l/hr.

4.6.7. GAS CONCENTRATIONS

Elevated methane concentrations were recorded on the first two visits in both WS102 and WS104 at concentrations peaking at 5.40% v/v and 7.40% v/v, respectively. No elevated concentrations of methane were recorded in the subsequent visits. The higher methane concentrations were also associated with low oxygen concentrations.

Carbon dioxide concentrations were recorded within all the monitoring wells at concentrations ranging from 0.1% v/v to 2.40% v/v (WS103).

4.6.8. GAS ASSESSMENT

In accordance with the methodology outlined with the CIRIA publication C665, E3P have utilised the results of the ground gas monitoring surveys to calculate a tentative gas screening value (GSV). The GSVs for the monitoring positions are summarised in Table 4.8.

TABLE 4.8 GAS RISK PROFILE AND LOCATION

LOCATION	MAX CH_4 (% v/v)	GSV (l/hr)	MAX CO_2 (% v/v)	GSV (l/hr)	CLASSIFICATION
WS102	5.40	0.0054	1.80	0.0009	**CS3 / Amber 2**
WS104	7.40	0.0074	2.40	0.0015	**CS3 / Amber 2**

The GSV has been compared to the criteria outlined with CIRIA C665 to determine the level of risk to the proposed development and to ensure the appropriate remedial options are incorporated into any future building design in this area.

Cooper Associates carried out ten monitoring visits over a nine month period, installed between depths of 4.00m and 16.00m bgl. The results recorded methane up to a maximum concentration of 57.7% and carbon dioxide concentrations up to 11.80%. Maximum flow rates were reported to be between 0.3l/hr and 0.8l/hr. It was therefore recommended the site is classified as Characteristic Situation 3. Coopers noted that previous gas investigations in 1990, 1994 and 200 by others has also recorded elevated concentrations of methane and carbon dioxide beneath the site. However, no further details of these historic investigations was presented in the Cooper Associates report.

Results within the REC Ltd report were limited (two visits). It was therefore suggested the site fall into CS3 primarily based on the previously findings by Cooper Associates.

Both E3P boreholes had response zones in the shallow Made Ground, and therefore the historic information has been relied upon for reference to concentrations within the deeper landfilled materials.

In light of the above, and based on the E3P monitoring of two further monitoring points, E3P recommend the site falls into Characteristic Situation 3 / Amber 2 and therefore specialist ground gas protection measures will be required in all new dwellings.

However, due to elevated methane concentrations recorded by Cooper Associates, E3P would also suggest that post enabling works monitoring is undertaken to confirm the final gas regime. This could be completed using continuous monitoring installations to expedite the monitoring period.

In addition, due to the presence of volatile compounds within the Made Ground, a vapour risk assessment is required and if a unacceptable level of risk is identified, local hotspot removal or installation of a suitable vapour membrane will be required for new structures to prevent vapour ingress.

4.6.9. RESIDENTIAL BUILDING GAS RISK MITIGATION

British Standard BS8485 (2015)+A1(2019) provides two types of residential property that require assessment. These building types are:

- **Type A Building** – Private ownership with no building management controls on alterations to the internal structure, the use of rooms, the ventilation of rooms or the structural fabric of the building. Some small rooms are present. Probably conventional building construction (rather than civil engineering). Examples include private housing and some retail premises.

- **Type B Building** – Private or commercial property with central building management control of any alterations to the building or its uses but limited or no central building management control of the maintenance of the building, including the gas protection measures. Multiple occupancy. Small- to medium-sized rooms with passive ventilation of rooms and other internal spaces throughout ground floor and basement areas. May be conventional building or civil engineering construction. Examples include managed apartments, multiple occupancy offices, some retail premises and parts of some public buildings (such as schools, hospitals, leisure centres) and parts of hotels.

Based on the ground gas risk assessment and the proposed Type A Building, it is envisaged that a point score of 4.5 will be required for affected properties, as summarised in Table 4.9.

TABLE 4.9 BS 8485 (2015) POINTS REQUIRED FOR TYPE A AND TYPE B BUILDINGS

CHARACTERISTIC SITUATION	MINIMUM GAS PROTECTION SCORE (POINTS)	
	HIGH SENSITIVITY	
	TYPE A BUILDING	TYPE B BUILDING
1	0	0
2	3.5	3.5
3	4.5	4
4	6.5	5.5
5	N/A	6.5
6	N/A	N/A

Residential buildings should not be built on CS4 or higher sites unless the type of construction or site circumstances allow additional levels of protection to be incorporated, for example, high-performance ventilation or pathway intervention measures, and an associated sustainable system of management of maintenance of the gas control system such as in institutional and/or fully serviced contractual situations.

The requisite 4.5 points must be achieved by the installation of a suitable combination of measures detailed in Table 4.10.

TABLE 4.10 SUMMARY OF GROUND GAS MITIGATION MEASURES – BS8485 (2015)+A1(2019)

GAS PROTECTION SCORES FOR THE STRUCTURAL BARRIER	**SCORE[A]**
Floor and Substructure Design	
Precast Suspended Segmental Subfloor (Beam and Block)	0
Cast In-Situ Ground-Bearing Floor Slab (With Only Nominal Mesh Reinforcement)	0.5
Cast In-Situ Monolithic Reinforced Ground-Bearing Raft or Reinforced Cast In-Situ Suspended Floor Slab With Minimal Penetrations	1 or 1.5[B]
Basement Floor and Walls Conforming to BS 8102:2009, Grade 2 Waterproofing[C]	2
Basement Floor and Walls Conforming to BS 8102:2009, Grade 3 Waterproofing[C]	2.5

A) The scores are conditional on breaches of floor slabs, etc. being effectively sealed.
B) To achieve a score of 1.5 the raft or suspended slab should be well reinforced to control cracking and have minimal penetrations cast in (see **A.2.2.2**).
C) The score is conditional on the waterproofing not being based on the use of a geosynthetic clay liner waterproofing product (see **C.3,** Note 4).

PROTECTION ELEMENT SYSTEM		**SCORE**	**COMMENTS**
Gas protection scores for ventilation protection measures			
(a) Pressure Relief Pathway – Usually formed of low fines gravel or with a thin geocomposite blanket or strips terminating in a gravel trench external to the building.		0.5	Whenever possible a pressure relief pathway (as a minimum) should be installed in all gas protection measures systems. If the layer has a low permeability and/or is not terminated in a venting trench (or similar), then the score is 0.
(b) Passive Subfloor Dispersal Layer – Media used to provide the dispersal layer are: • Clear void; • Polystyrene void former blanket; • Geocomposite void former blanket; • No-fines gravel layer with gas drains; and • No-fines gravel layer.	Very good performance	2.5	The ventilation effectiveness of different media depends on a number of different factors including the transmissivity of the medium, the width of the building, the side ventilation spacing and type and the thickness of the layer. The selected score should be assigned taking into account the recommendations in Annex B of BS 8485 (2015). Passive ventilation should be designed to meet at least "good performance".
	Good performance	1.5	
(c) Active Dispersal Layer – Usually comprising fans with active abstraction (suction) from a subfloor dilution layer with roof-level vents. The dilution layer may comprise a clear void or be formed of geocomposite or polystyrene void formers.		1.5 to 2.5	This system relies on continued serviceability of the pumps, therefore alarm and response systems should be in place.

		There should be robust management systems in place to ensure the continued maintenance of the system, including pumps and vents. Active ventilation should always be designed to meet at least "good performance".
(d) Active Positive Pressurisation – Provided by the creation of a blanket of external fresh air beneath the building floor slab by pumps supplying air to points across the central footprint of the building into a permeable layer, usually formed of a thin geocomposite blanket.	1.5 to 2.5	This system relies on continued operation of the pumps, therefore alarm and response systems should be in place. The score assigned should be based on the efficient "coverage" of the building footprint and the redundancy of the system. Active ventilation should always be designed to meet at least "good performance".
(e) Ventilated Car Park – Floor slab of occupied part of the building under consideration is underlain by a basement or undercroft car park.	4	Assumes that the car park is vented to deal with car exhaust fumes, designed to Buildings Regulations 2000, Approved Document F [9].
PROTECTION ELEMENT SYSTEM	**SCORE**	**COMMENTS**
Gas Protection Score for the Gas-Resistant Membrane		
Gas-resistant membrane meeting all of the following criteria: • Sufficiently impervious to the gases with a methane gas transmission rate < 40.0 ml/day/m²/atm (average) for sheet and joints (tested in accordance with BS ISO 15105-1 manometric method); • Sufficiently durable to remain serviceable for the anticipated life of the building and duration of gas emissions; • Sufficiently strong to withstand in-service stresses (e.g. settlement if placed below a floor slab); • Sufficiently strong to withstand the installation process and following trades until covered (e.g. penetration from steel fibres in fibre-reinforced concrete, penetration of reinforcement ties, tearing due to working above it, dropping tools); • Capable, after installation, of providing a complete barrier to the entry of the relevant gas; and • Verified in accordance with CIRIA C735.	2	The performance of membranes is heavily dependent on the quality and design of the installation, resistance to damage after installation and integrity of joints. For example, a minimum 0.4 mm thickness (equivalent to 370 g/m² for polyethylene) reinforced membrane (virgin polymer) meets the performance criteria opposite. If a membrane is installed that does not meet all the criteria opposite, then the score is 0.
This table should be read in conjunction with the notes presented in BS 8485 (2015)+A1 (2019)		

4.7. POTABLE WATER SUPPLY

The site was historically landfilled and therefore the site will require PE Barrier Pipe Type A for potable water supply infrastructure.

4.8. CONCEPTUAL SITE MODEL

Following the completion of the intrusive site investigation, chemical analysis and risk assessment, the conceptual model shown in Table 4.11 has been prepared for the site.

TABLE 4.11 CONCEPTUAL MODEL

POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
PL1 PL2	Heavy Metals, non-volatile PAH (Made Ground)	Dermal contact. Dermal contact and ingestion.	Future site users. Off-site receptors.	Likely	Moderate	Low
Discussion: Heavy metals, non-volatile TPHs and PAHs have been identified throughout the shallow Made Ground deposits which pose a potential risk to future site users. **Recommendation:** A suitable cover system will be required in all private gardens and soft landscaped areas which will serve to prevent exposure to future site users. Construction works completed with PPE and provision of welfare.						
PL3	ACM in Made Ground	Inhalation of dust.	Future site users. Buildings. Off-site land users.	Likely	Moderate	Low
Assessment: Asbestos has been recorded as trace fibres within the Made Ground soils and it can be reasonably assumed that trace fibres are potentially present throughout the Made Ground deposits. **Recommendation:** The soils will require placement in accordance with the asbestos CSM and will ultimately be capped by the proposed structures, hardstanding or cover system, thereby removing the exposure pathway to future site users and third party property. Construction works completed with PPE and provision of welfare.						

POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
PL4	Volatile Contaminants (Napthalene, TPH C12-C16)	Inhalation of vapours. Migration through permeable strata and preferential pathways.	Future site users. Off-site receptors.	Likely	Moderate	Low
Assessment: Elevated concentrations of TPH C12-16 and naphthalene have been identified in the Made Ground deposits across the site which have the potential to pose a vapour risk within the proposed new dwellings. **Recommendation:** Due to the presence of volatile compounds within the Made Ground, a vapour risk assessment is required and if a unacceptable level of risk is identified, local hotspot removal or installation of a suitable vapour membrane will be required for new structures to prevent vapour ingress.						
PL4	Methane, carbon dioxide	Inhalation of gas. Migration through permeable strata and preferential pathways. Explosion in confined spaces.	Future site users. Buildings. Off-site land users.	Low likelihood	Moderate	Low
Assessment: The site is a former landfill and based on historic site investigations, in addition to the limited E3P results, E3P recommend the site falls into Characteristic Situation 3 / Amber 2 and therefore specialist ground gas protection measures will be required in all new dwellings. **Recommendation:** The site falls into the Characteristic Situation 3 classification and protection measures are required. However, due to elevated methane concentrations recorded by Cooper Associates, E3P would also suggest that post enabling works monitoring is undertaken to confirm the final gas regime. This could be completed using continuous monitoring installations to expedite the monitoring period.						

POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
PL5	Mobile contaminants such as metals, PAHs, hydrocarbons, volatile compounds	Surface runoff. Migration through permeable strata and preferential pathways. Perched waters migration.	Principal Aquifer	Likely	Low	Low
Assessment: Elevated concentrations of chromium and lead were recorded in the leachate samples from the Made Ground. However, the site is underlain by cohesive deposits which will serve to prevent vertical migration towards the underlying Principal Aquifer. Furthermore, there are no surface watercourses within influencing distance of the site, as such, the site is considered to pose a very low risk to controlled waters. **Recommendation:** No further mitigation measures are considered necessary.						
PL6	Sulphate (potential ash within Made Ground)	Sulphate attack on concrete.	Building structure.	Likely	Moderate	Low
Assessment: The soils at the site meet class DS-1, AC-1s. **Recommendation:** Concrete should be designed in accordance with the chemical testing results.						
PL7	Organic contaminants such as hydrocarbons, solvents	Ingestion of tainted water supply.	Future site users. Water pipes.	Likely	Moderate	Low

POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
Assessment: Elevated concentrations of TPH have been identified at the proposed pipeline depth (0.75 m – 1.35 m) associated with the historic landfilled material. **Recommendation:** Barrier pipe type A will be required.						
PL8	Phytotoxic contaminants (Made Ground)	Direct Contact (plant uptake).	Flora.	Likely	Moderate	**Low**
Assessment: Contamination has been encountered within shallow Made Ground across the site which may be taken up by flora in soft landscaping. **Recommendation:** Installation of a clean cover system within any areas of soft landscaping to prevent plant uptake of contaminants.						

Main exposure pathways:
PL1 = soil ingestion, PL2 = dermal contact and ingestion, PL3 = dust inhalation; PL4 = Vapour/Gas Inhalation; PL5 = Vertical / Lateral Migration; PL6 = Corrosion of concrete; PL7=Tainting of water supply; PL8 = Uptake by plants.

5. GEOTECHNICAL ASSESSMENT

5.1. PROPOSED DEVELOPMENT

Kirklands Developments Ltd intend to develop the site with the construction of a low-rise residential development comprising c. 25 No. residential dwellings with associated gardens, estate roads and adopted utility infrastructure.

5.2. SUMMARY OF GROUND CONDITIONS

- *Made Ground deposits were recorded to a proven depths of between 7.50m and 11.00m bgl. Made Ground deposits comprise a reworked topsoil of dark brown slightly sandy clay overlying a brown clayey, sandy gravel and gravelly clay with occasional cobbles. Gravel is fine to coarse angular to subangular of brick, plastic, timber, concrete and ceramic. Cobbles are angular of brick and concrete. The Made Ground is understood to be associated with historic fill material used to upfill a railway cutting to current levels.*

- *The drift deposits were recorded from depths of between 7.50m and 9.70m bgl to a proven depth of 15.50m bgl. The superficial deposits were are varied, comprising a medium dense to dense brown silty fine to coarse SAND, which was typically interbedded and underlain by a stiff to very stiff, high to very high strength, brown sandy CLAY with occasional boulders. The cohesive deposits were not recorded in CP101.*

- *Solid Geology was not encountered during the site investigation; and*

- *No shallow groundwater (<3.500m bgl) has been recorded in the monitoring to date.*

5.3. SITE PREPARATION

The site should be cleared and any vegetation below areas of proposed development stripped in accordance with Series 200 of the *Manual of Contract Documents for Highway Works (MCHW)*. This should include the following:

- Roots present below the footprint of proposed structures and infrastructure should be grubbed out and the resulting void infilled with suitable compacted engineered fill.

- Demolition of all existing buildings and removal of all concrete hardstanding.

- Redundant services should be sealed off and grubbed out and replaced with suitable compacted engineered fill.

- Buried structures and old foundations have been encountered on site. These should be excavated from below the proposed development footprint with the resulting void backfilled.

5.4. FOUNDATION CONDITIONS AND ASSESSMENT OF POTENTIAL BEARING CAPACITIES

In due consideration of the identified ground conditions, in-situ and laboratory geotechnical testing, E3P has undertaken an assessment of the net safe allowable bearing pressure (ABP) within the underlying natural stratum to assist in the detailed design of foundations and infrastructure and determine the target founding stratum.

In addition, a preliminary slope stability assessment has been completed based on the proposed development scheme provided to date and the results of this assessment are presented in Section 5.12. The assessment indicates that the proposed structural (and infrastructure) loads induced by the construction of dwellings adjacent to the northern boundary have the potential to cause failure of the embankment. Therefore the proposed structures will need to be transferred to competent strata through the installation of piled foundations for all plots located adjacent to the northern boundary of the site to ensure no unacceptable loading is induced that could cause slope failure.

However, E3P understands that the client intend to stabilise the slope through construction of a retainment feature. Upon provision of the designs a final slope stability assessment will be completed which may negate the need for driven piled foundations.

The very stiff very high strength sandy CLAY soils and dense SAND at a depth of >11.50 m bgl typically offer an ABP of 100 kN/m² which generally increases with depth.

Based on the assessment of the relative undrained shear strength, relative in-situ densities and corresponding safe net allowable bearing pressure, the suitable target founding stratum for the plots adjacent to the slope has been identified as the underlying very stiff very high strength sandy CLAY.

While a detailed assessment of pile depths and bearing capacity is beyond the scope of this report, piles would likely achieve a 'set' within either the dense SAND or very stiff very high strength sandy CLAY soils at a depth of >11.50 m bgl where an ABP of 100 kN/m² can be achieved.

Consideration of the effects of negative skin friction due to variability on the Made Ground and natural drift strata will be required.

A specialist piling contractor should be contacted to obtain detailed designs and costs for a specialist piling technique and to allow them to reduce the factor of safety based on their extensive pile testing data.

However, for the remaining plots across the southern portion of the site, the use of ground improvement through installation of vibro stone columns (VSC) could also be utilised. Due to the depth of Made Ground, partial depth treatment (within the Made Ground) could be completed to facilitate the construction of raft foundations, however, settlement analysis would be required to confirm if a partial depth VSC treatment is possible to support a raft on the stone columns. If site levels are reduced, it may be feasible to achieve full depth VSC treatment.

Alternatively, the upper 3.00m of the site could be subject to a programme of reprocessing and re-engineering of the Made Ground at each plot to create a development platform for raft foundations. However, due to the depth of Made Ground across the site, settlement analysis will be required with respect to plots foundation and external areas to appraise the long term settlement and differential induced.

Should a raft be adopted zone load assessments will be required to understand the settlement over the 60 year design life of the proposed dwellings.

A detailed Geotechnical Enabling Works Specification will be required for the site upon completion of detailed design levels.

5.5. GROUND FLOOR SLABS

Current building control regulations require that where the infilled ground is present to depths in excess of 600 mm, or where the substratum is variable in terms of the structure and settlement potential, a suspended floor slab is required.

In this instance, the proposed care home will overlie historic landfilled material in excess of 600 mm deep, and as such, a suspended floor slab will be required.

Where a cast in-situ suspended slab is utilised with no subfloor void, appropriate compressible material (heave precautions) will be required in the construction of the substructure.

5.6. HEAVE PRECAUTIONS

The site has been proven to be underlain by clay soils, which are susceptible to volumetric instability due to fluctuations in moisture content, particularly within influencing distance of trees as per the NHBC/ LABC conjectured zones of influence.

As the clay is deemed to be moderate plasticity and therefore medium volume change potential, heave precautions are required and will need to be designed by a suitably qualified engineer.

A summary of heave precautions is presented in Table 5.1 below.

TABLE 5.1 SUMMARY OF HEAVE PRECAUTIONS

		MINIMUM VOID DIMENSION FOR FOUNDATIONS, GROUND BEAMS AND SUSPENDED IN-SITU CONCRETE GROUND FLOORS		MINIMUM VOID DIMENSIONS UNDER PRECAST CONCRETE AND SUSPENDED TIMBER FLOORS
Plasticity Index of Soil	**Required Foundation Depth (m)**	**Thickness of Void Former Against Side of Foundation or Ground Beam (mm)**	**Thickness of Void Former on Underside of Edge Beam and Floor Slab (mm)**	**Void Dimension (mm)**
High Plasticity (> 40)	> 2.5	Engineer Design		Engineer Design
	2.0–2.5	35	150	300
	1.5–2.0	25	75	
Moderate Plasticity (20–40)	> 2.5	Engineer Design		Engineer Design
	2.0–2.5	25	100	250
	1.5–2.0	25	50	
Low Plasticity (< 20)	2.0–2.5	N/A	50	200
	> 2.0	No Special Precautions		

5.7. CULVERT TRENCH

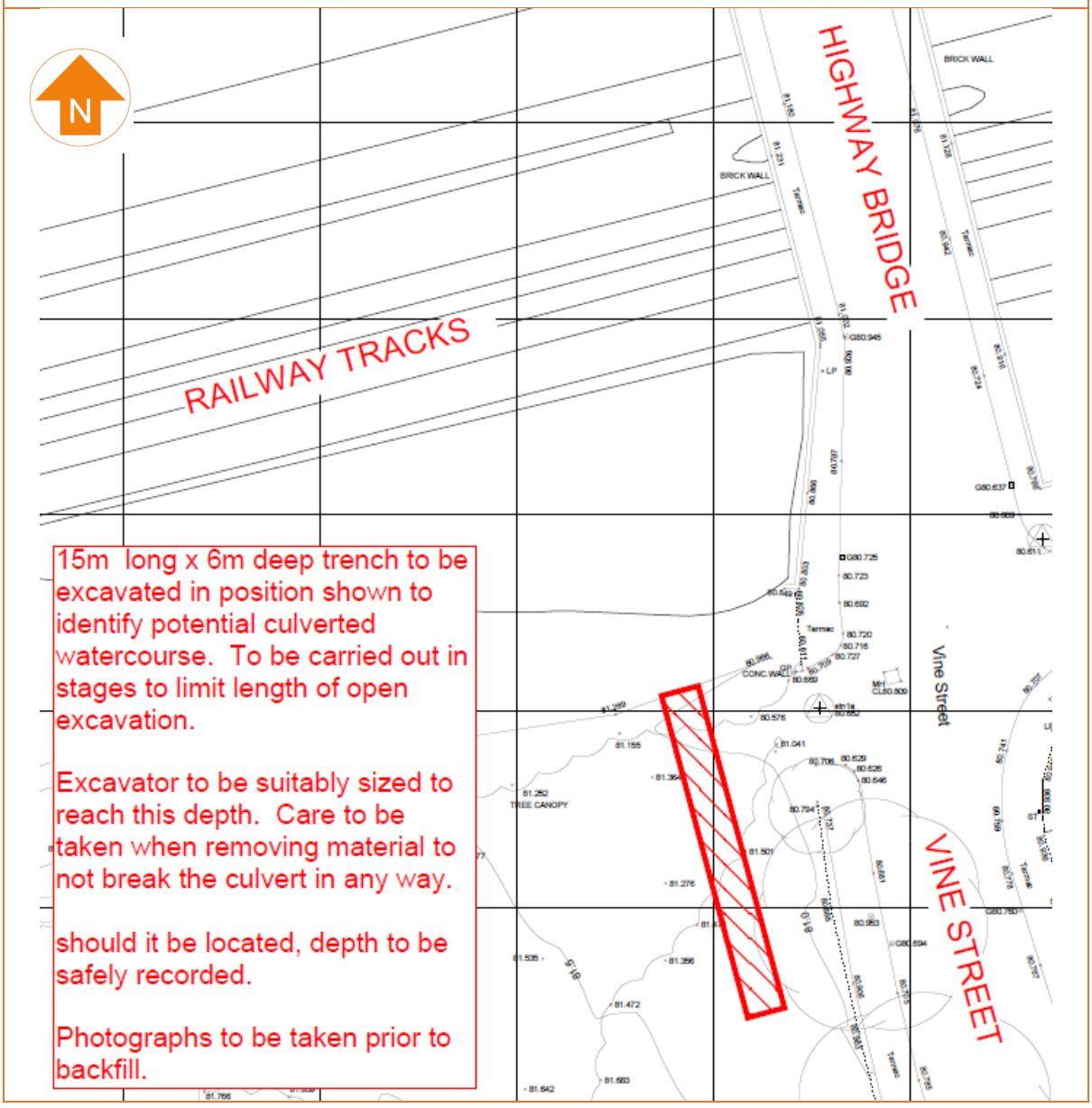
E3P were informed a history culvert may underlie the eastern portion of the site at a depth of 6.00m bgl.

To locate the trench, a 15m long and 6.50m deep slit trench was excavated in a north to south orientation as per the location plan provided by the client (presented in Figure 5.1 below)

No evidence of the culvert was encountered within the trench and photographs of the excavation are presented in Appendix IV.

However, during the enabling works, it is recommended that a watching brief is completed in this area to confirm the presence or absence of the feature.

FIGURE 5.1 CULVERT TRENCH LOCATION PLAN



5.8. HIGHWAYS CONSTRUCTION

A programme of remediation and enabling works will be required to remediate the proposed road subgrade in accordance with the requirements of the Manual of Contract Documents for Highway Works Volume 1 Specification For Highway Works (Series 600-Earthworks) for a method compaction.

It is considered that the shallow Made Ground material can be re-engineered using method compaction to achieve a CBR in excess of 5% if works are completed in favourable climatic conditions.

5.9. DRAINAGE

The presence of substantial depths of Made Ground across some areas of the site may result in settlement. It is therefore recommended that drain runs are designed using steeper gradients and flexible joints to allow for some differential settlement.

Furthermore, the Made Ground deposits are underlain by substantial depths (<5.00 m thick) of low permeability silty CLAY (alluvial deposits) which would preclude the use of soakaways for disposal of surface water runoff.

5.10. CONCRETE DURABILITY

Based upon the results of the chemical analyses it is considered that subsurface concrete can be designed in accordance with Design Sulphate Class DS-1, Aggressive Chemical Environment for Concrete Classification (ACEC) AC-1s in accordance with the recommendations provided in BRE *Special Digest 1* (2005).

5.11. EXCAVATIONS

Site observations indicated that excavations should be feasible in the near surface with normal plant.

It is anticipated that any obstructions will be grubbed out during the reduced-level dig for the substructure works. However, stability of the Made Ground in proximity to the slope should be considered prior to any reduced level excavations across the northern boundary.

However, due to the depth and variability of the Made Ground and likelihood of trench collapse, it is considered that all excavations are supported or battered back in accordance with guidance contained in CIRIA R97.

TABLE 5.2 CIVIL ENGINEERING EXCAVATION RISK MATRIX

RISK ITEM	PRESENT	COMMENT
Running Sands	No	No running sand has been identified.
Minor Water Ingress	Yes	Water ingress will require localised dewatering/sump pumping during the construction of site drainage infrastructure. Ingress of water into foundation excavation will potentially flood foundation excavations, limiting the viability of spread foundations to be constructed.
Shallow Bedrock	No	Shallow bedrock has not been identified for the subject site.

5.12. SLOPE STABILITY

5.12.1. INTRODUCTION

A significant embankment is present at the northern boundary leading to Network Rail infrastructure (train track) in a cutting at the lower elevation of this slope.

The proposed site redevelopment works and construction of the new development platform to accommodate the residential development will require alteration to the current topography, with due consideration of the anticipated structural and infrastructure loading and altered soil mechanics, in respect to the existing slope to the north of the site boundary.

In light of the identified potential mechanism for slope failure to be induced by the proposed development and addition of structural loading, E3P has been commissioned to undertake an initial slope stability analysis to assess the pertinent / relevant stability and potential failure mechanism.

This model will seek to determine the potential for newly imposed loadings to generate a risk of instability or failure within the off-site embankment and the need for any mitigation measures such as piled foundations to transfer loadings below the base of the slope.

For the avoidance of any doubt proposed levels have not yet been provided, therefore this interim analysis is based on existing topographical information with the proposed loadings applied to assess the stability for initial design considerations only.

5.12.2. GEOTECHNICAL SLIP CIRCLE ANALYSIS

Based on our review of the proposed development, the primary risk associated with future stability within the proposed embankment would be associated with the inducement of structural and infrastructure loadings to the top of the slope which could cause failure.

Given that the embankment was formed from variable Made Ground (landfilled) material placed during the mid 2000s, the potential for future failure associated with rotational slip is considered to be moderate to high.

Therefore, to ensure the potential risk is accurately appraised, E3P has developed a detailed slope stability model with induced loadings to assess any potential degree of risk.

To ensure the perceived risk is fully appraised, E3P have created a slope stability model to assess the perceived location of all slip circles, their zone of influence, EC7 ratio of stabilising to destabilising and thus the potential of negative impact on the proposed development.

This slope stability analyses involves Limit Equilibrium (LE) analysis due to its simplicity and accuracy. This method consists of cutting the slope into fine slices and applying appropriate equilibrium equations (equilibrium of the forces and/or moments).

According to the assumptions made on the efforts between the slices and the equilibrium equations considered, many alternatives were proposed, such as the Bishop and Fellenius methods. In most cases, they are shown to give similar results. For this study, Oasys Slope, EC7 Ultimate Limit State (ULS) scenario slope stability analysis program has been used. This offers a number of methods but, for each analysis, the Bishop method was applied.

5.12.3. LIMITATIONS AND ASSUMPTIONS OF THE STUDY

The comments made and conclusions drawn concerning the proposed earthworks associated with the existing embankment (to the north of the subject site) are appropriate at this point in time only and are based on the information available to E3P at the time of writing.

The assessment has been completed this the existing slope to provide an initial assessment only based on loading the existing slope. E3P understands that the client intend to stabilise the slope through construction of a retainment feature(s). If more information becomes available or the site conditions alter then the aforementioned comments and conclusions may have to be re-assessed.

If any ambiguity exists concerning any point, for the avoidance of doubt guidance should be sought from E3P, in all instances.

The slope stability modelling has considered the positioning of the existing railway and the likely induced loading of 80kN/m² for the proposed dwellings to ensure a risk adverse assessment of potential future instability. This loading is based on a typical two storey dwelling.

The E3P assessment is limited to long term **overall global slope stability** (as indicated in Figure 9.2 in EC7 Part 1) after the proposed structures have been constructed. The temporary work including any excavations during construction and the stability in both short term and long term are designed and constructed by others. They are outside the remit of the current EP3 slope stability assessment.

5.12.4. ASSESSMENT METHOD AND SOFTWARE

Appropriate soil mechanics parameters derived from site investigation & data obtained during the enabling works were analysed and interpreted in the Oasys Slope software.

For this assessment the Bishops method has been utilised.

Assessment of the slope has been undertaken at three critical sections as detailed within the Section Location Plan (Ref: 14-944-001) presented in Appendix X.

To ensure a suitably robust assessment, conservative values of the soil material property parameters were utilised in the development of the Slope Modelling as detailed below:

5.12.5. GEOTECHNICAL INPUT PARAMETERS

The input parameters for the slope stability assessment are based on the ground conditions identified during the site investigation works completed by E3P, namely in boreholes CP101, CP102 and CP103.

It should be noted that a degree of conservatism applies to the model with respect to the ground conditions within the existing slope. Prior to the site investigation works, E3P agreed with Network Rail that the deeper cable percussive boreholes would be advanced at least 10m from the top of the slope.

Therefore, the exact composition of the soils at the northern boundary and within the slope has not been confirmed. The ground conditions have been assumed based on the information recorded in boreholes CP101 to CP103.

The parameters for each material type underlying the site (and assumed to form the slope) are presented in Table 5.3 below.

TABLE 5.3 INPUT PARAMETERS

MATERIAL TYPE	C' – EFFECTIVE COHESION (KPA)	Ø' (°) ANGLE OF EFFECTIVE FRICTION	Γ (KN/M2) BULK UNIT WEIGHT
Made Ground (Sandy Gravel)	0	35	18
Made Ground (Gravelly Clay)	0	20	16
Medium Dense SAND	0	30	18
Dense SAND	0	40	18
Stiff CLAY	0	20	20

Groundwater strikes and seepages were noted within the shallow Made Ground at depths of between 1.20m and 2.50m bgl, however, these likely represent perched water within the landfilled waste. Deeper water strikes were noted within the cable percussive boreholes at 7.50 to 8.50m bgl.

For the purpose of this preliminary slope stability assessment, the model has been run with each section in an unsaturated state, with groundwater present at 8.00m bgl.

E3P understands that as and when the final proposed development design is provided, finished floor levels (FFLs) and structural loadings are confirmed a final slope stability model will be required. The final model will incorporate the FFLs and accurate groundwater levels to determine if groundwater is lower than the craticular slope curve, and therefore if the results of the FoS at the critical section will change.

5.12.6. SLOPE ANALYSIS RESULTS

For the avoidance of doubt, all the design has been undertaken based on EC7 and all results presented are based on EC7 DA1 C2. The results are presented in Table 5.4 below.

The results of the slope stability analyses have yielded a EC7 DA1 C2 ratio of stabilising to destabilising results ranging between 0.500 – 1.064 for the three modelled sections (with multiple slice calculation) in due consideration of the ground profile as and when the development levels have been constructed.

TABLE 5.4 SUMMARY OF RESULTS

SECTION	EC7 DA1 C2 RATIO OF STABILISING TO DESTABILISING
Section 1 (existing embankment) – No Groundwater	**0.690**
Section 2 (existing embankment) – No Groundwater	**0.284**
Section 3 (existing embankment) – No Groundwater	**1.064**

The calculus was also performed following the Bishop's Method utilising the calculus for Design Approach 1 according to EN 1997:2004 Eurocode 7: Geotechnical Design which requires the compliance with the following the ratio of stabilising to destabilising for a ULS analysis for DA1 to be >1.

The EC7 DA1 C2 has included partial factors of safety on the soil and loading.

In the absence of any site investigation information from within 10m of the Network Rail boundary, we do not have the exact factor of safety or over design ratio at the embankment slope. However, based on the assumed ground conditions, the results suggest that the existing slope in its current state will not meet the EC7 DA1 C2 requirements following the inducement of structural and infrastructure loads at the northern boundary of the site and therefore is liable to fail.

5.12.7. CONCLUSIONS

The assessment confirms that the existing slope is likely to fail based on the inducement of dwellings at the northern boundary of the site without suitable mitigation measures.

Any surcharge associate with the construction of residential plots within the locality of the embankment may pose a risk of slope failure and therefore E3P recommend mitigation measures are required to ensure long term stability as part of the development.

Based on the current assessment, in the absence of any retainment features, E3P recommend that piled foundations will be required for those plots adjacent to the northern boundary which are considered to be within influencing distance of the embankment,

E3P understand the client intend to construct a retaining feature to stabilise the slope, however, no designs are available at this stage. Upon receipt of the final proposed development scheme, retainment feature designs, finished floor levels (FFLs) and structural loadings are confirmed a final slope stability model will be required. If further negative impacts on the slope are recorded (such as the potential for shallow failure) based on the revised assessment, additional mitigation measures will need to be considered, such as regrading of the slope, reinforcement or greater structural retainment.

5.13. CONSTRUCTION ACTIVITY AND INSPECTION

The following activities and inspections should be incorporated into the site works:

- Due to the variability of the soils at the site, it is recommended that sufficient allowance is made for the inspection of formations and sub-formations to foundations and pavement construction.
- Excavations where access is required should be subject to a risk assessment from a competent person and, where appropriate, mitigation measures such as benching back the sides or use of support systems in accordance with CIRIA R97 should be utilised.
- It is considered that dewatering may be required, especially following periods of heavy rainfall. Removal of surface water and water within trenches should be possible with conventional sump pumping. Discharge of any water should be agreed with the relevant regulatory body and be undertaken under a trade effluent discharge, where required. Measures to remove silt and suspended solids may be required and consideration should be given to provision of space for settling tanks or an attenuation pond.
- Where access to confined spaces is required, appropriate mitigation measures should be addressed within the construction stage health and safety plan. Particular account should be taken of the gas results.
- The presence of potential contamination and mitigation measures should be addressed as part of the construction stage health and safety plan and should include measures to design out the risks, reduce their impact and, finally, to include the use of personnel protective equipment (PPE).

5.14. GEOTECHNICAL RISK REGISTER

POTENTIAL ABNORMAL CONSTRAINT	LOCATION ON SITE	ESTIMATED AREA OF SITE AT RISK (%)	ASSESSMENT AND MITIGATION
Remediation of Contaminated Soils	Site	100	Made Ground deposits are present on the subject site to depths of circa 11.00 m bgl, which are impacted by heavy metals, asbestos, non-volatile and volatile PAH and TPH compounds. Mitigation measures are required to ensure no exposure to future site users.
Obstructions	Site	10	Numerous concrete obstructions were noted within the shallow Made Ground. All below-ground obstructions will require grubbing out to facilitate the installation of piled foundations.
Artificially Levelled and Filled Platforms	Site	100	The site is understood to have been landfilled and artificially levelled.
Trench Collapse	All	100	Made Ground present beneath the site is likely to be loosely compacted and possibly prone to collapse.
Mature Trees	N/A	N/A	No mature trees present at the subject site.
Volume Change Potential Clay	Site	100	The site is underlain by reworked cohesive deposits with a low to medium volume change potential.
Peat	N/A	N/A	Peat has not been identified.
Running Sands	N/A	N/A	Data searches indicate Low Risk.
Ground Dissolution	N/A	N/A	Data searches indicate No Hazard.
Concrete Design	Site	100	Concrete design can be classed as DC-1 AC-1s
Low Permeability Ground	Site	100	Deeper low permeability clay soils have been encountered, underlying the landfilled soils.
Services / Sensitive Structures	Site	10	Gas and electricity infrastructure are recorded at the site, however, it is unknown if these services are live. A manhole and deep chamber are located in the southwest corner of the site.
Abnormal Foundation Solutions	Site	100	A driven pile solution is recommended for plots adjacent to the northern boundary due to the potential for slope failure of the embankment to the north of the site.
Slope	Northern Boundary	20	A slope is located to the north of the site falling (c. 8-10m) towards the railway.

5.15. FURTHER WORKS

Based on the findings of the intrusive site investigation, the following additional works are recommended to be completed in due course:

- Final Slope Stability Assessment (upon receipt of further information);
- Post enabling works monitoring to confirm the final gas regime;
- Arboricultural Survey (for off-site trees within the embankment);
- Geotechnical Earthworks Strategy (Infrastructure);
- Remediation and Enabling Works Strategy; and
- Construction Phase Surface Water Management Plan.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. CONTAMINATED LAND ASSESSMENT

Human Health	The preliminary Tier I human health risk assessment has identified the presence of heavy metals, non-volatile TPH and PAHs, volatile TPH compounds and asbestos within the sub-surface at a number of locations within the shallow Made Ground. Asbestos has been identified within the shallow Made Ground, and as such it will be necessary to carefully manage these impacted soils and place them in a legislatively compliant manner that will negate any possibility of future exposure. In respect to the non-volatile PAHs, TPH and heavy metals, external areas will be covered by hard-standing or a chemically suitable cover system within all private garden and soft landscaped areas thereby removing the exposure pathway to future site users. Volatile TPH C12-16 and naphthalene has been encountered at the site, which poses a potential vapour inhalation risk. Due to the nature of the fill material, the presence of such volatile compounds throughout the Made Ground cannot be discounted. Therefore, a vapour risk assessment is required and if a unacceptable level of risk is identified, local hotspot removal or installation of a suitable vapour membrane will be required for new structures to prevent vapour ingress. It is possible that as yet unidentified contaminant impact is present within localised hotspots at the site. It is considered that any such contamination could be addressed by the delineation, excavation and treatment of impacted soils.
Controlled Waters	Elevated concentrations of chromium and lead were recorded in the leachate samples from the Made Ground soils. However, the site is underlain by cohesive deposits which will serve to prevent vertical migration towards the underlying Principal Aquifer. Furthermore, there are no surface watercourses within influencing distance of the site, as such, the site is considered to pose a very low risk to controlled waters.
Ground Gas	Based on a review of historic site investigation information, the site falls into classification Characteristic Situation 3; as such protection measures are required. However, due to elevated methane concentrations recorded by Cooper Associates, E3P would also suggest that post enabling works monitoring is undertaken to confirm the final gas regime. This could be completed using continuous monitoring installations to expedite the monitoring period.
Potable Water	The site was historically landfilled and therefore will require PE Barrier Pipe Type A for potable water supply infrastructure.

6.2. GEOTECHNICAL ASSESSMENT

During a phase of enabling works to create a suitable developable platform, any below-ground obstructions will require grubbing out to facilitate the installation of piled foundations.

A preliminary slope stability assessment has been completed based on the proposed development. For the avoidance of any doubt proposed levels have not yet been provided, therefore this interim analysis is based on existing topographical information with the proposed loadings applied to assess the stability for initial design considerations only. The assessment indicates that the proposed structural (and infrastructure) loads induced by the construction of dwellings adjacent to the northern boundary have the potential to cause failure of the embankment.

However, E3P understands that the client intend to stabilise the slope through construction of a retainment feature. Upon provision of the designs a final slope stability assessment will be completed which may negate the need for driven piled foundations.

Therefore the proposed structures will need to be transferred to competent strata through the installation of piled foundations for all plots located adjacent to the northern boundary of the site. While a detailed assessment of pile depths and bearing capacity is beyond the scope of this report, piles would likely achieve a 'set' within either the dense SAND or very stiff very high strength sandy CLAY soils at a depth of >11.50 m bgl where an ABP of 100 kN/m² can be achieved. Pre-boring of piles would likely be required due to the presence of obstructions within the upfilled Made Ground.

However, for the remaining plots across the southern portion of the site, the use of ground improvement through installation of vibro stone columns (VSC) could also be utilised. Due to the depth of Made Ground, partial depth treatment (within the Made Ground) could be completed to facilitate the construction of raft foundations, however, settlement analysis would be required to confirm if a partial depth VSC treatment is possible to support a raft on the stone columns. If site levels are reduced, it may be feasible to achieve full depth VSC treatment.

Alternatively, the upper 3.00m of the site could be subject to a programme of reprocessing and re-engineering of the Made Ground at each plot to create a development platform for raft foundations. However, due to the depth of Made Ground across the site, settlement analysis will be required with respect to plots foundation and external areas to appraise the long term settlement and differential induced. Should a raft be adopted zone load assessments will be required to understand the settlement over the 60 year design life of the proposed dwellings.

A detailed Geotechnical Enabling Works Specification will be required for the site upon completion of detailed design levels. The final foundation solution will be dependent on the structural loadings, elevation and should be designed by a suitably qualified structural engineer with detailed designs from a specialist piling contractor.

The presence of deep Made Ground would preclude the use of soakaway drainage systems in this instance.

The site is not located in an area of historic mine workings or ground instability and the risk of future subsidence is considered to be very low; and

It is considered the Made Ground will be suitable to re-engineer and may provide a sub-grade formation to support proposed roads and infrastructure with a likely CBR of >5%.

END OF REPORT

APPENDIX I
LIMITATIONS

1. This report and its findings should be considered in relation to the terms of reference and objectives agreed between E3P and the client as indicated in Section 1.3.

2. For the work, reliance has been placed on publicly available data obtained from the sources identified. The information is not necessarily exhaustive and further information relevant to the site may be available from other sources. When using the information it has been assumed it is correct. No attempt has been made to verify the information.

3. This report has been produced in accordance with current UK policy and legislative requirements for land and groundwater contamination which are enforced by the local authority and the Environment Agency. Liabilities associated with land contamination are complex and requires advice from legal professionals.

4. During the site walkover, reasonable effort has been made to obtain an overview of the site conditions. However, during the site walkover, no attempt has been made to enter areas of the site that are unsafe or present a risk to health and safety, are locked, barricaded, overgrown, or the location of the area has not been made known or accessible.

5. Access considerations, the presence of services and the activities being carried out on the site limited the locations where sampling locations could be installed and the techniques that could be used.

6. Site sensitivity assessments have been made based on available information at the time of writing and are ultimately for the decision of the regulatory authorities.

7. Where mention has been made to the identification of Japanese Knotweed and other invasive plant species and asbestos or asbestos-containing materials, this is for indicative purposes only and do not constitute or replace full and proper surveys.

8. The executive summary, conclusions and recommendations sections of the report provide an overview and guidance only and should not be specifically relied upon without considering the context of the report in full.

9. E3P cannot be held responsible for any use of the report or its contents for any purpose other than that for which it was prepared. The copyright in this report and other plans and documents prepared by E3P is owned by them and no such plans or documents may be reproduced, published or adapted without written consent. Complete copies of this may, however, be made and distributed by the client as is expected in dealing with matters related to its commission. Should the client pass copies of the report to other parties for information, the whole report should be copied, but no professional liability or warranties shall be extended to other parties by E3P in this connection without their explicit written agreement there to by E3P.

10. New information, revised practices or changes in legislation may necessitate the re-interpretation of the report, in whole or in part.

APPENDIX II
GLOSSARY

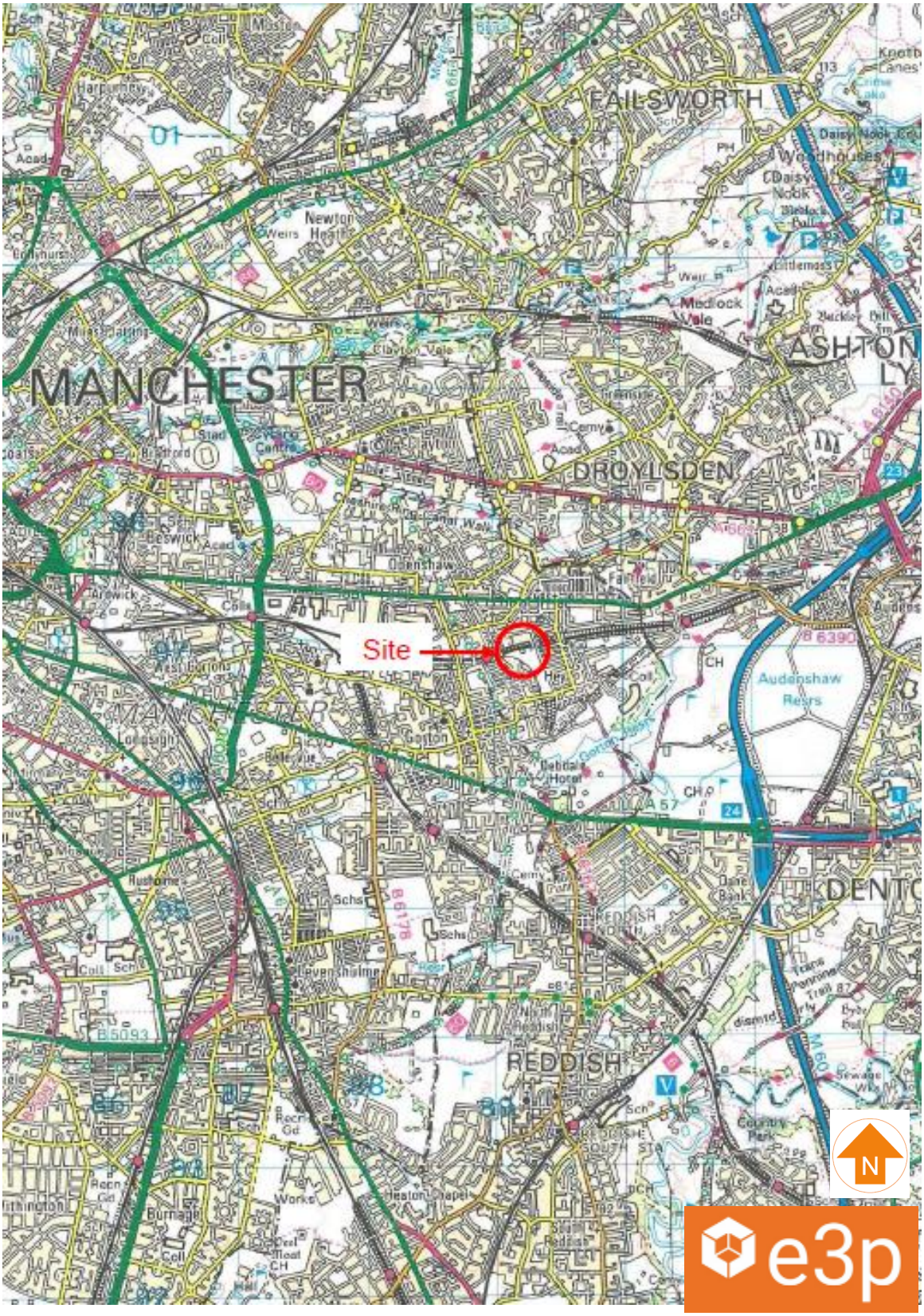
TERMS

ACM	Asbestos-containing material	**MMP**	Materials management plan
ADS	Acoustic design statement	**ND**	Not detected
AST	Above-ground storage tank	**NDP**	Nuclear density probe
BGS	British Geological Survey	**NMP**	Noise management plan
BSI	British Standards Institute	**NPSE**	Noise policy statement for England
BTEX	Benzene, toluene, ethylbenzene, xylenes	**NR**	Not recorded
CA	Coal Authority	**PAH**	Polycyclic aromatic hydrocarbon
CBR	California bearing ratio	**PCB**	Polychlorinated biphenyl
CIEH	Chartered Institute of Environmental Health	**PI**	Plasticity index
CIRIA	Construction Industry Research Association	**PID**	Photo ionisation detector
CLEA	Contaminated land exposure assessment	**POS**	Public open space
CML	Council of Mortgage Lenders	**PPE**	Personnel protective equipment
CoC	Contaminants of concern	**ProPG**	Professional practice guidance
CSM	Conceptual site model	**QA**	Quality assurance
DNAPL	Dense non-aqueous phase liquid (chlorinated solvents, PCB)	**SGV**	Soil guideline value
DWS	Drinking water standard	**SPH**	Separate-phase hydrocarbon
EA	Environment Agency	**SPT**	Standard penetration test
EQS	Environmental quality standard	**SVOC**	Semi-volatile organic compound
FFL	Finished floor level	**TPH**	Total and speciated petroleum hydrocarbon
GAC	General assessment criteria	**TPH CWG**	Total Petroleum Hydrocarbon (Criteria Working Group)
GL	Ground level	**UKWIR**	United Kingdom Water Infrastructure Risk
GSV	Gas screening value	**UST**	Underground storage tank
HCV	Health criteria value	**VCC**	Vibro-concrete column
ICSM	Initial conceptual site model	**VOC**	Volatile organic compound
LEL	Lower explosive limit	**VRSC**	Vibro-replacement stone columns
LMRL	Lower method reporting limit	**VSC**	Vibro-stone columns
LNAPL	Light non-aqueous phase liquid (petrol, diesel, kerosene)	**WHO**	World Health Organisation
MCV	Moisture condition value	**WRAP**	Waste and Resources Action Programme

MIBK	Methyl isobutyl ketone	**WTE**	Water table elevation
m	Metres	**ppm**	Parts per million
km	Kilometres	**mg/m^3**	Milligram per metre cubed
% v/v	Percent volume in air	**m bgl bgl**	Metres below ground level
mb	Millibars (atmospheric pressure)	**m bcl**	Metre below cover level
l/hr	Litres per hour	**mAOD**	Metres above ordnance datum (sea level)
µg/l	Micrograms per litre (parts per billion)	**kN/m^2**	Kilonewtons per metre squared
ppb	Parts per billion	**µm**	Micrometre
mg/kg	Milligrams per kilogram (parts per million)	**SSRT**	Site Specific Remediation Target
PSD	Particle Size Distribution	**DD**	Dry Density
CL:AIRE	Contaminated Land: Applications in Real Environments	**Mc**	Moisture Content
ρ	Bulk Density	**GPR**	Ground Penetrating Radar
NDP	Nuclear Density Probe	**FFL**	Finished Floor Level
LEL	Lower Explosive Limit	**UKWIR**	UK Water Industry Research
CIRIA	Construction Industry Research and Information Association	**LOD**	Limit of Detection

APPENDIX III
DRAWINGS

DRAWING 19-944-001 – SITE LOCATION PLAN



APPENDIX IV
PHOTOGRAPHS

PLATE 1 SITE VIEWED LOOKING WEST

PLATE 2 VIEW OF EXCAVATION WITHIN THE WESTERN SECTOR

PLATE 3 VIEW OF WASTE STOCKPILES IN THE WESTERN SECTOR

PLATE 4 EXCAVATION FOR CULVERT TRENCH (EASTERN SECTOR)

PLATE 5 EXCAVATION FOR CULVERT TRENCH (EASTERN SECTOR)

PLATE 6 EXAMPLE OF SHALLOW GRANULAR MADE GROUND (TP106)

APPENDIX V
E3P EXPLORATORY HOLE LOGS

APPENDIX VI
CHEMICAL TESTING RESULTS

APPENDIX VII
ORIGIN OF TIER I GENERIC ASSESSMENT CRITERIA

CONSTITUENT	ORIGIN OF RISK ASSESSMENT VALUE
Arsenic	2014 LQM/CIEH S4ULs
Cadmium	2014 LQM/CIEH S4ULs
Chromium	2014 LQM/CIEH S4ULs
Lead	2014 LQM/CIEH S4ULs
Mercury	2014 LQM/CIEH S4ULs – methylmercury
Nickel	2014 LQM/CIEH S4ULs
Selenium	2014 LQM/CIEH S4ULs
Copper	2014 LQM/CIEH S4ULs
Zinc	2014 LQM/CIEH S4ULs
Cyanide – Total	2014 LQM/CIEH S4ULs
Phenols – Total	2014 LQM/CIEH S4ULs
Naphthalene	General assessment criteria (GAC) developed by CIEH/LQM Suitable 4 Use Levels with supporting data from SR3, SR7 and existing Tox report where applicable. 1% SOM.
Acenaphthylene	
Acenaphthene	
Fluorene	
Phenanthrene	
Anthracene	
Fluoranthene	
Pyrene	
Benzo(a)Anthracene	
Chrysene	
Benzo(b/k)Fluoranthene [iii]	
Benzo(a)Pyrene	
Indeno(123-cd)Pyrene	
Dibenzo(a,h)Anthracene	
Benzo(ghi)Perylene	
TPH C_5-C_6 (aliphatic)	
TPH C_6-C_8 (aliphatic)	
TPH C_8-C_{10} (aliphatic)	
TPH C_{10}-C_{12} (aliphatic)	
TPH C_{12}-C_{16} (aromatic)	
TPH C_{16}-C_{21} (aromatic)	
TPH C_{21}-C_{35} (aromatic)	

APPENDIX VIII
GEOTECHNICAL TESTING RESULTS

APPENDIX IX
WM3 WASTE CLASSIFICATION RESULTS

APPENDIX X
SLOPE STABILITY ASSESSMENT