Pell Frischmann

Finchley Road

Land Contamination Risk Assessment (Part 1)

2021 Site investigation and generic quantitative risk assessment

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Executive Summary	
Site name	The O2 Masterplan Site
Location	Finchley road, London, NW3 6LU (National Grid Reference: 525650, 184730)
Development proposals	Mixed use residential and commercial development set within landscaped areas of public open space.
Preliminary Risk Assessment (PRA)	The 2021 preliminary risk assessment (PRA) identified a series of *potential* Contaminant Linkages (CLs) and recommended further investigation and assessment to evaluate the potential risks, to enable the conceptual site model to be updated and to identify if any of the CLs could present unacceptable land contamination risks to proposed development. The conceptual site model from the PRA has been used as the basis upon which intrusive site investigation activities were designed and land contamination risk assessment have been undertaken.
Site investigation scheme	The design of the site investigation was constrained by the active commercial and industrial occupation and use of many areas of the site. An intrusive site investigation was carried out in September 2021. The investigation comprised a combination of cable percussive boreholes, windowless sample boreholes and machine excavated trial pits. 12 locations were advanced.
Monitoring	Five ground gas monitoring wells were installed as part of the site investigation. Groundwater and ground gas monitoring was undertaken on four between 13th October and 29th November 2021.
Ground conditions	Made Ground was encountered to depths of between 0.45 and 2.94 mbgl across the site in all locations. The Made Ground was underlain by a 0.45 to 1.10m thickness of reworked London Clay in seven locations. Bedrock of the London Clay formation was encountered below the Made Ground in all locations and proven to a depth of >60m bgl. Groundwater seepages were observed in two locations within the London Clay at depths between 2.4m to 3.9mbgl, Perched groundwater within the Made Ground was identified in 3 of 5 installed wells, however, the perched groundwater was considered to be isolated, laterally discontinuous and vertically confined by the London Clay. Wider groundwater flow in these deposits is not anticipated.
Generic quantitative risk assessment (GQRA Part 1)	**Human Health:** The GQRA-Part 1 identified elevated concentrations of lead and polycyclic aromatic hydrocarbon (PAH) within the near surface soils (Made Ground) onsite with respect to human health of end-users. Asbestos in soils screening identified asbestos in 7 out of 29 samples. Brown asbestos was identified in five samples and white asbestos was identified in two samples; quantification recorded concentrations ranging between <0.001% to 0.0072%. While visible Asbestos Containing Materials (ACMs) were not identified, laboratory testing identified asbestos within 30% of the Made Ground samples. With respect to the proposed development: ➢ viable exposure pathways have not been identified in areas of proposed hardstanding (including the main buildings and roads); however, ➢ viable exposure pathways and therefore potentially unacceptable risks have been identified in areas of proposed ground level landscaping. Consequently, these CoC and associated risks will require further consideration. **Controlled Waters**: No viable controlled waters receptors have been identified; the site is underlain by London Clay which is classified as unproductive strata in regard to aquifer potential. No further action in respect to risks to controlled waters is considered necessary or proposed. **Ground Gas:** The GQRA Part 1 indicated that the ground gas risks would fall within 'Characteristic Situation 1' risk categories with a very low hazard potential therefore ground gas protection measures are not considered necessary.
Recommendations for further work	It is recommended that a second phase of site investigation be undertaken as additional parts of the site become accessible and/ or post demolition when site wide access will be available to produce a site wide GQRA. Based on the results of the GQRA-Part 1, no further works are required regarding Controlled Waters or Ground Gas.

1 Introduction

1.1 Commission

This Land Contamination Risk Assessment (LCRA) has been prepared by Pell Frischmann on behalf of LS (Finchley Road) Limited (the "Applicant"), to support an application made in part in detail and part in outline (the "Application") for the demolition and redevelopment of land encompassing the O2 Centre and associated car park, Homebase store, car showrooms and a Builder's Merchant (the "Site") within the London Borough of Camden ("LBC").

Development Plots N3-E, N4 and N5 and the associated landscaping, access roads and infrastructure form the detailed element of the Application which extends to 1.79ha and these proposals are referred to as the "Detailed Proposals". The remainder of the Application (comprising Development Plots N1, N2, N3, N6, N7, S1 and S8) is submitted in outline and these proposals are referred to as the "Outline Proposals". The Detailed Proposals and Outline Proposals together are referred to as the "Proposed Development". Full details and scope of the Applications is described in the submitted Planning Statement, prepared by Gerald Eve LLP.

The Site will be known as "the O2 Masterplan Site" and lies between Finchley Road (east) and West End Lane (west), in the London Borough of Camden, and includes the O2 Centre at 255 Finchley road, NW3 6LU, as shown in Figure 1-1 and for the proposed redevelopment detailed within section 1.5.

This LCRA provides continuation of Land Contamination Risk Management (LCRM) services and includes a Generic Quantitative Risk Assessment (GQRA) for the site.

The Pell Frischmann Land Contamination Desk Study (March 2021) included a Preliminary Risk Assessment (PRA) for the proposed development. Based on the findings of the PRA, intrusive site investigation was recommended to enable the LCRM process to progress to GQRA (see section 1.3).

Figure 1-1 Site location

Site location	
	
Ordnance Survey (OS) Open Mapping	Google Satellite Image
Site information	Details
Site area	5.75 hectares (Ha)
National Grid Reference (centre of the site) (NGR)	525650, 184730
Nearest postcode	NW3 6LU

1.2 GQRA phases (due to access restrictions)

Based on the findings of the PRA, a site wide site investigation scheme (SIS) was initially designed in early 2021. However, due to active commercial and industrial occupation and use of many areas of the site, including, from east to west: the O2 Centre, a car park, a Homebase store, car dealerships and a builder's yard; access to most of the proposed exploratory hole locations could not be arranged.

Consequently, the GQRA process for the proposed development will need to be undertaken in multiple phases as these access restrictions are resolved. It is currently anticipated that the GQRA process (and preceding SISs) will be undertaken in two or three phases.

- **GQRA (part 1)** *(this report)***:** an initial phase of site investigation (Autumn 2021), followed by GQRA has been undertaken.
- **GQRA (part 2):** a second phase of site investigation may be undertaken as additional parts of the site become accessible.
- **GQRA (part 3):** the remainder of the site investigation will be implemented post demolition when site wide access will be available.

Depending on the overall development programme GQRA (part 2) and (part 3) may be combined and undertaken post demolition.

1.3 Land Contamination Risk Management

The Environment Agency 'Land Contamination Risk Management' guidance (LCRM, 2020) sets out the process that should be followed for managing the risk from land contamination; including within the planning regime. The process of LCRM should be used to:

- *Identify and assess if there is an unacceptable risk*
- *Assess what remediation options are suitable to manage the risk*
- *Plan and carry out remediation*
- *Verify that remediation has worked*

LCRM includes three risk-based stages 'risk assessment', 'remediation options appraisal' and 'remediation and verification'. Each LCRM stage is broken down several steps (or tiers), as outlined in Appendix A. A simplified summary of the LCRM process, is also presented in Figure 1-2.

Figure 1-2 LCRM simplified summary

LCRM simplified summary

LCDS & PRA	SIS	LCRA	LCROA	LCRS	LCRV
Desk study to identify sources of contamination and sensitive receptors. PRA to identify potential So**urce**-Pathway-Receptor (S-P-R) contamination linkages (CLs)	Investigate potential sources and receptors	Quantitative and qualitative risk assessment to assess risks for each CL to identify and assess unacceptable risks **GQRA (1) [this report]**	Identify remediation option to address unacceptable risks	Strategy: steps and measures required to implement remediation onsite. Verification plan: activities and records that must be kept during remediation	Record of all remediation activities as evidence that remediation has been successful

1.4 Scope of Work

This report includes a summary of the ground and geoenvironmental conditions and an assessment of the land contamination risks associated with the proposed development based on the findings of an initial phase of intrusive site investigation undertaken in 2021 (GQRA part 1).

The main aims of this report are:

- To provide a summary of the ground conditions and geoenvironmental conditions;
- To assess potential land contamination risks initially identified by the preliminary risk assessment;
- To consider potential geoenvironmental constraints which could impact upon or restrict the proposed redevelopment of the site.

1.5 Proposed development

The Application is for the following Proposed Development: "Part full and part outline planning permission comprising the following:

Detailed planning permission for Development Plots N3-E, N4, and N5 including demolition of existing above ground structures and associated works, and for residential development (Class C3) and commercial, business and service (Class E) uses in Development Plot N3-E, residential development (Class C3) and local community (Class F2) and commercial, business and service (Class E) uses in Development Plot N4, and residential development (Use Class C3) and commercial, business and service uses (Class E) uses in Development Plot N5 together with all landscaping, public realm, cycle parking and disabled car parking, highway works and infrastructure within and associated with those Development Plots.

Outline planning permission for Development Plots N1, N2, N3, N6, N7 ,S1 and S8 including the demolition of all existing structures and redevelopment to include residential development (Class C3) commercial, business and service uses (Class E), sui generis leisure uses (including cinema and drinking establishments) together with all landscaping, public realm, cycle parking and disabled car parking, highway works and infrastructure within and associated with those Development Plots."

The Application is submitted in hybrid form – this means that (part of the application is made in detail and part is made in outline). The Application site has been subdivided into 10 Development Plots (N3-E, N4 and N5 N1, N2, N3, N6, N7, S1 and S8). The first three Development Plots (N3-E, N4 and N5), located in the centre of the Site, are submitted in detail, and form the first phase – "Detailed Phases". Development Plots S8, N7 and N6 located in the west of the Site are submitted in Outline and form the Second Phase - "Outline Phases West". Development Plots N3, N2, N1 and S1 located in the east of the Site are submitted in Outline and form the third Phase – "Outline Phases East".

The Application site has been subdivided into 10 Plots (N1, N2, N3, N3-E, N4, N5, N6, N7, S1 and S8). These are identified on Parameter Plan 19066_X_(02)_102. The 10 plots sit within three indicative phases. Phase 1 covers the Detailed Proposals and is located at the centre of the Site. Phase 2 (also referred to as Outline Phases West) and Phase 3 (also referred to as Outline Phases East) form the Outline Proposals.

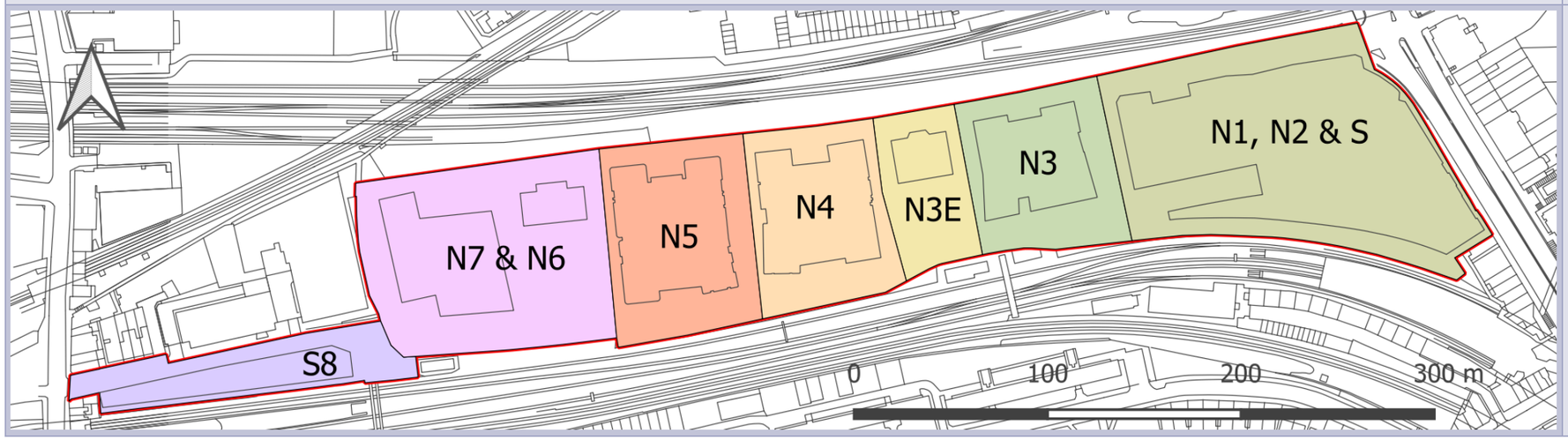
The Outline Proposals will include up to 115,000sq. m GIA of residential floorspace including an allowance for car parking and basements.

Therefore, the total residential use across the Site, including residential parking in podiums could be up to 170,180sq. m GIA which for the sake of the Environmental Impact Assessment has assumed that this equates to around 1,800 residential units.

For the purposes of land contamination risk assessment, the proposed development can be summarised as comprising: a mixed use residential and commercial development set within areas of landscaped public open space (including ground level soft landscaping and play areas). Illustrative masterplans, site areas and cross sections for the proposed development are summarised within Figure 1-3. Larger scale, more detailed extracts of the development proposals are provided within Appendix C.

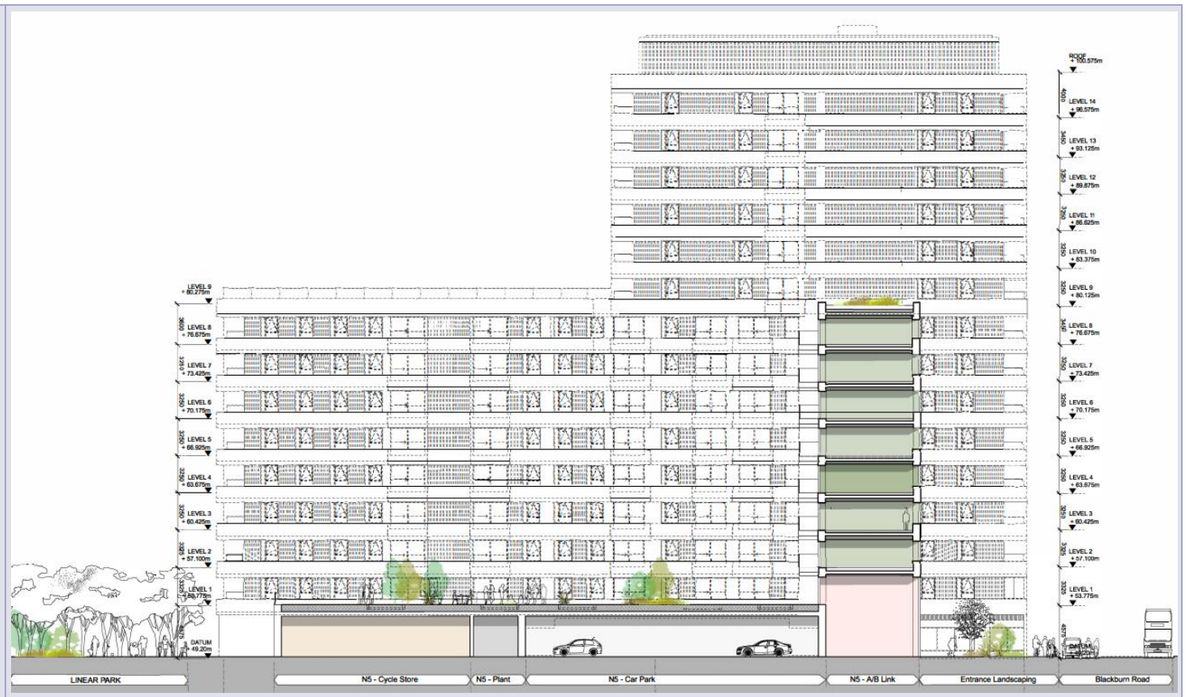
Figure 1-3 Proposed development

Lower ground floor



Illustrative development areas

Cross section from east to west across N3, showing groundfloor commercial / community space and bike & refuse stores, with residential units on floors 1-9.



Cross section from north to south across N5, showing groundfloor parking / bike storage, comercial / community space and refuse stores, with residentual units on floors 0-14 and a raised podoum garden on floor 1.

View of southern face of N4 development showing central raised podium gardens, with 8 & 9 story blocks in front and the outline of the 13&14 story blocks in the back.

Cross section from east to north to south across N5, showing groundfloor parking / bike storage, comercial / community space and refuse stores, with residentual units on floors 0-14 and a raised podoum garden on floor 1.

2 LCRM Background

2.1 Preceding information and reports

Preliminary risk assessment (March 2021)

The LCRM process starts with a preliminary risk assessment (PRA). The PRA process includes developing a *preliminary* Conceptual Site Model (CSM) summarising potential 'source-pathway-receptor' Contaminant Linkages (CLs) that may be relevant to the proposed development. Each *potential* Contaminant Linkage is assigned a qualitative level of risk, before updating the CSM and considering what further action is needed. A site wide preliminary risk assessment for the proposed development was presented in the Pell Frischmann *Land Contamination Desk Study (report ref.*1*04878-PEF-ZZ-XX-RP-GG-600002, March 2021)*.

The development of a conceptual site model (CSM) is an iterative process that requires the model to be updated throughout the land contamination risk management process. The *preliminary* CSM should be used as the basis upon which intrusive site investigation activities are designed and land contamination risk assessment is undertaken.

Initial phase of site investigation scheme (Autumn 2021)

An initial phase of site investigation, designed by Pell Frischmann, was undertaken by RSK in September 2021 to provide data and information to enable an initial phase of generic quantitative risk assessment (GQRA Part 1) to be undertaken. The RSK and previous Pell Frischmann reporting is detailed within Table 2-1.

Table 2-1 Previous Reports

Report title and reference	Source	Date
Land Contamination Desk Study, Finchley Road. 104878-PEF-ZZ-XX-RP-GG-600002	Pell Frischmann	March 2021
Factual Ground Investigation Report, O2 Centre Finchley Road 1921993 R01(00)	RSK Geosciences (RSK)	November 2021

2.2 Generic quantitative risk assessment (part 1) '*this report*'

Quantitative land contamination risk assessment (LCRA) typically starts with 'generic quantitative risk assessment' (GQRA) which uses site investigation findings/data, generic assessment criteria and assumptions to estimate risk before evaluating the risks qualitatively and deciding whether a risk is 'unacceptable'. An initial phase of GQRA has been undertaken for the proposed development based on the 2021 site investigation findings [this report], in order to:

- Identify potential contaminants of concern
- Indicate where further information or detailed quantitative risk assessment may be required
- Update the conceptual site model
- Update the qualitative risk ratings for each contaminant linkage
- Identify unacceptable risks and residual 'contaminants of concern' (that may require remediation)
- Where appropriate assess if the status of a contaminant linkage/s should be updated from '*potential'* to '*relevant* contaminant linkages'.

Relevant contaminant linkages represent Source-Pathway-Receptor relationships where potentially unacceptable risks are identified. Relevant linkages could be considered for detailed quantitative risk assessment (DQRA) or may progress directly into 'remediation options appraisal'. DQRA uses site investigation data and detailed site-specific information to estimate risk.

As described earlier in this report additional phases of site investigation and GQRA will be required to provide a site wide GQRA for the proposed development.

2.3 Preliminary conceptual site model

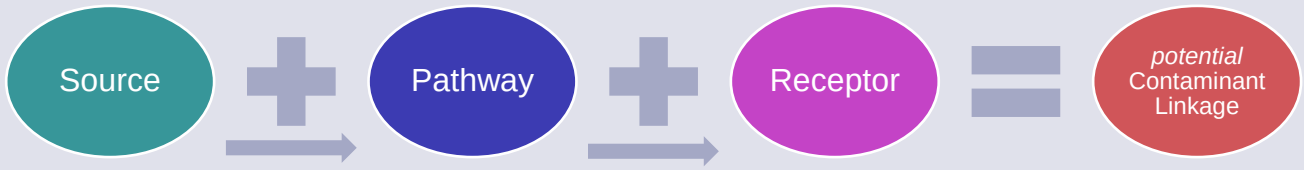
As introduced above, the LCRM process started with a preliminary risk assessment (PRA). The PRA included developing a *preliminary* conceptual site model (CSM) summarising the possible 'source-pathway-receptor' Contaminant Linkages (CLs) that may be relevant to the proposed development. Each *potential* Contaminant Linkage was assigned a qualitative level of risk as part of the PRA.

A copy of the *preliminary* conceptual site model (CSM) is included in Appendix B. The preliminary CSM was also used to summarise uncertainties and gaps in information and provided recommendations for further investigation and assessment to address them, including intrusive site investigation and monitoring followed by quantitative risk assessment.

The S-P-R approach is summarised in Figure 2-1. All three elements (S-P-R) of a contaminant linkage must be present for a land contamination risk to exist, as detailed within the land contamination risk management guidance: "*A contaminant linkage must be present for there to be a S-P-R relationship. Without a linkage, there is not a risk – even if a contaminant is present*". During the risk assessment stage, the term '*potential* contaminant linkage' is used until the CLs have been confirmed.

Figure 2-1 Contaminant linkages (S-P-R)

Contaminant Linkage (CL) - Source-Pathway-Receptor relationships



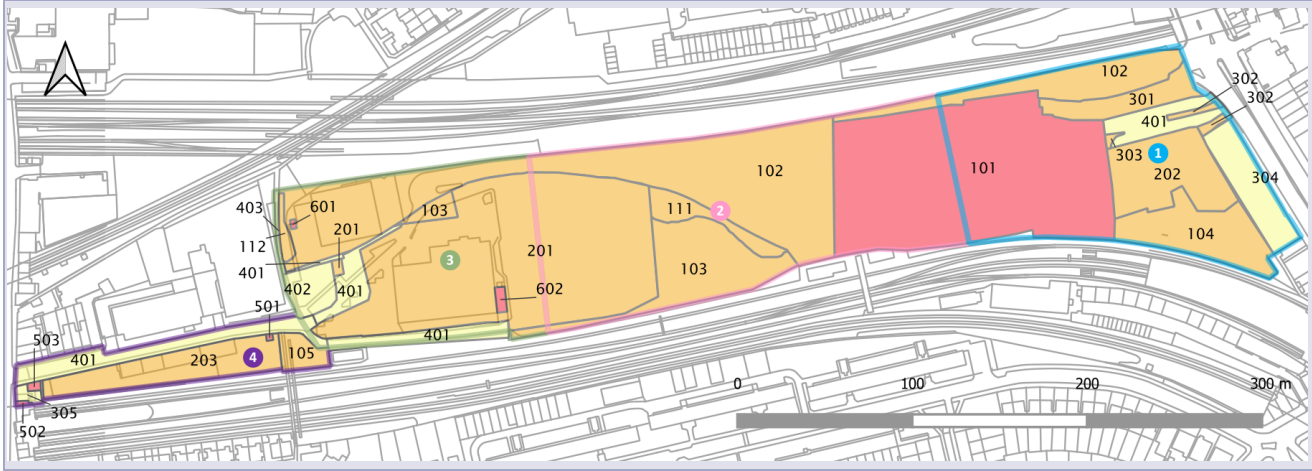
Term	Definition
Source	A contaminant that is in, on or under the land and has the potential to cause harm or pollution.
Pathway	A route by which a receptor is or could be affected by a contaminant.
Receptor	Something that could be adversely affected by a contaminant for example a person, controlled waters, an organism, an ecosystem or Part 2A receptors such as buildings, crops or animals.
Contaminant linkages	The presence an S-P-R relationship between contaminants, pathways and receptors.

2.4 Preliminary constraints plan

Potentially significant contamination sources or constraints identified as part of the desk study were also collated into a 'preliminary constraints plan', with key areas shown with a traffic light red-amber-yellow-green classification to indicate where contamination is most likely to require further consideration and where design could play an important role in working with or resolving these constraints. A copy of the preliminary constraints plan from the desk study is presented in Figure 2-2 overleaf. The constraints plan is provided to be referenced and used alongside the CSM.

Figure 2-2 Land contamination constraints plan

Preliminary constraints plan and summary



Series Ref.	Details	Area	Constraint Classification
100 Series	Waste and rail activities		
101	Waste Transfer Station	Area 1, 2	Red
102	Railway sidings	Area 1, 2, 3	Amber
103	Rail land	Area 2, 3	Amber
104	Rail land, car park	Area 1	Amber
105	Rail sidings, compound	Area 4	Amber
111-112	Made Ground (potential fill)	Area 2, 3	Amber
200 Series	Larger works and depots		
201-203	Depot/ works/ warehouse	Area 1, 2, 3, 4	Amber
300 Series	Small industrial areas and commercial/residential properties		
301-303	Industrial	Area 1	Amber
304-305	Commercial & residential	Area 1, 4	Yellow
400 Series	Road, footpaths, parking only		
401	Roads	Area 1, 3, 4	Yellow
402	Parking/ forecourt	Area 3	Yellow
403	Footpath	Area 3	Yellow
500 Series	Localised 'Red' zone, including historic land uses		
501	Substation	Area 4	Red
502	Dry cleaners (historic)	Area 4	Red
503	Printers (historic)	Area 4	Red
600 Series	Localised 'Red' zones, current fuel storage		
601	Above ground storage tanks	Area 3	Red
602	Drum storage area	Area 3	Red

3 Site investigation

3.1 Introduction

An initial phase of intrusive site investigation designed by Pell Frischmann was tendered and subsequently awarded to RSK Geosciences (RSK) in line with the Pell Frischmann *Site Investigation Specification (ref.104878-PEF-XX-XX-SP-C-200004 P02 v4, September 2021).*

3.2 Fieldwork

The intrusive site investigation (SI) works for the GQRA (part 1) were undertaken by RSK in September 2021; followed by groundwater and ground gas monitoring by RSK. The main site investigation activities are summarised in Table 3-1 and a copy of the Contractor's factual report is included in Appendix G.

Due to the access restrictions described in Section 1.2, exploratory locations were advanced within the large external carpark located between the Homebase store (west) and the O2 Centre (east) and two locations adjacent to roadways to the west of Homebase.

The land contamination site investigation elements discussed in this report formed part of a combined geotechnical and land contamination investigation. The geotechnical elements including geotechnical testing are not presented in this report.

Table 3-1 Site investigation activities

Site investigation item	Details		
Exploratory Holes (fieldwork)	Purpose	Number	Max depth
Boreholes (BH)	Investigate deeper ground conditions for foundation design, soil sampling and monitoring well installation	4	60.00mbgl
Window or windowless sampling	Investigate shallow ground conditions, soil sampling and monitoring well installation	6	6.45 mbgl
Trial Pits	Investigate ground conditions and soil sampling	2	3.90 mbgl
Monitoring installations (fieldwork)	Purpose	Number	Max depth
Ground gas monitoring wells	Targeted monitoring - constraint ref. 101	5	1.90 mbgl
Monitoring (post main work)	Purpose	Rounds	
Groundwater level monitoring	To investigate the presence or absence of perched groundwater above the London Clay	4	
Ground gas monitoring	Investigate ground gas sources provisionally identified by the PRA (constraint ref. 101)	4	
Sampling (fieldwork)	Undertaken by		
Geochemical soil sampling	RSK as part of the fieldwork		
Geochemical laboratory analysis	Undertaken by		
Soil sample analysis	Arranged separately by Pell Frischmann, therefore not included in SI Factual Report		
Contractor's reporting			
Factual Report	Appendix G		

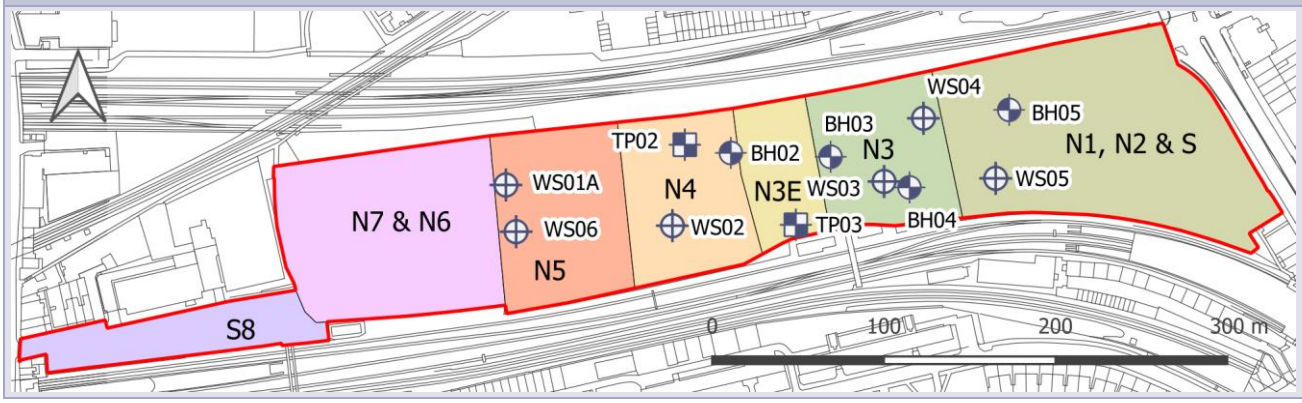
A series of exploratory hole location plans are presented in Figure 3-1 (overleaf) that include cross referencing to the existing site, the original constraints plan and the proposed development areas.

Figure 3-1 Exploratory hole location plan

Exploratory hole location plan

Constraints plan and exploratory hole location plan combined

Development areas and exploratory hole location plan combined



3.3 Monitoring, testing and analysis

Monitoring: As introduced in Table 3-1, the main site investigation fieldwork was followed by a period of groundwater and ground gas monitoring undertaken every fortnight by the Contractor between 13 October and 29 November 2021.

Testing: On site soil samples were tested using a photo ionisation detector (PID), this data is summarised and discussed within Section **3.6**

Analysis: Soil samples collected by the Contractor during the site investigation were sent to ALS Life Sciences Limited (ALS), a UKAS accredited geochemical analysis laboratory. Pell Frischmann subsequently arranged and scheduled geochemical analysis directly with ALS. The geochemical analysis and data are summarised and discussed within the GQRA Chapter of this report (Section 4).

Monitoring installation details, monitoring results and laboratory analysis data were undertaken to inform the land contamination risk assessment process and therefore the associated information and results are presented within the respective GQRA sub-sections of this report as detailed within Table 3-2.

Table 3-2 Monitoring and analysis future information

Item	Details	See Report chapter or section
Groundwater wells	Monitoring wells details	See Section 4.6
	Level monitoring results	
Ground gas	Monitoring well details	See Section 4.7
	Monitoring type	
	Ground gas results	

3.4 Ground conditions

3.4.1 Summary

Table 3-3 summarises the overall vertical distribution of the strata encountered by the exploratory holes, in all locations, a thickness of Made Ground was underlain by London Clay. Further details of the encountered materials are provided in the report sections below.

Table 3-3 Ground conditions summary

Location	Made Ground	Reworked London Clay		London Clay Formation	
	Base and thickness (m bgl)	Base (m bgl)	*Thickness (m)*	Base (m bgl)	*Thickness (m)*
BH02	1.90	2.90	*1.00*	>60.00	*>57.10 Unproven*
BH03	1.50	2.60	*1.10*	>35.00	*>32.40 Unproven*
BH04	0.50	1.60	*1.10*	>35.00	*>33.40 Unproven*
BH05	1.00	-	-	>35.00	*>34.00 Unproven*
WS01A	1.15	2.10	*0.95*	>4.45	*>2.35 Unproven*
WS02	1.90	2.40	*0.50*	>6.45	*>4.05 Unproven*
WS03	1.70	-	-	>4.45	*>2.75 Unproven*
WS04	0.70	-	-	>3.45	*>2.75 Unproven*
WS05	0.45	0.90	*0.45*	>3.45	*>2.55 Unproven*
WS06	1.60	2.00	*0.40*	>3.50	*>1.50 Unproven*
TP02	1.60	-	-	>3.75	*>2.15 Unproven*
TP03	2.95	-	-	>3.90	*>0.95 Unproven*

3.4.2 Made Ground

The site investigation locations comprised a surface layer of hardstanding (asphalt or concrete slab) underlain by Made Ground. Made Ground (of varying thickness and type) was encountered in all exploratory locations including layers of sub-base/likely sub-base under the hardstanding over silty sandy GRAVEL or gravelly SAND. Made Ground was encountered to greater thicknesses within the central portion of the carpark, becoming clayey from a depth of approximately 1.0m bgl. The gravel component included fragments of brick and concrete, occasional ceramics, rare metal, plastic, clinker and coal fragments.

3.4.3 Reworked London Clay

Reworked London Clay was noted within seven locations, typically comprising silty gravely CLAY with frequent black relic rootlets. Gravel typically consisted of rounded flints, but occasionally included brick and concrete fragments.

3.4.4 London Clay Formation

London Clay Formation was encountered within all exploratory locations underlying the Made Ground, and typically comprised firm to stiff brown clay becoming blue grey silty clay at depth with numerus selenite crystals or thin weak layers of Claystone noted at shallower depths. From a depth of 10m, the London Clay becomes stiff to very stiff fissured dark grey CLAY with localised shell fragments.

3.5 Groundwater strikes and seepages

During the site investigation the following groundwater strikes and seepages were recorded:

- WS03: Groundwater seepage at 2.40m bgl within the London Clay Formation.
- TP03: Slight groundwater seepage observed at 3.90m bgl within the London Clay Formation.

3.6 Visual and olfactory evidence of contamination

In addition to the general presence of anthropogenic materials within the Made Ground, the exploratory hole records only recorded as a faint hydrocarbon odour in WS03 (between 0.9 and 1.3mbgl).

Notably, visually identifiable fragments of potential asbestos containing materials (ACM) were not recorded.

Field PID measurements: a photo ionisation detector (PID) was used to screen for the presence of volatile organic compounds during the formation of the exploratory holes. PID results above the instrument detection limit, are summarised in Table 3-4. The recorded values are relatively low and only the response from WS03 is considered noteworthy and may be indicative of low to moderate hydrocarbon contamination.

Table 3-4 PID Readings during fieldwork

Location	Strata	Depth (m bgl)	PID (ppm)
BH02	Made Ground	0.30	0.2
		0.80	0.4
BH03	Made Ground	0.25	0.3
		0.75	0.1
	Made Ground – Reworked LC	1.25	0.1
BH05	Made Ground	0.25	0.2
WS01A	Made Ground	0.90	0.1
WS02	Made Ground	0.20	0.1
		0.35	0.1
		0.80	0.2
	Made Ground – Reworked LC	2.00	0.2
WS03	Made Ground	0.40	0.2
		0.60	0.5
		1.70	16.8
WS04	Made Ground	0.20	0.3
	London Clay	1.00	0.1
WS05	Made Ground	0.20	0.2
WS06	Made Ground	1.00	0.3
TP03	Made Ground	2.50	0.3

4 Generic quantitative risk assessment (GQRA part 1)

4.1 Introduction

Quantitative land contamination risk assessment typically starts with 'generic quantitative risk assessment' (GQRA); which uses site investigation data, generic assessment criteria and assumptions to estimate risk before evaluating the risks qualitatively and deciding whether 'unacceptable' risks are likely to exist. Table 4-1 details the GQRA (part 1) that has been undertaken for the proposed development based on the preliminary conceptual site model and the findings of the 2021 initial site investigation.

Table 4-1 Land contamination risk assessment next steps

Land Contamination Risk Assessment	Recommended
Human health GQRA	Yes
Controlled water GQRA	Not applicable – no linkage (receptor not present)
Ground gas GQRA	Yes
Ecological receptors GQRA	Not applicable – no linkage (receptor not present)
Geologically sensitive sites (SSSI)	Not applicable – no linkage (receptor not present)

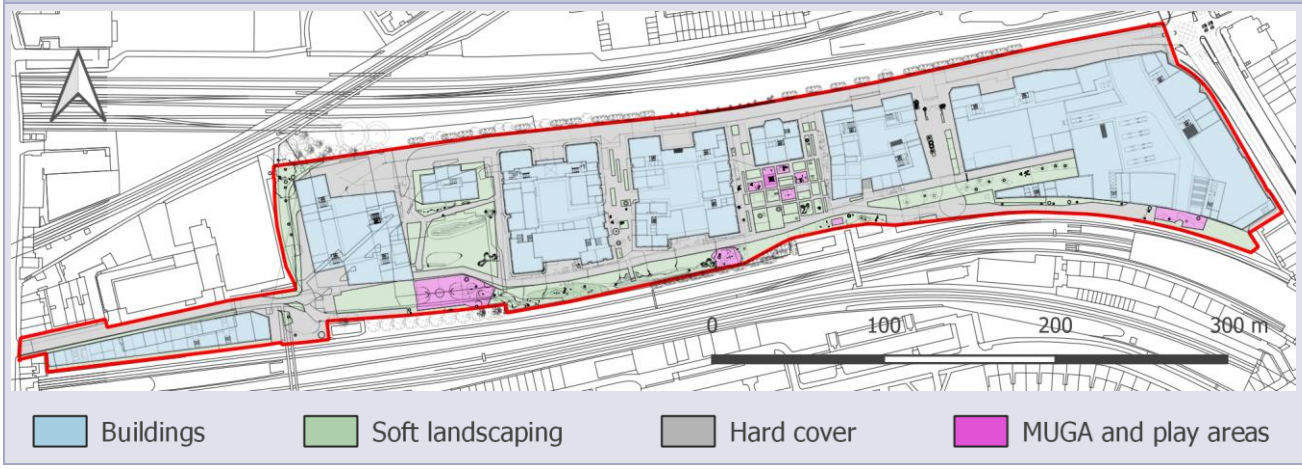
4.2 Land use scenarios and exposure pathways

Exposure pathways are the routes by which a receptor is or could be affected by a contaminant. With respect to land-use scenarios and exposure pathways the development includes the following key areas:

- Buildings: multi-story mixed use structures including residential units (ground floor and above), commercial units (retail, restaurants, leisure and workspaces) along with a health centre, nursery and podium gardens (outlined in blue).
- Hardstanding infrastructure areas including roads, footways, cycleways, vehicle loading bays / drop-off points and viewing platforms (outlined in grey).
- Recreation areas including a MUGA sports pitch and children play areas (outlined in pink).
- Ground level soft landscaping to include amenity grassed areas, communal flower beds and rain gardens (outlined in light green).

Figure 4-1 Land-uses and exposure pathways

Land use and site cover



4.3 GQRA format

Each of the GQRA (part 1) elements listed in Table 4-1 are described in a separate report section. Each section follows a broadly similar format including the following:

- Introduction
- Contaminant linkage
- Site investigation data
- Generic assessment criteria
- Screening assessment and Potential CoC
- Conceptual site model (CSM)

Introduction: the purpose and nature of the assessment undertaken within that section will be detailed.

Contaminant linkage: each section will list the contaminant linkage/s that are being assessed.

Site investigation data: each section will summarise the available site investigation data that will be considered and assessed as part of the GQRA (part 1).

Generic assessment criteria (GAC): are screening criteria which are derived using a standard set of assumptions and are designed to be broadly applicable to a wide range of site conditions and exposure scenarios. The GAC will need to be appropriate and suitable for the site, where changes are proposed to the site the GAC will be selected based on the future land-uses.

Screening assessment: each GQRA will typically start with a screening assessment comparing the contaminant concentrations from the site investigation against the relevant published generic assessment criteria. If the assessment criteria are exceeded, these contaminants will be identified as potential Contaminants of Concern (CoC).

Potential CoC discussion: For potential CoC (where contaminant concentrations exceed generic assessment criteria) the assessment will then consider whether the associated level of risk is acceptable or unacceptable, this will include considering:

- If the GAC referenced are too conservative which could lead to unnecessary detailed risk assessment or remediation or not conservative enough which would result in the assessment of risk being incorrect.
- If further assessment is needed and whether suitable site investigation data exists to undertake additional assessment (or if additional site investigation information is needed).
- Identifying unacceptable risks and residual CoC, where appropriate.
- Considering whether the site would be considered 'suitable for use' under the 'land use planning system'.

Conceptual site model (CSM): towards the end of the GQRA (part 1), the conceptual site model (including risk ranking for each CL) will be updated and if further actions are needed, suitable recommendations will be included. Where appropriate this will include assessing if the status of a contaminant linkage/s should be updated from '*potential'* to '*relevant* contaminant linkages'. Relevant linkages could be considered for detailed quantitative risk assessment or may progress directly into remediation options appraisal.

4.4 Human health GQRA (end users)

4.4.1 Introduction

This human health GQRA (part 1) includes comparing the contaminant concentrations recorded in soil samples from the site investigation against appropriate generic assessment criteria, to consider future land contamination risks for the *potential* contaminant linkage summarised below.

Table 4-2 *Potential* contaminant linkage

Source	Pathway	Receptor
Contaminants within Made Ground or ground contamination on site	Ingestion, inhalation and dermal contact	Human health of end users

4.4.2 Soil sample geochemical data

During the site investigation, soil samples were collected from each stratum encountered in the exploratory holes. The soil samples were sent to ALS for geochemical laboratory analysis. The number of soil samples scheduled for geochemical analysis (from each stratum) are summarised in Table 4-3. A breakdown of the geochemical analysis used within the scheduled testing suite is provided in Appendix F.

Table 4-3 Geochemical analysis - soil sample summary

Strata	No. of samples analysed (Suite PF-D)
Made Ground	22
Made Ground – Reworked London Clay	4
London Clay Formation	3
Total	**29**

The geochemical analysis suite includes determinands intended for several assessment purposes plus determinands that provide information about the soil but are not contaminants; only relevant soil contaminants have been assessed as part of the human health GQRA (part 1).

A table summarising the geochemical results for the contaminants assessed and key soil information referenced as part of the GQRA (part 1) is presented in Appendix F. Copies of the laboratory Certificates of Analysis are included in Appendix G.

4.4.3 Risk assessment sequence and generic assessment criteria

The GQRA (part 1) will be undertaken in a series of sequential steps, with each step aimed at refining, screening and focusing the risk assessment process. The risk assessment sequence, key assessment criteria and information are summarised in Figure 4-2 overleaf.

Figure 4-2 Human health risk assessment sequence

Assessment sequence

1 Screening assessment: The recorded concentrations for each contaminant will be compared with their respective GACs as an initial screening exercise to identify potential contaminants of concern (CoC).

- If all concentrations are below the GAC, it is considered that these contaminants would be highly unlikely to represent a significant risk to human health and no further assessment or action is considered necessary.
- If a contaminant records one or more concentration above GAC threshold they will be identified as *potential* contaminants of concern (CoC) and the GQRA for will progress to Step 2 or Step 3 for these potential CoC.

2 Statistical analysis: Where appropriate, statistical analysis will be undertaken to help assess if the site would be considered 'suitable for use' (for the proposed development) under the 'land use planning system' for the potential CoC identified in Step 1. Statistical analysis will only be applied on a site-by-site basis considering details such as averaging areas and sample frequencies. This method is intended to assess the statistically probable range of geochemical concentrations that may exist on a site and therefore enables the overall nature of the site to be considered with respect to a potential CoC.

3 Site specific considerations: Each *potential* CoC will be reviewed in more detail to consider whether potentially unacceptable risks may exist with respect to the proposed development, or whether further assessment or site investigation is likely to be required to determine the level of risk. (Whereas Step 2 considers the site as a whole. Step 3 looks more specifically at the contaminant and the locations and depth of the identified elevated concentrations and the nature of the proposed development in more detail).

Risk assessment criteria	*Details*			
Published generic assessment criteria (GAC)	Category 4 Screening Levels (C4SLs) (Defra) ; or Suitable 4 Use Levels (LQM/CIEH), where C4SLs are not available.			
GAC land use scenarios	Public open space residential (POSresi) & Commercial			
Soil organic matter (%)	2.5% soil organic matter (SOM) C4SLs/S4ULs have been referenced, based on site data.			
	Strata	*Minimum*	*Average*	*Maximum*
	Made Ground	0.344%	7.19%	33.88%
	Made Ground - Reworked London Clay	0.344%	1.10%	3.11%
	London Clay Formation	0.344%	0.344%	0.349%

The LCRM guidance references published Generic assessment criteria (GAC) 'for assessing risk to human health from exposure to contaminants' for a series of land-use scenarios: residential (with or without homegrown produce, (RwHP and RwoHP)), allotments, public open space (residential (POS_{resi}) and park (POS_{park})) and commercial. Each land-use scenario is based on a pre-defined series of exposure pathways and a 'critical receptor'. These GACs are '*the levels in soil above which may present an unacceptable risk of harm to human health'* (LCRM). The land-use scenarios considered by this GQRA (based on the current development proposals) are highlighted in Table 4-4.

Table 4-4 Land-use scenarios

Allotments	Residential with/without homegrown produce		Public Open Space		Commercial
	RwHP	RwoHP*	POS_{resi}	POS_{park}	
No	No	No*	Yes	No	Yes
Most sensitive					Less sensitive

* the proposed development does not include private residential gardens but does include ground floor residential units, consideration of volatile contaminants (only) to indoor air have been conservatively considered using GACs for RwoHP as detailed within the 'Indoor Air' section detailed below.

The exposure pathways associated with each of the generic land-use scenarios have been reviewed with respect to the proposed development details including ground cover and building type. It is considered that with respect to 'ingestion and dermal contact' viable exposure pathways will only remain in areas of soft

landscaping once the development is complete. Exposure pathways applicable to inhalation will be present across all site areas. On this basis, GAC for the following generic land-use have been selected:

Commercial: This land use defined a workplace used by adults over a typical working life (5 days per week for 46 weeks of the year) where most of the time is spent indoors and where a worker could be exposed to soil (outdoors) and soil derived dust and vapours (indoors and outdoors). The areas of land and the nature of the properties can be highly variable (e.g. small offices, commercial properties and light industrial properties to larger warehouses). This land-use considered light-uses (i.e. not heavy manual labour) where most of the site typically comprises hard-standing with areas of landscaping/soil around the buildings or nearby (80:20). The critical receptor is a female worker (age range 16 to <65 years).

Public Open Space – residential (POS_{resi}): this land-use considers predominantly grassed areas or green spaces close to housing that are likely to be used by children playing including for informal sport; up to 500m^2 (0.05 ha) and up to 50% of the area may be bare soils. The exposure pathways include tracking back of soils to residential properties. The critical receptor is a female child (age range 3 to <9 years).

Residential without homegrown produce (RwoHP): this land-use has only been considered for the assessment of contaminants which have the potential to partition to the air phase. Most notably this applies to VOCs and selected SVOCs. The critical receptor is a female child (age range 0 to <6 years). The use of RwoHP GACs is conservative for this purpose as these GACs also include direct contact and ingestion exposure pathways within a residential garden setting, however, the development does not include this land use and as such the use of RwoHP for the assessment of risks from volatile contaminants is conservative.

Technical note: Lifetime averaging is applied when generating GACs for cadmium and the critical receptor for cadmium for residential, allotments, POSresi is a female child/adult (age rage 0-74), and POSpark female child/adult (age range 3-74).

4.4.4 Screening Assessment

The results of the screening assessment are provided in Table 4-5 and summarised in the text below, the detailed results of the screening assessment are presented in Appendix E.

Table 4-5 Concentration screen results

Group		Maximum concentrations screen – pass (less than GAC)		
	Determinand	Detected?	POSresi GAC	Commercial GAC
Heavy metal and metalloids	Arsenic	Yes	Pass	Pass
	Cadmium	Yes	Pass	Pass
	Chromium and hexavalent chromium	Yes / No	Pass	Pass
	Copper	Yes	Pass	Pass
	Lead	Yes	Fail	Pass
	Mercury	Yes	Pass	Pass
	Nickel	Yes	Pass	Pass
	Selenium	No	Pass	Pass
	Vanadium	Yes	Pass	Pass
	Zinc	Yes	Pass	Pass
TPH[1]	Total petroleum hydrocarbons (TPH)	Yes	Pass	Pass
PAHs	17 speciated polycyclic aromatic hydrocarbons (PAHs)	Yes	Fail: 2x PAHs	Pass
BTEX	Benzene, Toluene, Ethylbenzene, Xylene	No	Pass	Pass
MTBE	Methyl Tertiary Butyl Ether (MTBE)	No	Pass	Pass
Phenol and PCBs	Phenol	Yes	Pass	Pass
	Polychlorinated biphenyls (PCBs)	No	Pass	Pass
VOCs	Volatile organic compounds (VOCs)	No	Pass	Pass
Notes: [1] Includes individual Aliphatic and Aromatic TPH (CWG working group) bandings >C5-C35				

Pass: The determinants that pass the screening assessment summarised above either recorded concentrations below the GAC or detectable concentrations were not recorded i.e. all results were below the laboratory minimum limit of detection (LoD). These contaminants: are not considered to be contaminants of concern (CoC), are unlikely to represent unacceptable risks to human health and no further assessment is considered warranted. It should be noted that all samples pass the Commercial end-use GACS.

Fail: Elevated concentrations have been identified for a limited number of contaminants when assessed against published POS(resi) GACs for Lead in two locations and 2 out of 17 PAH compounds in one sample.

Lead: elevated concentrations were encountered within two samples compared to the POSresi GACs. It is considered that the population sample size is too small for reliable statistical analysis and assessment to be undertaken at this stage (Step 2) and therefore PAH compounds are considered in additional detail below as potential Contaminants of Concern.

PAH compounds: elevated concentrations of two out of 17 PAH compounds (Benzo(b)fluoranthene, and Dibenzo(a,h)anthracene) have been identified in one location compared to the POSresi GACs. It is considered that the population sample size is too small for reliable statistical analysis and assessment to be undertaken at this stage (Step 2) and therefore PAH compounds are considered in additional detail below as *potential* Contaminants of Concern.

4.4.5 Indoor air considerations (vapours)

The POSresi GACs do not consider indoor air vapour inhalation pathways for volatile contaminants. The potential Source-Pathway-Receptor contaminant linkage 'Made Ground – inhalation of vapours indoors – human health of end users' has therefore been considered and assessed separately as described below.

The LCDS PRA did not identify volatile organic compounds (VOCs) as likely contaminants within the site, PID testing of 46 soil samples across 12 locations showed approximately 60% with no PID detection of volatile organic compounds and of the remaining samples only a single response above 0.5ppm was detected. Concentrations of BTEX and MTBE were not recorded above their respective laboratory detection limits as highlighted in Table 4-5. Based on the absence of detectable VOC concentrations, unacceptable risks have not been identified with respect to indoor air and end users for these contaminants.

Naphthalene: The 'inhalation of vapours indoors' exposure pathway has also been considered for the more volatile PAH fraction Naphthalene. In summary, 17 out of 29 samples did not record detectable concentrations of naphthalene (i.e. all results were below the laboratory detection limit). Detectable concentrations were recorded in the twelve remaining samples. These results have been conservatively screened against the residential without homegrown produce (RwoHP) GAC for naphthalene (5.6mg/kg, based on 2.5% soil organic matter, SOM):

- Detectable naphthalene concentrations ranged between 0.015 and 1.06mg/kg, below the RwoHP GAC of 5.6mg/kg in all 12 samples.
- The average naphthalene concentration of all samples is 0.155mg/kg which is significantly below the RwoHP GAC.

Based on the geochemical analysis results and the site-specific considerations discussed above, potential contaminants of concern have not been identified with respect to the Source-Pathway-Receptor CL 'Made Ground – inhalation of vapours indoors – human health of end users'.

4.4.6 Potential contaminants of concern

The geochemical laboratory results for the soil analytes failing the screening assessment above, i.e., elevated Lead and PAH compounds, are summarised in Table 4-6 along with a risk assessment plan showing the locations of the elevated concentrations. No GACs were exceeded within any of the samples taken from within natural strata.

Table 4-6 Potential CoC concentration ranges (mg/kg)

Analyte	No. of samples	No. >LOD	Min mg/kg	Avg mg/kg	Max mg/kg	*GAC POSresi*	*No. above POSresi GAC*	*GAC Comm*	*No. above Comm GAC*
Lead	29	29	11.1	170.54	1640	*630*	*2*	*2330*	*0*
Benzo(b)fluoranthene	29	6	<0.015	1.529	14.7	*7.2*	*1*	*44*	*0*
Dibenzo(a,h)anthracene	29	19	<0.023	0.257	1.41	*0.57*	*1*	*3.60*	*0*

Risk Assessment Plan – Proposed development

Risk Assessment Plan – Development phases

This risk assessment plan shows the results of the GQRA screening assessment for all 29 soil samples against POSresi and Comm GACs. Samples with one or more elevated concentration are represented by orange circles around the exploratory hole icon; the green circles represent samples with concentrations below the GAC. Where multiple soil samples were collected from the same exploratory hole the outermost circles around the hole icon represent the shallowest samples, each additional (and deeper) sample is represented inner circles, resulting in a series of concentric rings going from shallowest on the outside to deepest on the inside.

Analyte	TP02 @1.0m bgl	TP03 @0.75m bgl	WS06 @1.0m bgl	*GAC POSresi*	*GAC Comm*
Lead	1640	168	964	*630 mg/kg*	*2330 mg/kg*
Benzo(b)fluoranthene	2.62	14.7	3.15	*7.2 mg/kg*	*44 mg/kg*
Dibenzo(a,h)anthracene	0.28	1.41	0.303	*0.57 mg/kg*	*3.60 mg/kg*

Lead: Elevated lead concentrations (above POSresi GAC of 630mg/kg) were recorded in 2 out of 29 soil samples (26 Made Ground samples and 3 London Clay samples) and from two of the twelve locations assessed (TP02 and WS06). Both exceedances were from Made Ground layers of non-uniform composition. The maximum concentration of Lead (1,640mg/kg) was recorded in TP02 @1.0m bgl located within an area of

proposed soft landscaping around the northern residential foyer of buildering N-4. The second exceedance was recorded from WS06 @1.0m bgl located along the proposed western edge of building N-5.

Human health risk assessment focuses on ground contamination concentrations within 1mbgl (based on final ground levels) as contamination at greater depths is unlikely to be accessible with respect to the exposure pathways of dermal contact, particulate inhalation and ingestion. Depending on final ground levels in these locations and relatively minor elevation of Lead in theses samples, they are not considered to pose a significant risk to buildings N-4 & N-5. However, given the limitations imposed on the extent of ground investigation as described in Section 1.2 it is considered that the sample distribution is currently too constrained to remove lead as a CoC within GQRA (part 1) and elevated lead concentrations may reside at depths shallower than 1mbgl within other areas of proposed soft landscaping not yet investigated. On this basis Lead has been identified as CoC.

PAH Compounds: Elevated PAH concentrations (above POSresi GACs) have been identified in a single location (TP03 @ 0.75mbgl) within a Made Ground sample comprising clayey sandy gravels. No visual or olfactory evidence of contamination or high PID readings were recorded within this location during field works. TP03 @0.75m bgl recorded PAH compounds of Benzo(b)fluoranthene and Dibenzo(a,h)anthracene, one order of magnitude above POSresi GACs. TP03 is located within a proposed roadway between two large areas of proposed soft landscaping.

On the basis of the limited spatial sample distribution imposed on the extent of ground investigation as described in Section 1.2 and the proximity of potential sensitive receptors PAHs have been identified as a CoC.

In summary the GQRA (part 1) has identified lead and two PAHs as residual CoC where soft landscaping is proposed.

4.5 Asbestos in soils

4.5.1 Introduction

The PRA considered there to be a risk in regard to Asbestos Containing Soils (ACSs) resulting from the historical construction, operation, demolition, and subsequent redevelopment of buildings on site.

Table 4-7 *Potential* contaminant linkage

Source	Pathway	Receptor
Asbestos containing soils	Inhalation of liberated respirable fibres	Human health of end users

4.5.2 Asbestos in soils available data

Visually identifiable pieces of asbestos containing material (ACM) were not recorded in the exploratory hole records. All 29 soil samples were screened for ‘asbestos in soils’ as part of the laboratory analysis, asbestos was detected in 7 out of the 29 soil samples screened, all 7 positive asbestos identifications were encountered within samples of Made Ground indicating 30% of all Made Ground samples. When ‘asbestos in soils’ was detected these samples were also scheduled for quantification analysis. The asbestos results are summarised in Figure 4-3.

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Figure 4-3 Asbestos results

Asbestos Screening – Proposed development

Asbestos ≥0.1% or ACM [0]
Asbestos ≥0.001% [1]
Asbestos <0.001% [6]
Not Detected [22]

Each ring represents a tested soil sample, the shallowest sample is represented by the outer-most ring. The deepest sample is the inner-most ring.

Asbestos Screening – Development phases

Location	Depth (m bgl)	Type	Description	Quantification
BH02	0.80	Amosite (brown) asbestos	"loose fibre in soil"	<0.001%
BH05	0.70	Amosite (brown) asbestos	"loose fibre in soil"	<0.001%
TP03	0.20	Amosite (brown) asbestos	"loose fibre in soil"	<0.001%
WS03	0.40	Amosite (brown) asbestos	"loose fibre in soil"	0.0072%
	0.60	Amosite (brown) asbestos	"loose fibre in soil"	<0.001%
WS04	0.20	Chrysotile (white) asbestos	"loose fibre bundle in soil"	<0.001%
WS05	0.50	Chrysotile (white) asbestos	"loose fibre in soil"	<0.001%

4.5.3 Qualitative risk ranking

The Joint Industry Working Group (JIWG) 'Decision support tool' for the '*qualitative risk ranking of work activities and receptors involved in or exposed to asbestos in soils and construction & demolition materials*' (JIWG & CL:AIRE, 2017) has been used to qualitatively assess the potential risk to end-users of the development in areas of soft landscaping within the development. As part of the assessment the age of the receptor was set to *'infant (under 5)'* and the duration of exposure/site occupancy was set *'>10 hours per day (e.g. 24 hour residential exposure)'*.

With respect to the proposed development viable pathways will not exist in areas occupied by new buildings and areas of hardstanding. However, viable pathways may exist in areas of soft landscaping where the JIWG tool indicates a **Medium** risk if the existing soils were to remain near the surface where they could potentially 'be disturbed during non-construction/ routine use of land'.

Due to the sample population size, the nature of the identified asbestos (predominantly amosite), the concentration in WS103 (0.0072%) and the medium risk ranking (using the JIWG tool), asbestos in soils has been identified as a contaminant of concern (CoC).

4.6 Controlled waters GQRA

4.6.1 Introduction

The PRA did not identify potential contaminant linkages with respect to controlled waters receptors considering the following:

- There are no surface water features within 1km,
- The site is directly underlain by unproductive strata of London Clay (bedrock).

London Clay has been classified by the Environment Agency (EA) as unproductive strata, "*Rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow*." London Clay has been proven to a thickness of over >57m on site, and is considered to act as an aquiclude forming a hydraulic barrier to downward migration of any dissolved phase contaminants at shallow depth.

The site investigation recorded slight groundwater seepage in two locations (WS03 @ 2.40m bgl and TP03 @ 3.90m bgl) within the London Clay, however, considering the nature of the strata, these seepages are considered to be temporary, localised and discontinuous.

4.6.2 Groundwater monitoring

Combined groundwater and ground gas wells were installed in borehole locations where the thickness of Made Ground was equal to or above 1.5m. While the purpose of the wells was predominantly for ground gas monitoring purposes, their installation allowed entry of any groundwater perched above the London Clay, their response zone details are summarised in Table 4-9.

Groundwater level monitoring was undertaken alongside ground gas monitoring by the site investigation Contractor across four rounds of sampling undertaken every fortnight between 13 October and 29 November 2021 and is summarised in a table in Appendix D.

The results of groundwater level monitoring indicate he following:

- WS02 & BH03 were recorded as dry over all four monitoring visits,
- WS03 was recorded dry during the second visit (26 October 2021) only, however the groundwater level on the fourth visit fell below the top of the London Clay indicating temporary perched groundwater presence.
- Where present, groundwater was typically encountered as a relatively thin perched layer at the base of the well between 0.08 to 0.85m high, e.g. WS06 recorded a water column of between 0.08m to 0.19m high across the monitoring visits,
- Maximum permanent groundwater head was recorded in BH02 @ 48.11m AOD and the minimum groundwater head was recorded in WS06 @ 47.38m AOD.

The perched groundwater within Made Ground is considered to be isolated, laterally discontinuous and vertically confined by the London Clay. Notable groundwater flow in these deposits is not anticipated.

4.6.3 Controlled waters GQRA summary

Based on the desk study and ground investigation findings it is concluded that there are no viable receptors or potential pathways to controlled waters receptors at the site and as a result no additional assessment of risks to controlled waters is considered to be required and no further action is proposed.

4.7 Ground Gas GQRA

4.7.1 Introduction

The PRA identified historical waste activities on site (waste transfer sites between the 1960s and 1990s) and a record of a possible historic landfill positioned within the site boundary – however, the record appears to match the footprint of a building that formed part of the known Waste Transfer Station onsite. Landfills and infilled ground have the potential to generate ground gas and the following potential contaminant linkages were provisionally identified at desk study stage as part of the preliminary risk assessment:

Table 4-8 Ground gas - potential contaminants linkages

Source	Pathways	Receptors
Ground gas (associated with historic waste activities on localised parts of the site) constraint 101 in Figure 2-2	Inhalation of indoor air	Human health of end users
	Migration and accumulation	Building and structures

Based on the PRA findings the ground investigation targeted the area of the historic landfill record and selected boreholes were installed with ground gas monitoring wells as detailed within Section 4.6.2 and were subject to ground gas monitoring across four return visits. The ground conditions and gas monitoring data from the recent site investigation has been used to undertake a preliminary ground gas GQRA for the proposed development for the ground gases methane (CH_4) and carbon dioxide (CO_2).

4.7.2 Site investigation and ground gas monitoring installations

The site investigation included exploratory holes to target areas within and around the historic landfill record and Waste Transfer Station, identified as constraint 101 within Figure 5.

Investigation locations BH03, BH04, BH05, WS03, WS04 and WS05 were all positioned within the footprint of constraint 101 and ground gas monitoring wells were installed in five locations, the response zone details are summarised in Table 4-9.

Table 4-9 Monitoring well response zones

Location	Strata	Response zone details			
		Top (mbgl)	Bottom (mbgl)	Top (mAOD)	Bottom (mAOD)
BH02	Made Ground + Reworked London Clay	1.00	2.00	48.37	47.37
BH03	Made Ground	0.50	1.50	48.92	47.92
WS02	Made Ground & Made Ground (Reworked LC)	1.00	2.35	48.36	47.01
WS03	Made Ground & London Clay	1.00	2.70	48.05	46.35
WS06	Made Ground & Made Ground (Reworked LC)	1.00	2.00	48.28	47.28

4.7.3 Ground conditions and ground gas sources

The land contamination desk study identified a historical waste transfer station onsite between the 1960s and 1990s and a possible historic landfill record which appeared to match the footprint of building within waste transfer station, identified as constraint 101 within Figure 2-2. The desk study report hypothesised that part of the waste transfer station had been incorrectly recorded as a landfill in the Envirocheck Data.

The Made Ground onsite typically comprised sub-base/likely sub-base, over sandy/gravelly Made Ground that became clayey with depth. Which in turn was underlain by a layer of Reworked London Clay. Made Ground comprising sub-base type materials or reworked clay are not considered to represent sources of ground gas.

Therefore this risk assessment focuses on the sandy/gravelly/clayey Made Ground. The average thickness of this Made Ground was around 0.6m which limits the potential for it to present a significant source of ground

gas, deeper Made Ground was locally recorded in TP03 (2.95mbgl). No evidence of landfill type materials or deleterious material were identified within this Made Ground. The overall nature, thickness and age of the Made Ground indicate that there is not a significant source of hazardous ground gas onsite and provides further evidence that a landfill is highly unlikely to have been present onsite.

Note: TP03 (outside constraint 101) encountered Made Ground up to 2.95m bgl. The Made Gound in this location comprised potential sub-base to 0.4mbgl, underlain by a thickness of granular Made Ground comprising concrete, brick, flint, chalk, coal and slate (0.5m thick, up to 0.9mbgl) and further underlain by reworked clay with inclusions of the same materials (2.05m thick, to 2.95mbgl). No evidence of landfill material or waste deposits were recorded within in this location.

4.7.4 Ground gas monitoring

Ground gas monitoring was undertaken between 13 October and 29 November 2021. During the ground gas monitoring the following information and ground gas concentrations were recorded:

- Atmospheric pressure and ground gas flow rates
- Ground gases: methane (CH_4) and carbon dioxide (CO_2) hydrogen sulphide (H_2S) and carbon monoxide (CO)
- Additional gases: oxygen (O_2)

4.7.5 Risk assessment methodology and assessment criteria

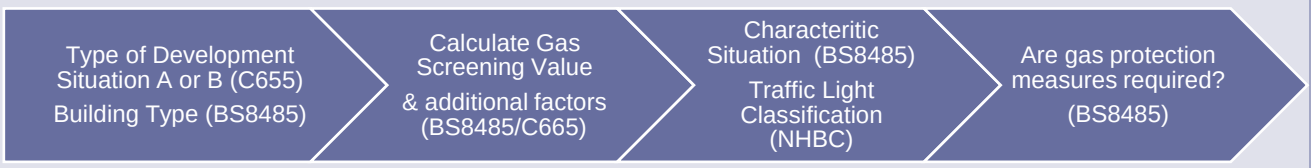
The risk assessment has been undertaken in line with BS8485:2015(+A1:2019) 'Code of Practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings' (BS8485), and guidelines from CIRIA Report C665 'Assessing risks posed by hazardous ground gases to buildings' (C665). Additional assessment has been undertaken referencing CL:AIRE (2012) 'Research bulletin RB17, A pragmatic Approach to Ground Gas Risk Assessment' and NHBC Publication NF94 (2023) 'Hazardous ground gas – an essential guide for housebuilders'.

As part of the ground gas risk assessment the maximum recorded gas concentrations and flow rates have been used to derive a Gas Screening Value (GSV) which is used to characterise the gas regime for a site (as outlined below):

- A 'Characteristic Situation' is then assigned (in line with C665 and BS8485); and/or
- A traffic light green-amber-red classification is then assigned (in line with C665 and NHBC guidance).

The Characteristic Situation is then used to inform the requirements and nature of likely gas mitigation measures. The risk assessment sequence and criteria used in this assessment are summarised in Table 4-10.

Table 4-10 Ground gas risk assessment sequence, criteria and methodology

Risk assessment sequence			
			
Title	Criteria	Details	Site Details
Development proposals (C655)	Situation A	All forms of development (residential and industrial/commercial development, other low risk residential development)	Proposed buildings
Building type (BS84858)	Type B	Private, or commercial, public, possible multiple	Proposed buildings
GSV calculation			
GSV (l/hr)	Gas screening values have been calculated for methane and carbon dioxide both for individual wells and where appropriate for the site. GSV (l/hr) = borehole flow rate (l/hr) x gas concentration (%v/v)		

It is noted that although the CIRIA guidance recommends more than four visits for high sensitivity sites, the CL:AIRE pragmatic approach allows for fewer visits if the site conditions and gas generation potential are well understood and low. Additionally, while monitoring under low and falling pressure conditions was not conducted, the CL:AIRE pragmatic approach suggests that the overall gas generation potential and site conditions can provide a robust risk assessment without extensive monitoring under all conditions.

4.7.6 Ground gas GQRA results

Gas screening values have been calculated and the results have been used to identity a Characteristic Situation (CS) hazard potential classification for each monitored location, as summarised in Table 4-11. An overall hazard classification has also been provided for the historical Waste Transfer Station constraint area 101 identified within Figure 2-2.

Table 4-11 Ground gas screening values

Hole ID	Max Flow Rate l/hr	Maximum (Peak) Concentration %		Gas Screening Values l/hr		Characteristic Situation (CS) BS8485	
		CH_4	CO_2	CH_4	CO_2	CH_4	CO_2
BH02	0.1	0.4	4.9	0.0004	0.0049	CS1	CS1
BH03	0.2	0.2	2.5	0.0004	0.005	CS1	CS1
WS02	0.1	0.3	4.8	0.0003	0.0048	CS1	CS1
WS03	0.1	0.2	8.3	0.0002	0.0083	CS1	CS1*
WS06	0.0	0.3	3.3	0.0	0.0	CS1	CS1
Constraint area 101 [a]	*0.2*	*0.2*	*8.3*	*0.0004*	*0.0166*	*CS1*	*CS1**

[a] peak concentrations used to calculate a worst case scenario from BH03 & WS03 located within the footprint of constraint 101 (historical waste transfer site)
* GSV indicate CS1, however maximum carbon dioxide over 5%.

Methane: The calculated GSVs for methane all fall within Characteristic Situation 1 (CS1) 'very low' hazard potential, no special ground gas protection measures are considered necessary (BS 8485).

Carbon dioxide: The GSVs for carbon dioxide all fall within Characteristic Situation 1 (CS1) 'very low' hazard potential where no special ground gas protection measures are considered necessary (BS 8485). However, carbon dioxide concentrations above 5% were only recorded in one location out of five (WS03) which in turn impacted the worst-case scenario was considered for constraint area 101 as highlighted in red in Table 4-11. The guidance suggests that consideration should be given to increasing the hazard potential from CS1 to CS2 (BS8485) if carbon dioxide concentrations are recorded above 5%.

4.7.7 Carbon dioxide concentrations - WS03

Carbon dioxide concentrations above 5% were only recorded in one out of the five monitoring wells, WS03.

- The well response zone in WS03 was placed within the Made Ground & London Clay (between 1m and 2.7m).
- Four monitoring visits were undertaken at this location.
- Carbon dioxide concentrations were recorded as 6.5% on the first visit, 8.3% on the second visit, 7.6% on the third visit and 7.3% on the fourth visit.

Although slightly higher carbon dioxide levels were noted in WS03, the CIRIA guidance indicates that isolated elevated readings do not necessarily indicate a high risk if the overall site conditions and gas generation potential are low. The Made Ground at this location comprised predominantly sand and gravel including content of flint, brick, slate, concrete, metal and glass, none of which represent a ground gas source. The presence of concrete, limestone and chalk can contribute to carbon dioxide, but these components do not present a credible risk of gas emissions. The ground conditions do not include any deleterious materials or evidence that suggests a viable source of hazardous ground gas exists.

A ‘faint hydrocarbon odour’ was recorded within a band of Clay (Made Ground) between 0.9 to 1.3mbgl in WS03. Geochemical data for soil samples collected from this location recorded very low hydrocarbon concentrations of 20.7mg/kg @1.0mbgl and low concentrations (<200mg/kg) in soil samples from 0.4m and 0.6mbgl. While not directly relevant to ground gas risk assessment, but provided for context, the maximum hydrocarbon concentrations at this location are between 2 to 5 orders of magnitude lower than their respective residential Generic Assessment Criteria (GAC). These low concentrations of hydrocarbon (<200mg/kg) may be contributing to locally elevated carbon dioxide concentrations, but the narrow and isolated occurrence of this low concentration contaminant is not considered to represent a wider source.

4.7.8 Total organic carbon

The NHBC guidance emphasises that the type and age of the fill material are critical in assessing gas risk. The high TOC concentrations alone do not necessarily indicate a high risk if the material is not highly degradable.

The total organic carbon (TOC) results from the geochemical analysis have been considered which indicate that the Made Ground onsite has a variable organic content with TOC concentrations ranging between 0.2% and 19.7%, with an average of 3.6%. It is considered that the highest TOC concentrations likely relate to the presence of tarmac, coal, clinker and plastic with the Made Ground, which are not degradable and do not represent a source of hazardous ground gas.

The presence of coal fragments and descriptions of dark grey and black inclusions within some Made Ground may be suggestive of the presence of coal dust which aligns with the site’s history, having formally comprised railway land and sidings. The sporadic presence of these components explains the variable Made Ground TOC concentrations which span across an order of magnitude within the same location.

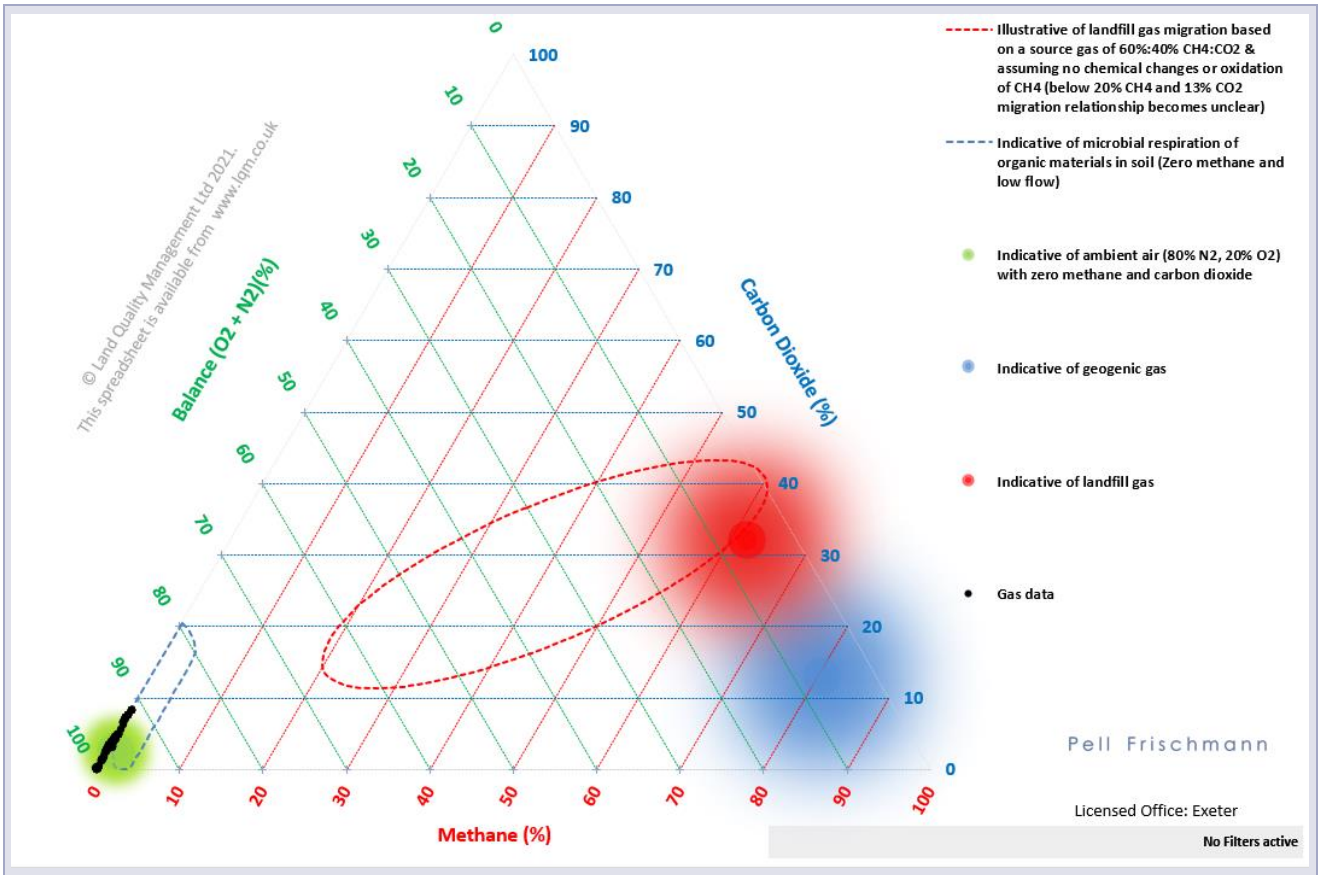
4.7.9 Gas composition

The GSVs used to assign a ground gas classification for a site takes no account of the source or the composition of the ground gas encountered. Ternary plots allow the composition of ground gases encountered to be examined further and can be used to identify when carbon dioxide concentrations above 5% are likely to be caused by microbial respiration or similar low-risk processes and therefore do not require an increase from Characteristic Situation CS1 to CS2.

A ternary plot has been produced using the available ground gas data results and the LQM Ternary Gas Composition Tool (Method 1), as shown in Figure 4-4 .

All monitoring data points within the ternary plot lie within indicative zones of ambient air or microbial respiration of organic materials in soil, i.e. near zero methane and low flow (Figure 4-4). The single location (WS03) which recorded elevated carbon dioxide concentrations is therefore most likely the result of organic degradation within the shallow Made Ground and underlying natural soils and consequently poses a lower risk to receptors than other gas sources would. This lower risk is supported by the absence of significant organic or deleterious materials as detailed within the exploratory hole logs and the low to negligible flow rates recorded during the monitoring.

Figure 4-4 Ternary plot - ground gas data



Ternary plot - method 1: methane (%), carbon dioxide (%) and the balance as oxygen plus nitrogen (%).

4.7.10 Ground gas discussion and summary

Based on the findings of the desk study, site investigation and ground gas risk assessment it is considered that the historic landfill record (identified from the Envirocheck Data) relates simply to the former waste transfer station and that no landfilling has occurred onsite. There is no evidence to support the existence of landfill type materials or deleterious material or buried waste onsite.

As detailed above, the locally deeper Made Ground, TOC results and the 'faint hydrocarbon odour' in one location have been accounted for within the assessment.

The CL:AIRE pragmatic approach allows for a qualitative assessment of gas risk based on the nature of the materials and site conditions. The NHBC and CIRIA guidance support that a CS1 classification can be justified if the overall site conditions, gas generation potential, and risk assessment indicate a low risk, even with some elevated readings. In this regard the overall risk is considered very low or absent based on the observed ground conditions which have not identified a viable source of hazardous ground gas at the site. Therefore, based on the available data, it is considered that there is no current requirement to increase the Characteristic Situation classification from CS1 to CS2 and no special ground gas protection measures are considered necessary.

Notwithstanding the absence of a viable ground gas source, both CIRIA C665 and BS 8485 indicate that large apartment blocks, such as those proposed at Finchley Road, are generally at lower risk due to the nature of their embedded structural design. This typically includes substantive continuous concrete ground floor slabs that extend across multiple accommodation units.

4.8 Health and safety of site preparation and construction workers

Table 4-12 summarises the potential contaminant linkages that were identified as part of the preliminary risk assessment with respect to the health and safety of site preparation and construction workers.

Table 4-12 Site preparation and construction workers

Source	Pathway	Receptor
Contaminants within Made Ground or ground contamination onsite	Ingestion, inhalation and dermal contact	Health and safety (H&S) of site preparation and construction workers
Asbestos containing soils (ACSs)	Inhalation of liberated respirable fibres	H&S of site preparation and construction workers
Ground gas associated with historic waste activities on site (localised parts of the site)	Inhalation of outdoor air within trenches/excavations	Health and safety (H&S) of site preparation and construction workers

The contractor responsible for site preparation and construction will need to consider health and safety with respect to any contamination present onsite including for example any personal protective equipment (PPE) that may be required. Therefore, the following observations are provided for information only:

There are no published GACs for construction workers. The ground investigation reported a variable thickness of Made Ground onsite ranging between 0.70m and 2.95m bgl, with an average thickness of 1.87m. A single occurrence of faint hydrocarbon odour was identified in one location within the Made Ground, however visual or olfactory evidence of obvious ground contamination was not identified, and the laboratory testing recorded generally low or only moderately elevated concentrations of TPH and PAHs across the site. More notable concentrations of PAH and Lead were identified in three of 29 samples. Potential ground contamination risks to construction and site maintenance workers associated with these types of contaminants can typically be mitigated by the adoption of suitable working methods, utilising appropriate personal protective equipment (PPE) and maintaining good hygiene.

Amosite and chrysotile asbestos was respectively identified in 5 of 23 and 2 of 23 samples of Made Ground at concentrations ranging from <0.001% to 0.0072%. Visible ACM was not identified. While it is not known if asbestos is present in other locations between the existing sample locations, 30% of the Made Ground samples identified asbestos presence. Preliminary reference to the JIWG Work Categories tools indicates that respiratory protective equipment (FFP3 disposable masks) and manual/localised dust suppression and localised and basic personal decontamination facilities may be required based on non-licenced work.

4.9 Water supply pipes review

The geochemical results from the site investigation have also been used to undertake a preliminary review with respect to the selection of water supply pipes for the proposed development, in line with guidance published by United Kingdom Water Industry Research (UKWIR) (2011). Given the heterogeneous nature of the Made Ground across the Site, the risk assessment is based on all of the geochemical results obtained from throughout the Made Ground profile.

The review is based on the geochemical results for samples obtained from the Made Ground onsite. The investigation works to-date have highlighted the presence of Made Ground across the entirety of the Site, to depths of between 0.45m and 2.95m bgl. While the exploratory hole records did not indicate the presence of visual contamination in the Made Ground, TPH concentrations were recorded above the laboratory detection limits within all Made Ground samples. While detected TPH concentrations were identified in most carbon bands the greatest recorded concentrations were above C12 and variable split across aliphatic and aromatic fractions. For water pipe selection, UKWIR provides a distinction for only two ‘Mineral Oil’ bandings of ‘C11-C20’ and ‘C21-C40’ with threshold concentrations for PE pipes of 10mg/kg and 500mg/kg respectively.

A summary of the petroleum hydrocarbon results summed into the bandings most closely representative of UKWIR are provided in Table 4-13.

Table 4-13 TPH concentrations in Made Ground vs UKWIR thresholds (mg/kg)

TPH bands	Units	No. of samples	UKWIR Threshold*	No. >LOD	Minimum	Average	Maximum	No. above threshold
TPH C10 – C21	mg/kg	23	10	23	<6	38	170	18
TPH C21 – C40	mg/kg	23	500	24	5	160	619	1

*UKWIR mineral oil thesholds do not exactly align with the carbon bandings reported by the TPHCWG analysis method, as such the the threshold comparison are provided as broadly indicative rather than precisely representative.

In summary, hydrocarbons above UKWIR threshold values have been identified within a majority of the Made Ground samples, on this basis the use of PE water supply pipe is not considered suitable. While only limited concentrations of other organic contaminants (including VOCs, SVOCs and phenols) have been identified, the use of barrier pipe could be considered and would mitigate potential risks from the identified petroleum hydrocarbons described above. Final pipe selection should be determined in line with Thames Water new mains and connections processes and guidance.

4.10 Conceptual Site Model

4.10.1 Introduction

Conceptual site models are part of an iterative process and the CSM will need to be updated throughout the land contamination risk management process. As stated in the LCRM guidance, the CSM should be used to "*inform the basis of your initial assessment and all future decisions as you progress through Land Contamination Risk Management*" (LCRM, 2020).

The land contamination desk study presented a *preliminary* conceptual site model (CSM) summarising *potential* contaminant linkages (source-pathway-receptor relationships) in a preliminary risk assessment (PRA).

4.10.2 Revised CSM

The September 2021 site investigation information and data has been used to undertake generic quantitative risk assessment (GQRA Part 1) using generic assessment criteria and assumptions to consider and assess the potential contaminant linkages (CLs) initially identified in the land contamination desk study. Based on the results of the GQRA and the qualitative assessments summarised above the tabulated Conceptual Site Model for the site/proposed development has been updated as presented in Table 4-15 (overleaf).

4.10.3 Risk Ratings

The qualitative risk rating for each CL have also been reviewed and updated. The risk ratings consider the product of the 'severity of the consequence' and the 'probability or likelihood' (as shown in in Table 4-16). The revised risk ratings are presented as part of the conceptual site model (Table 4-15) and are summarised in Table 4-14. It should be noted that the assigned risk ratings do not take account of likely mitigation measures.

The updated land contamination risk ratings for the proposed development ranged from moderate to low.

Table 4-14 Contaminant linkage revised risk ranking summary

Risk Rating	Number of contaminant linkages			
	PRA		GQRA	
	construction	end use	construction	end use
Very high	-	-	-	-
High	-	-	-	-
Moderate	4	4	2	1
Moderate/low	-	-	1	1
Low	-	-	1	2
Very low	-	-	-	
Number of contaminant linkages	8		8	
Overall risk rating	Moderate		Moderate/low	

Table 4-15 Conceptual site model and qualitative risk ratings (GQRA stage)

CL Ref.	Source/s	Pathway/s	Receptor/s	Probability	Consequence	Risk rating	Comments
101	Contaminants within Made Ground onsite	Ingestion, inhalation and dermal contact	Human health of end users	Likely to low likelihood	Medium	Moderate	The site investigation was spatially confined by current site use, so is not considered sufficient to cover the entire proposed development. A variable thickness of Made Ground onsite ranging between 0.70m and 2.95m bgl, with an average thickness of 1.87m. Elevated concentrations of lead and polycyclic aromatic hydrocarbon (PAH) compounds have been locally identified onsite, however, GAC exceedances were not widespread. Viable exposure pathways have been identified in areas of proposed ground level soft landscaping but have not been identified in areas of proposed hardstanding (including below buildings and roads) On this basis, lead and PAH compounds have been identified as residual CoC in areas of proposed ground level soft landscaping. These CoC will require further consideration. **Recommend**: further SI works, and soil testing is needed to assess the whole development, particularly regarding areas of proposed soft landscaping. Following this, the GQRA should be updated to account for further data (including the use of statistical analysis) prior to the LCRM process progressing to remediation options appraisal and a Remediation Strategy if needed. A watching brief during any prior construction activities is also recommended in case unexpected contamination is encountered during site clearance and construction.
201	Asbestos containing soils (ACSs)	Inhalation of liberated respirable fibres	Human health of end users	Likely	Medium	Moderate	Soil samples screened for 'Asbestos in soils' identified the asbestos detections within 7 of the 23 Made Ground samples. Amosite (brown) asbestos was identified in 5 samples and chrysotile (white) asbestos was identified in 2 samples. Quantification analysis indicated concentrations of <0.001% for 6 of the 7 positive asbestos identifications. A single sample (WS03 @ 0.40m bgl) had a quantification of 0.0072% for amosite. The results indicate that asbestos (while at low concentrations and with no visible ACM identified) is present within approximately 30% of the Made Ground samples. While it is not known if asbestos is present in other locations between the existing sample locations, given that laboratory testing identified asbestos within 30% of the Made Ground samples, its presence more widely in other locations across the site cannot be discounted. While the presence of hardstanding will break viable exposure pathways, viable pathways could exist within areas of ground-level soft landscaping. Therefore, asbestos in soils has been identified as a potential CoC with respect to ground level soft-landscaped areas. This risk assessment considers soils risks only and does not cover risks from fugitive dust during demolition or construction of existing buildings or structures. **Recommend:** While further investigation may provide improved resolution, it is likely that the LCRM process will need to progress to remediation options appraisal and a Remediation Strategy for areas of proposed soft landscaping. Contractors will need to determine appropriate H&S measures including reference to Control of Asbestos Regulations (CAR 2012) and CAR-SOIL guidance.
301	Ground gas associated with historic waste activities on site (localised parts of the site)	Inhalation of indoor air	Human health of end users	Unlikely	Mild	Very low	While Made Ground was identified across the site the nature and generally limited thickness of this material does not indicate a likely ground gas source. No evidence of landfill material was recorded within any locations across the site and the existence of infilled ground or buried waste at the site was not identified. Negligible concentrations of methane were detected during the ground gas monitoring to-date and limited carbon dioxide concentrations were recorded. The ground gas risk assessment suggests ground gas conditions indicative of BS8485 Characteristic Situation 1 (CS1) conditions, whereby no special gas protection measures are considered necessary. **Recommend**: Based on the ground conditions and gas monitoring information no further action proposed.
302		Migration and accumulation	Building and structures	Unlikely	Mild	Very low	
401	*Contaminants within Made Ground onsite*	*Ingestion, inhalation and dermal contact*	*Health and safety (H&S) of site preparation and construction workers*	*Low likelihood*	*Medium*	*Moderate / low*	See pCL101 comments. Variable concentrations of PAH, TPH and lead have been identified within the Made Ground at the site. Potential ground contamination risks to construction and site maintenance workers associated with these types of contaminants can typically be mitigated by the adoption of suitable working methods, utilising appropriate personal protective equipment (PPE) and maintaining good hygiene. The final measures will need to be determined and implemented by the contractor during construction as part of the health and safety plan. **Recommend**: contractors to consider nature of Made Ground as part of their H&S procedures.
501	*Asbestos containing soils (ACSs)*	*Inhalation of liberated respirable fibres*	*H&S of site preparation and construction workers*	*Likely*	*Medium*	*Moderate*	See pCL201 comments. With respect to the health and safety of site preparation and construction workers, preliminary reference to the JIWG Work Categories tools indicates that respiratory protective equipment (FFP3 disposable masks) and manual/localised dust suppression and localised and basic personal decontamination facilities may be required based on non-licenced work. **Recommend**: contractor to undertake and prepare appropriate risk assessments and method statements (including reference to the Control of Asbestos (CAR) regulations and CAR-soil guidance).
502			*H&S of neighbouring users (dust migration) during demolition/ construction*	*Low likelihood*	*Medium*	*Moderate / low*	
601	*Ground gas associated with historic waste activities on site (localised parts of the site)*	*Inhalation of outdoor air within trenches /excavations*	*Health and safety (H&S) of site preparation and construction workers*	*Unlikely*	*Mild*	*Very low*	See pCL301 comments.
701	Hydrocarbon contamination within Made Ground	Migration through water supply pipes (depending on material type) into potable water.	Health of end-users following consumption of potable water	A thickness of Made Ground is present onsite, TPH concentrations were encountered within the Made Ground, with a maximum concentration (EC10-EC21) of 170mg/kg and (EC21-EC40) of 619mg/kg. Due to the presence of these PE water supply pipes are unlikely to be suitable for the development and barrier pipes should be considered. Pipe selection should be determined in line with Thames Water new mains and connections processes and guidance **Recommend**: consult with Thames Water			

Note: while most asbestos containing materials (ACMs are legally required to be removed from buildings before demolition, some ACMs may remain. Residual ACMs (or unrecorded ACMs) that remain in-situ during demolition may increase the risk of future asbestos is soil e.g. from future stockpile placement and re-use of demolition arisings onsite.

Table 4-16 Risk matrix

Risk = probability x consequence		Consequence			
		Severe	Medium	Mild	Minor
Probability	High likelihood	Very high	High	Moderate	Moderate/ low
	Likely	High	Moderate	Moderate/ low	Low
	Low likelihood	Moderate	Moderate/ low	Low	Very low
	Unlikely	Moderate/ low	Low	Very low	Very low
	No linkage	Without a linkage, there is not a risk – even if a contaminant is present (LCRM 2020)			

Based on the CIRIA good practice guide (C552, 2001).

5 Conclusions and Recommendations

5.1 Conclusions

Based on the results of the GQRA, the land contamination risk ratings ranged from moderate to very low and an overall risk rating of moderate/low has been assigned with respect to the proposed development.

Moderate risks have been identified with respect to the following: Asbestos, lead and PAH (polycyclic aromatic hydrocarbon) compounds have been identified as Contaminants of Concern (CoC) with respect to the areas of soft landscaping within the proposed development.

Based on the GQRA findings and with respect to the proposed development (pre-mitigation):

- Localised elevated PAH and lead concentrations within soil above POS(Resi) GAC have been identified within the Made Ground onsite. GAC exceedance we only identified within Made Ground.
- Viable exposure pathways have not been identified in areas of proposed hardstanding (including below proposed buildings under roads or hard landscaping) However, viable exposure pathways are likely to exist with respect to areas of proposed ground level soft-landscaping and soft cover public open space.
- No vapour risks have been identified at the site.
- Asbestos (while at low concentrations and with no visible ACM identified) was identified within approximately 30% of the Made Ground samples. Viable exposure pathways are likely to exist with respect to areas of proposed ground level soft-landscaping and soft cover public open space.
- Significant ground gas sources were not identified, and ground gas monitoring and risk assessment confirms Characteristic Situation 1 (CS1) whereby no special ground gas protection measures are considered necessary. As the site investigation scheme described in this report targeted the only potential source of ground gas onsite and has determined very low risk that do not require protection measures it is considered that future ground investigation in other parts of the will not need to include for ground gas monitoring unless new ground gas sources are identified.
- Controlled waters risks have not been identified at the site and no further investigation or assessment is proposed.

Due to access constraints associated with potential locations available to the 2021 investigation, the site investigation was spatially confined so is not considered sufficient to cover the entire proposed development most notably in regard to the proposed areas of soft landscaping within the southern part of the site and further assessment and update of the GQRA will be required when data becomes available as part of post demolition ground investigation undertaken at a future date.

In additional to the end-user risks identified above, moderate risk ratings have also been assigned with respect to site preparation and construction workers and potential ‘asbestos in soils’ within the Made Ground onsite, this will need to be considered as part of the contractor’s health and safety procedures including reference to the Control of Asbestos Regulations (CAR, 2012) and CAR-soil guidance.

5.2 Recommendations

Based on the findings of the GQRA, the following Source-Pathway-Receptor relationship has been identified as a relevant contaminant linkage for the proposed development. These relevant CLs have been identified based on the results of the GQRA (part 1) and are summarised in Table 5-1.

Table 5-1 Relevant CLs GQRA (part 1)

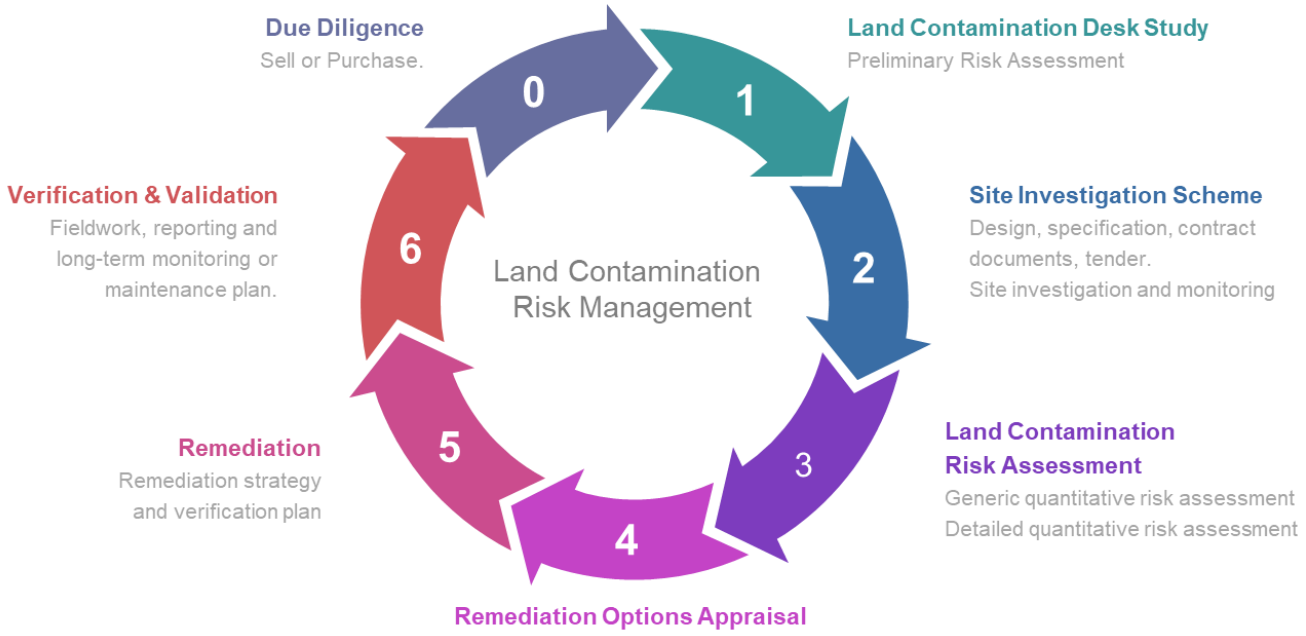
CL ref	Source	Pathway	Receptor	CL Status
101	PAH compounds and lead within Made Ground onsite	Ingestion, inhalation and dermal contact associated with areas of ground level soft landscaping only.	Human health of end users	***Relevant***
101	Asbestos in soils (within the Made Ground onsite)	Inhalation of liberated respirable fibres associated with areas of ground level soft landscaping only.	Human health of end users	***Relevant***

Section 0 of this report highlighted that the GQRA process for the proposed development will need to be undertaken in multiple phases, as a result of access constraints imposed on the design of the site investigation. It is recommended that further site investigation be undertaken as additional parts of the site become accessible and/ or post demolition when site wide access will be available to undertake a site wide GQRA focused on human health assessment.

When quantitative risk assessment (GQRA or DQRA) identifies unacceptable risks, the status of the associated CLs is updated from *potential* to ***relevant*** CLs and the LCRM sequence will need to progress to Remediation Options Appraisal and a Remediation Strategy will need to be prepared to address the relevant CLs.

At this stage it is considered that further site investigation and GQRA will better define these identified contaminants of concern. Future site investigation and GQRA should focus on shallow soil sampling in areas of proposed soft landscaping, analysis and human health risk assessment. Further investigation of ground gas and controlled waters risks is not currently considered necessary.

Figure 5-1 Land Contamination Risk Management process - simplified



6 Limitations and Liabilities

This report has been prepared by Pell Frischmann with reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the Client in accordance to the agreed scope of services.

This report has been prepared to provide pre-development geoenvironmental and land contamination information for the redevelopment of Finchley Road. The report contents should only be used in that context and Pell Frischmann disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.

The report details the findings of work carried out by Pell Frischmann during a study period of November 2021 to January 2022, updated October 2024 (ground gas only). The report has been prepared on the basis of available information obtained during that study period. Information provided by the referenced third parties has been used in good faith and is taken at face value; however, Pell Frischmann cannot guarantee its accuracy or completeness.

Although every reasonable effort has been made to gather all relevant information within the context of the agreed scope of work, all potential environmental constraints or liabilities associated with the site may not have been revealed. Should additional Information become available (including new legislation and changed practices), after the date of the report submission, Pell Frischmann reserves the right to reconsider the recommendations and alter the report accordingly.

Notwithstanding any site observations concerning the presence or otherwise of archaeological sites, asbestos-containing materials or invasive weeds such as Japanese knotweed, this report does not constitute a formal or specific survey of these potential development hazards. Unless otherwise stated, no assessment has been made for the presence of radioactive substances or unexploded ordnance.

Appendix A Land Contamination Risk Management

Land Contamination Risk Management (LCRM) process

The Environment Agency 'Land Contamination Risk Management' guidance (LCRM, 2020) sets out the process that should be followed for managing the risk from land contamination within regulatory and site management contexts. For example, as part of due diligence assessments and planning applications. The process of LCRM should be used to:

- *Identify and assess if there is an unacceptable risk*
- *Assess what remediation options are suitable to manage the risk*
- *Plan and carry out remediation*
- *Verify that remediation has worked*

LCRM includes three risk-based stages (1) risk assessment, (2) remediation options appraisal and (3) remediation and verification. Each LCRM stage is broken down several steps (or tiers), as outlined in the Figure A-1, along with an illustrative summary of the key LCRM steps in sequence.

Figure A-1 Land Contamination Risk Management process - summary

LCRM process - simplified

LCRM Matrix	Tier 1	Tier 2	Tier 3 (and 4)
Stage 1 **Risk assessment**	Preliminary Risk Assessment (PRA)	Generic Quantitative Risk Assessment (GQRA) [this report]	Detailed Quantitative Risk Assessment (DQRA)
Stage 2 **Options appraisal**	Identify feasible remediation options	Evaluate options to identify suitable remediation	Select the final remediation option
Stage 3 **Remediation**	Remediation strategy (and verification plan)	Remediation	Verification Report (3) Long term monitoring and maintenance, if required (4)

Planning

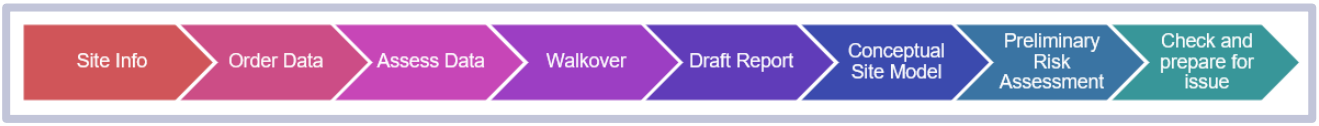
The LPA would typically expect to see a preliminary risk assessment submitted as a supporting document with the planning application. Future LCRM requirements (including site investigation, risk assessment and remediation) will typically form part of the planning conditions and subsequent discharge activities.

Preliminary risk assessment (and land contamination desk study)

The guidance states that the land contamination risk management process *must always start with a preliminary risk assessment (PRA)*; which includes undertaking a land contamination desk study.

- As part of a land contamination desk study (LCDS) we collate and review desk-based information (including site specific geoenvironmental data and historic maps purchased based on the site boundary), the review includes identifying potential sources of contamination and sensitive receptors.
- The preliminary risk assessment includes developing a *preliminary* Conceptual Site Model (CSM) summarising the possible 'source-pathway-receptor' relationships i.e. Contaminant Linkages (CLs, see Figure 3) that may be relevant to the site or the proposed development, as shown in Figure A-3.
- Each *potential* Contaminant Linkage is assigned a qualitative level of risk, before updating the CSM and considering what further action is needed.
- he *preliminary* CSM also summarises uncertainties and gaps in information and provides recommendations for further investigation and assessment to address them, which may include intrusive site investigation and monitoring followed by quantitative risk assessment.

Figure A-2 Land contamination desk study and preliminary risk assessment

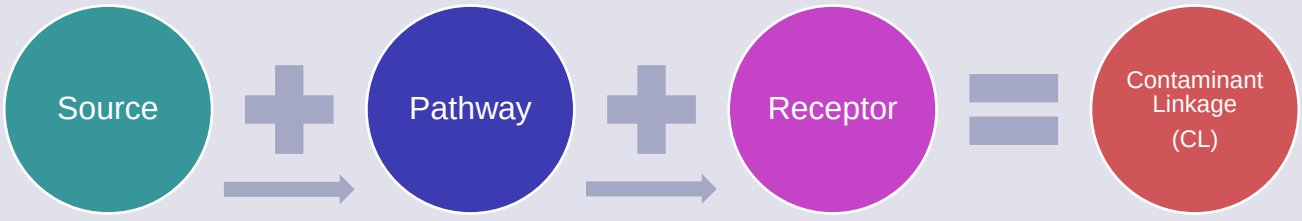


Conceptual Site Model

The CSM is an iterative process that needs to be updated as a project progresses through Land Contamination Risk Management. As stated in the LCRM guidance, the CSM should be used to "*inform the basis of your initial assessment and all future decisions as you progress through Land Contamination Risk Management*" (LCRM, 2020).

Figure A-3 Contaminant Linkages (S-P-R)

Contaminant Linkage - Source-Pathway-Receptor relationships



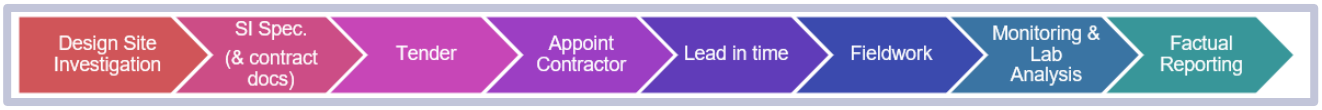
Term	Definition
Source	A contaminant that is in, on or under the land and has the potential to cause harm or pollution
Pathway	A route by which a receptor is or could be affected by a contaminant
Receptor	Something that could be adversely affected by a contaminant for example a person, controlled waters, an organism, an ecosystem or Part 2A receptors such as buildings, crops or animals.
Contaminant Linkages & risks	The presence and S-P-R relationship between contaminants, pathways and receptors.
	All three elements (S-P-R) of a contaminant linkage must be present for a land contamination risk to exist "*A contaminant linkage must be present for there to be a S-P-R relationship. Without a linkage, there is not a risk – even if a contaminant is present*" (LCRM, 2020). e.g. if a source has been identified; but there is no receptor/s or no pathway/s then the S-P-R linkage is incomplete and there is not a risk.

Site investigation scheme (SIS)

Preliminary risk assessment assesses land contamination risks based on qualitative judgement only. Intrusive site investigation information and data will be needed before quantitative risk assessment can be undertaken. Geotechnical ground investigation and land contamination site investigation fieldwork activities are typically combined into a single package of work as a practical and cost-effective option that can be undertaken by a single ground investigation contractor.

Pell Frischmann's site investigation services include site investigation design, contract and specification document preparation, prepare and oversee tender and appointment of suitable contractors, oversee and manage site investigation, schedule and manage geochemical analysis and monitoring (as required).

Figure A-4 Site investigation scheme

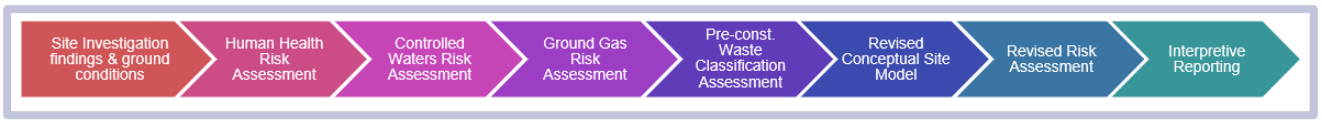


Land Contamination Risk Assessment

Quantitative risk assessment uses the site investigation data to assess if the *potential* contaminant linkages identified by the preliminary risk assessment could present unacceptable risks that would drive the need for remediation. Land contamination risk assessment typically starts with generic quantitative risk assessment (GQRA) which can process into detailed quantitative risk assessment (DQRA) for more complex land contamination scenarios.

- Generic quantitative risk assessment (GQRA) uses generic assessment criteria and assumptions to estimate risk.
- Details quantitative risk assessment (DQRA) uses detailed site-specific information to estimate risk.

Figure A-5 Generic quantitative risk assessment



GQRA uses site investigation findings, generic assessment criteria and assumption to consider and assess the *potential* contaminant linkages identified in the preliminary risk assessment in order to Identify potential contaminants of concern (CoC), indicate where additional information, site investigation or monitoring may be required, indicate where detailed quantitative risk assessment (DQRA) may be required, update the conceptual site model and the risk ratings for each of the *potential* contaminant linkages, and where appropriate, update the status of the contaminant linkage including assessing whether any of the CLs should be considered 'relevant contaminant linkages' i.e. likely to require remediation due to unacceptable risks.

Remediation (remediation options appraisal, remediation strategy and remediation)

If land contamination risk assessment (GQRA or DQRA) identifies "*unacceptable risks then remediation or mitigation [will be] required*" and the LCRM process will need to progress to remediation options appraisal (LCRM stage 2) and the development of a land contamination remediation strategy (LCRS) followed by remediation (LCRM stage 3). Remediation options appraisal includes setting remediation objectives and criteria and identifying a suitable remediation option that '*can be implemented in practice'*. The remediation strategy is a record '*of how you will meet and carry out the remediation objectives'* (LCRM, 2020) and includes a verification plan setting out compliance criteria and the records and 'lines of evidence' that need to be captured during or after remediation to demonstrated that the remediation is in place and is working or has worked.

Verification Inspections and Reporting

Verification is intended 'to provide a complete record of all remediation activities' as evidence that the remediation has been successful that consequently the development areas subject to remediation can be considered suitable for use. Pell Frischmann would typically undertaken verification inspections during construction and would work with the contractor to ensure that suitable data is collated during construction to enable Pell Frischmann to produce a land contamination verification report.

Appendix B *Preliminary* conceptual site model (CSM)

Preliminary Conceptual Site Model (CSM)

pCL	Source/s	Pathway/s	Receptor/s	Probability	Consequence	Risk	Comments
101	Contaminants within Made Ground onsite	Ingestion, inhalation and dermal contact	Health of end users	Likely	Medium	Moderate	The site has a detailed history and several potentially contaminative land-uses have been identified onsite. As a result, it is considered that a variable thickness of Made Ground is likely to exist onsite and the geochemical nature of the Made Ground is likely to be variable. Localised hotspots of contamination relating to the different land-uses onsite may be present. The site was subject to site-wide redevelopment in the mid to late 1990s, earthworks during the redevelopment could have moved/mixed the near surface soils, thus altering any geochemical patterns that may previously have been present. Reworked natural soils are also likely to be present. **Recommend**: intrusive site investigation, soil sampling and analysis followed by Generic Quantitative Risk Assessment (GQRA).
201	Asbestos containing soils (ACSs)	Inhalation of liberated respirable fibres	Health of end users	Likely to low likelihood	Medium	Moderate	Asbestos is likely to have been present in the former buildings onsite and residual asbestos may have been incorporated into the soil during construction, operation, demolition, and subsequent redevelopment. Voluntary bans on the import of blue asbestos occurred in the late 1960s followed by brown asbestos in 1980, with white asbestos not being banned in the UK until 1999. Therefore, it is also possible that asbestos may be present in the current building and structures onsite. Note this risk assessment considers soils risks only and does not cover risks from fugitive dust during demolition or construction of existing buildings or structures. **Recommend**: screen soil samples from the site investigation for Asbestos in Soils, plus quantification analysis for all samples with positive asbestos identification to allow for quantitative risk assessment.
301	Ground gas associated with historic waste activities on site (localised parts of the site)	Inhalation of indoor air	Health of end users	Likely to low likelihood	Medium	Moderate	Records indicate that historic waste transfer sites operated on site for over 30 years (between the 1960s and 1990s). A historic landfill record is positioned within the site boundary – but appears to match the footprint of a building that formed part of a known Waste Transfer Station onsite. **Recommend**: targeted site investigation within the likely footprint of the historic waste transfer station, including the installation of dedicated ground gas monitoring wells; and continuous ground gas monitoring of these wells; followed by generic quantitative ground gas risk assessment.
302		Migration and accumulation	Buildings and structures	Likely to low likelihood	Medium	Moderate	
401	*Contaminants within Made Ground onsite*	*Ingestion, inhalation and dermal contact*	*Health and safety (H&S) of site preparation and construction workers*	*Likely*	*Medium*	*Moderate*	See pCL101 comments.
501	*Asbestos containing soils (ACSs)*	*Inhalation of liberated respirable fibres*	*H&S of site preparation and construction workers*	*Likely*	*Medium*	*Moderate*	See pCL201 comments.
502			*H&S of neighbouring users (dust migration) during demolition/construction*	*Likely to low likelihood*	*Medium*	*Moderate*	
601	*Ground gas associated with historic waste activities on site (localised parts of the site)*	*Inhalation of outdoor air within trenches/excavations*	*Health and safety (H&S) of site preparation and construction workers*	*Likely to low likelihood*	*Medium*	*Moderate*	See pCL301 comments.
701	Hydrocarbon contamination within Made Ground	Migration through water supply pipes (depending on material type) into potable water.	Health of end-users following consumption of potable water	It is anticipated that a thickness of Made Ground is likely to be present onsite, low concentrations of hydrocarbons can impact on standard water supply pipes. Where contamination may be present, water companies require suitable data to be provided as part of applications for 'new mains and water connections' to enable pipe selection risk assessment (PSRA) to be undertaken. Several factors determine whether the water company or developer undertakes the PSRA. Note: pipe selection sits outside the contaminated land regime and is unlikely to form part of a remediation strategy. **Recommend**: intrusive site investigation, soil sampling and analysis to inform pipe selection risk assessment (PSRA).				

Qualitative risk ratings have been applied to each *potential* contaminant linkage based on the available data and qualitative judgement. These ratings consider the product of the product of the 'severity of the consequence' and the 'probability or likelihood' (as shown in the risk matrix below).

Risk matrix

Risk = probability x consequence		Consequence			
		Severe	Medium	Mild	Minor
Probability	High likelihood	Very high risk	High risk	Moderate risk	Moderate/ low risk
	Likely	High	Moderate	Moderate/ low risk	Low risk
	Low likelihood	Moderate	Moderate/ low risk	Low risk	Very low
	Unlikely	Moderate/ low risk	Low risk	Very low	Very low
	No linkage	Without a linkage, there is not a risk – even if a contaminant is present (LCRM 2020)			

Based on the CIRIA good practice guide (C552, 2001).

Appendix C Plans/drawings

Appendix D Monitoring summary data

Groundwater Monitoring Summary

Location	Response Zone Strata	Groundwater Levels							
		13/10/2021		26/10/2021		08/11/2021		29/11/2021	
		Depth (m bgl)	Depth (m AOD)	Depth (m bgl)	Depth (m AOD)	Depth (m bgl)	Depth (m AOD)	Depth (m bgl)	Depth (m AOD)
BH02	Made Ground	1.26	48.11	1.40	47.97	1.42	47.95	1.38	47.99
BH03	Made Ground	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
WS02	Made Ground & Made Ground (Reworked LC)	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
WS03	Made Ground & London Clay	1.35	47.69	DRY	DRY	1.57	47.47	1.81	47.23
WS06	Made Ground & Made Ground (Reworked LC)	1.78	47.49	1.78	47.49	1.80	47.51	1.89	47.42

Ground Gas Monitoring Summary

Location	Flow rate (l/hr)		Methane (CH_4) (%v/v)		Carbon dioxide (CO_2) (%v/v)		Oxygen (O_2) (%v/v)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
BH02	-0.1	0.1	0.0	0.4	0.0	4.9	0.0	17.1
BH03	-0.2	0.2	0.0	0.2	0.2	2.5	7.4	20.5
WS02	0.0	0.1	0.0	0.3	0.4	4.8	1.5	19.6
WS03	-0.2	0.1	0.0	0.2	0.1	8.3	1.3	21.7
WS06	-0.5	0.0	0.0	0.3	0.0	3.3	2.3	21.0

Appendix E Geochemical Analysis

Appendix F Geochemical analysis suites

Geochemical analysis suites	Soil suite	Groundwater suite	Surface water suite
	PF-D	PF-GW-GF	PF-SW-GF
pH	Yes	Yes	Yes
Total Organic Carbon	Yes	-	-
Loss on Ignition	Yes	-	-
Asbestos Screen and ID	Yes	-	-
Asbestos Quantification (only if asbestos identified)	Yes	-	-
Metals and Metalloids			
Arsenic	Yes	Yes	Yes
Barium	Yes	-	-
Boron	-	-	Yes
Cadmium	Yes	Yes	Yes
Chromium (total)	Yes	Yes	Yes
Chromium hexavalent	Yes		
Copper	Yes	Yes	Yes
Mercury	Yes	Yes	Yes
Molybdenum	Yes		
Nickel	Yes	Yes	Yes
Lead	Yes	Yes	Yes
Antimony	Yes		
Selenium	Yes	Yes	Yes
Vanadium	Yes		
Zinc	Yes	Yes	Yes
Hydrocarbons and organics			
TPH-CWG (aliphatic/aromatic) including BTEX + MTBE	Yes	Yes	Yes
PAH (speciated 16 USEPA + Coronene)	Yes	Yes	Yes
Phenols	Yes	Yes	Yes
Inorganics			
Electrical conductivity			Yes
Suspended solids			Yes
Hardness Total as CaCO3			Yes
Chloride		Yes	Yes
Sulphate		Yes	Yes
Cyanide (total)		Yes	
Ammoniacal Nitrogen as N		Yes	Yes
Ammonia/Ammonium Low Level Ionised			Yes
Other			
Dissolved Oxygen			Yes
Calcium			Yes
Dissolved Organic Carbon			Yes

Appendix G Factual Ground Investigation Report