

LAND AT GREENBOOTH ROAD
NORDEN
ROCHDALE

GEOENVIRONMENTAL RISK
ASSESSMENT & REMEDIATION
STRATEGY

Job Number: LKC 20 1618

Date: September 2020

Client: Norden Developments Ltd



INCREASING LAND VALUE

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1 Introduction

1.1 Background

LK Consult Ltd (LKC) has been commissioned by Norden Developments Ltd to carry out a Geoenvironmental Risk Assessment and Remediation Strategy for land at Greenbooth Road, Rochdale.

The work is required to support proposals to develop the site for residential use with associated access, parking and landscaping.

LKC are aware of the following work pertaining to the site:

- »» Geoenvironmental Appraisal, undertaken by Encia Consulting Ltd (report ref. 7112/1, dated June 2006.

The above report comprised a Phase 1 Preliminary Risk Assessment and a Phase 2 intrusive investigation of the study site and areas to the north and south. Since this report has been produced, some of the site buildings have been demolished and UK generic contamination assessment criteria used in the report have been updated

Initial conversations with Rochdale Borough Council determined that in order to support a planning application, a contemporary risk assessment on the existing data would be acceptable.

The scope of works for this study are as follows:

- »» Identify and extract existing Encia data relevant to the study site only.
- »» Carry out an up to date site reconnaissance.
- »» Provide a contemporary preliminary conceptual model.
- »» Carry out a soil, gas and controlled waters risk assessment using current UK generic assessment criteria on pertinent Encia data.
- »» Provide updated conceptual model.
- »» Provide a remediation strategy.

A geotechnical testing has not been included as part of this study as the foundation design will be considered by others.

1.2 Site Details

A summary of the site details is presented in Table 1-1. Figure 1 indicates the site location and boundary.

The site may be considered as two areas of land. The central and western area is the former Tack Lea Works area with the eastern area the former Shepherd Mill area. These areas are split by Woodhouse Lane Brook which flows south into Naden Brook.

Figure 2 indicates the proposed development.

Location	To the north of Greenbooth Road, Norden, Rochdale, OL12 7TG. Centred at approximate National Grid Reference 385820E 414719N
Area	Approx. 26,500m ² .
Topography	Located in a valley with higher ground to the north and north east, a central flatter "plateau" and further fall in levels to Naden Brook to the south. Tack Lea 182 metres above ordnance datum (AOD) in the extreme north to 164mAOD on the southern boundary. Shepherd Mill: 175mAOD on the north eastern fringe to 160mAOD on the southern boundary with Naden Brook.
Land Use	<u>Site</u> Tack Lea works: Two buildings remnant with a coal bunker on the northern boundary. Majority of handstanding remains. Slopes to the north and east heavily vegetated. Shepherd Mill: No buildings remain although substantial handstanding remains. Slopes to the north east and south west heavily vegetated. <u>Surrounding Area</u> West and South: Naden Brook and, with housing, open land (former Tenterhouse Mill site) and Edenfield Road beyond. North: Open land, formerly part of Tack Lea works and low-density housing. East: Valley slope and housing development beyond.
Proposed Development	Residential dwellings, with associated access, parking and landscaping.

Table 1-1. Summary of site details.

2 Previous Work

2.1 Summary of Existing Information

Pertinent information from the Encia report supplemented by contemporary environmental information and a site reconnaissance summarised in Sections 2.2-2.6.

The conceptual model (Section 2.6) has been derived by LKC and is in line with current risk assessment methodology.

2.2 Site History

The site history, including the history of the surrounding area taken from the Encia report, is shown in Plate 2-1. The area to the south referred to as Tenterhouse Mill is not part of the study site boundary.

Copies of historical maps are provided in Appendix A.

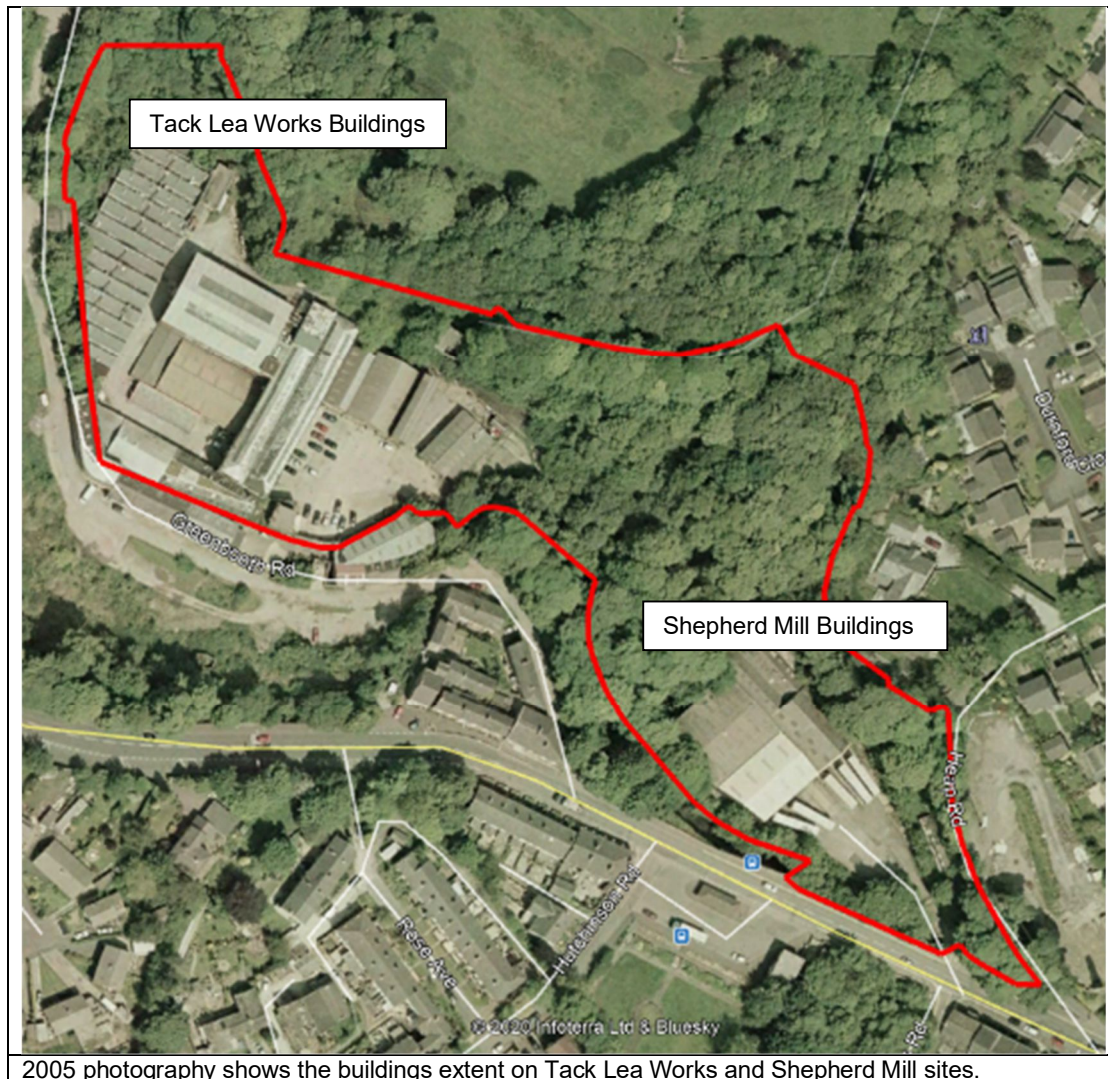
Date(s)	Site	Surrounding Land
1851	Woodhouse Mill (bleaching works) is shown in the central site area. A number of smaller buildings are indicated in the south eastern corner of the site. The western and northern parts of the site remain undeveloped . Naden Brook is shown entering the site from the north, running through the centre of the site before exiting the south eastern corner. Woodhouse Lane Brook is also shown entering the north eastern part of the site before discharging into Naden Brook.	A possible pond is shown adjacent to the northern site boundary. A large pond is located 100m to the north west of the site boundary. A sandstone quarry is located approximately 50m north of the site. Several sandstone quarries and coal pits are shown to the west of the site.
1894	The central southern part of the site is occupied by a large building , indicated to be part of Woodhouse Mill .	A number of old quarries, shafts and springs are indicated to the north, east and west of the site. A ' Tenter ' (drying field) is shown immediately north of the site. Clap Gate Colliery is located 80m south east of the site.
1910	The building on the southern portion of the site is now shown as Tenterhouse Bleaching & Dyeing Mill . Several new buildings and filter tanks have been constructed in the central part of the site associated with Woodhouse Mill. A number of ' tanks ' are shown in the north west of the site. Three small reservoirs and a tank are located in the eastern part of the site associated with Shepherd Mill Bleaching & Finishing Works .	A series of filter tanks are located adjacent to the central northern boundary with a small pond 70m to the north. A possible clay/gravel pit is shown adjacent to the south eastern site boundary. Two reservoirs and a disused tank are located between 100m and 140m south east of the site boundary. The Clap Gate Colliery is no longer shown.
1929/1931	The Tenterhouse Mill located in the southern and western site areas has increased in size and now has two chimneys . More filter tanks are indicated in the central and northern site areas. One of the reservoirs located in the south east of the site is no longer shown. Another building is shown in the south east of the site associated with Shepherd Mill.	A collection of buildings, labelled as Woodhouse Mills Oil Works have been developed adjacent to the north eastern site boundary.
1963/1979	The original Shepherd Mill building is no longer shown in the south eastern part of the site. The reservoirs associated with Shepherd Mill are no longer shown and assumed to have been infilled . The mill building located in the southern and western part of the site is now labelled as Tenterhouse Tannery . An electrical sub station is shown in the central southern portion of the site.	Woodhouse Oil Mills are no longer shown to the north. A chimney is indicated 120m north of the site. The reservoirs located to the south east of the site are now shown as a ' refuse tip '. Greenbooth Reservoir is located 400m to the north of the site.
1993/1999	The Tenterhouse Tannery building located in the southern and western site area has been demolished .	No significant changes.

Plate 2-1: Extract from Encia Report of significant historical features.

The Encia report also included an “existing site features” plan and this is provided in Appendix A.

Following the Encia works in 2006, the former dyehouse and large works building on Tack Lea works have been removed – the boiler house and vehicle respraying workshop only remain, and all buildings have been removed from the Shepherd Mill site.

This can be seen on historical aerial photographs (Plates 2-2 and 2-3):



2005 photography shows the buildings extent on Tack Lea Works and Shepherd Mill sites.

Plate 2-2: Extract from Google Earth Imagery 2005 © Google 2020



2018 photography shows the former boiler house and former spraying workshop buildings only extant on Tack Lea Works and all buildings removed from the Shepherd Mill site.

Plate 2-3: Extract from Google Earth Imagery 2018 © Google 2020.

2.3 Environmental Setting

The environmental setting, taken from the Encia report data (Appendix B) and contemporary public domain information including Coal Authority, British Geological Survey and Environment Agency WMS data is summarised in Table 2-4.

Categories			Details
Geology	Artificial		- None shown on mapping. Made Ground expected, given the presence of former reservoirs and landfill on site.
	Superficial		- Devensian Till, Diamicton.
	Bedrock		- Rough Rock Sandstone. - Dip approx. 5° SE. - No faults indicated on site.
Hydro-geology & Hydrology	Aquifer Designation	Superficial	- Unproductive.
		Bedrock	- Secondary A.
	Source Protection Zone (SPZ)		- Site is not within an SPZ.
	Groundwater Abstractions		- None within 500m.

Categories		Details
	Nearest Surface Water	- Woodhouse Lane Brook on site and Naden Brook denotes the southern site boundary. - 2 springs / wells thought to be present below the former Tack Lea site and 2 culverted watercourses thought to be present (1 on Tack Lea and 1 on Shepherd Mill).
	Flooding	- No risk from rivers or sea.
	Surface Water Abstractions	- On site – Tack Lea Works.
	Pollution Incidents	- None relating to the site.
Mining	Coal Authority	- A Coal Authority Ground Stability Report from 2004 was included in the Encia report. The report noted the site was not in a zone of likely physical influence on the surface from past or present underground workings, there were no records of shafts or adits within 20m of the boundary, no records of subsidence or lines of weakness. - A review of Coal Authority online viewer and WMS data indicates the site is NOT in a development high risk area. - No mineshafts are noted on or within 20m of the site boundary. - Site is NOT in a surface coal resource area.
Landfill sites	Known/Registered	- On site. Known as Woodhouse Mill:  - EA database indicates licenced to accept inert and industrial waste. - Rochdale Council search indicates this was done under planning permission for “reclamation, tipping and landscaping”. Existing settlement tanks filled on condition that building waste and subsoil from the curtilage of Woodhouse Mill should be used and no off-site import. GMWDA reported in May 1989 that they had no objection to the extension of time application and that the site had been operated to a satisfactory standard.
	Potential	- Number of former reservoirs on site. Former quarry 50m N appears to be a current reservoir.
Radon		- WMS mapping shows probability of 5-10% of homes in the 1km grid square are above Action Level. - Basic protection measures may be required.

Table 2-4: Summary of the environmental setting.

The Encia report stated that Japanese Knotweed was identified in parts of the Tenterhouse Mill site (i.e. off-site).

2.4 Site Reconnaissance

Encia 2005

A site reconnaissance was undertaken by Encia in 2005 and photographs and report extracts are provided in Plates 2-5 and 2-6 below.

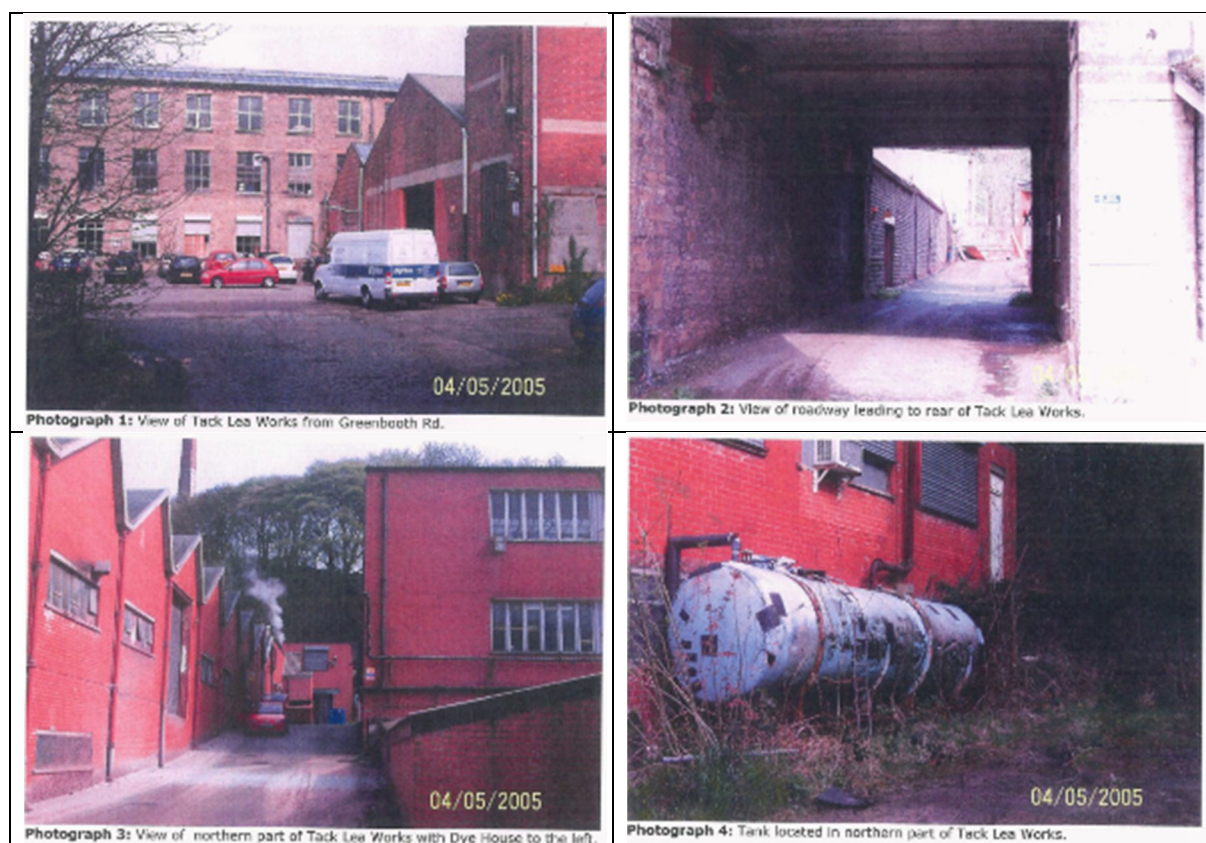
Area A – Tack Lea Works Site

- 2.2.4 Tack Lea Works comprises a textile dying and finishing mill, storage warehouses and a number of small industrial units which are leased to local small businesses including a garage and vehicle spraying workshop. A number of the buildings located adjacent to the Naden Brook have been constructed so as to "straddle" over the brook.
- 2.2.5 Access to the site is from Greenbooth Road located to the south east of the site. A stone bridge is present crossing the Naden Brook at the site entrance. A large concrete surfaced car park fronts the main mill building which comprises a three storey warehouse of mixed brick and stone construction with slate roofing. The dying and finishing works are located to the west of the main mill building. A narrow roadway leads to the rear of the buildings where a large storage tank and containers of dye stuffs, peroxides, antimony based chemicals and general bleaching chemicals were noted to be stored.
- 2.2.6 Anecdotal evidence indicates the presence of a culverted watercourse running in a south easterly direction beneath the mill building before discharging into the Naden Brook. It is considered possible that this culvert channels water rising from a spring beneath the mill building. Furthermore, it is understood that another 'spring' and stone lined well is located in the basement area of the dye house.
- 2.2.7 The northern part of the Tack Lea Works site is occupied by a steep hillside, vegetated by grass and mature trees with outcrops of sandstone and siltstone. The hillside rises up towards the north, with an approximate increase in elevation of 20m from the valley floor. A pond was previously located on the hillside. It was noted during the site walkover that the pond was dry and that the pond base had in fact been lined with concrete.
- 2.2.8 Immediately north of the mill building is a large disused coal bunker and hopper which were formerly used to supply the mill's coal fired boilers. A chimney located on the hillside approximately 50m to the north of the site boundary was used to release smoke emissions from the boilers via a 1.5m high brick constructed 'flue' which runs from the old boiler house, north over the hillside to the chimney. The flue was noted to have a large volume of ashy deposits inside.
- 2.2.9 The old boiler house, located in the eastern part of the mill building, was noted to now house an electricity sub-station and above ground fuel tank.
- 2.2.10 The eastern portion of the Tack Lea Works site is occupied by several disused filter beds which were formerly used to treat drainage from the mill building prior to discharge into the Naden Brook. It is understood that the current works are attached to the mains sewer drainage with an on-site pre-treatment facility located in the basement of the dye house.

Area C – Shepherd Mill

- 2.2.15 The Shepherd Mill area is located in the south eastern portion of the site and comprises a mixed tarmac and concrete covered car parking area and large single storey steel framed industrial unit (used recently as a distribution depot).
- 2.2.16 Conversations with the site owner indicate that a culvert is located beneath the mill building running in a north westerly direction before discharging into the Woodhouse Lane Brook.
- 2.2.17 To the north east of the car park and industrial unit lies a steep, densely vegetated slope. There is an approximate change in elevation of 15m from the car park to the hilltop. A 2.5m high brick retaining wall is located at the base of the slope. The wall appeared to be in poor condition.
- 2.2.18 To the south of the car park, the site slopes down to a stone retaining wall located alongside the Naden Brook. Anecdotal evidence suggests that demolition materials were deposited in this area following demolition of the old mill buildings. As such, deep fill deposits are expected to be present adjacent to the brook.
- 2.2.19 The site areas described above are shown on Drawing No 7112/2 in Appendix B to this report.

Plate 2-5: Extract from Encia report of site reconnaissance of Tack Lea Works and Shepherd Mill.



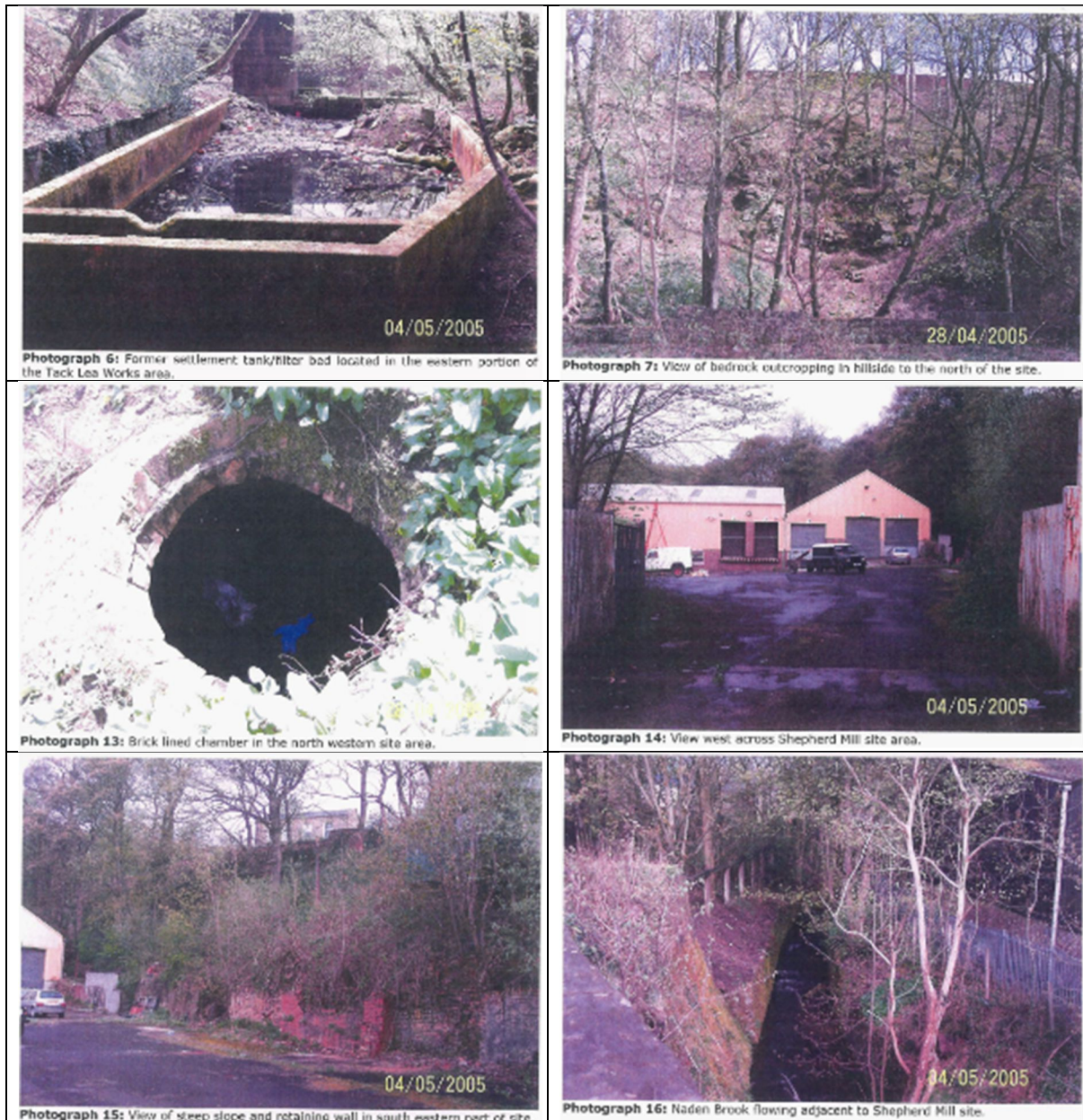


Plate 2-6: Photographs of Tack Lea Works and Shepherd Mill from Encia Report.

LKC 2020

LKC carried out a site reconnaissance on 16th July 2020 and observations are summarised below in Plates 2-7 and 2-8.

Tack Lea Works

	Former boiler house and garage remain extant.
	Remnant hardstanding in former Tack Lea works building. Boiler house visible. Compare to Encia photograph 1.
	Cleared former dye works building area. Compare to Encia Photograph 3.

	Former dyeworks looking towards Naden Brook (see visible building across the watercourse). Hardstanding and scrub vegetation.
	Substation to east of garage.
	View to north of garage. Brick building is adjoined to coal bunker at the upper level and has suspected asbestos cement roof.



Plate 2-7: Site Reconnaissance: Tack Lea Works.

Shepherd Mill

It was noted the Shepherd Mill site had been cleared of buildings. Hardstanding remained and the north eastern and western boundary (with Woodhouse Mill Brook beyond) were heavily vegetated.



	Hardstanding present on Shepherd Mill.
	Steep slope and vegetation to the north eastern boundary of Shepherd Mill. Compare to Encia photograph 15.

Plate 2-8: Site Reconnaissance: Shepherd Mill.

2.5 Contamination Sources / Pathways and Receptors

The contamination sources pathways and receptors identified in the Encia Report are shown in Plate 2-9.

Potential Source	Potential Pathway(s)	Potential Receptor
Inorganic contamination in Made Ground in infilled reservoirs and other areas of fill (including potential anthrax spores in area of former tannery)	Soil Ingestion Dust Inhalation Consumption of home grown vegetables Dermal Contact	Future residents Construction workers
Organic contamination (resulting from historical fuel spillages etc)	Soil Ingestion Dust Inhalation Vapour Inhalation Consumption of home grown vegetables Dermal Contact Consumption of contaminated water supply	Future residents Construction workers
Leachable or mobile contaminants in Made Ground	Leaching Infiltration Subsurface migration Leaching through culverts	Controlled Waters (surface water courses and minor aquifer)
Bio-degradable or organic rich materials in Made Ground within infilled reservoirs and landfilled areas	Hazardous gas accumulation and migration	Future on site Buildings and Future Residents
Bio-degradable or organic rich materials in Made Ground within infilled reservoirs and former 'refuse tip' located within close proximity to site.	Hazardous gas accumulation and migration	Future on site Buildings and Future Residents

Plate 2-9: Extract from Encia report of potential sources, pathways and receptors.

Encia also provided diagrammatical conceptual site models and these are provided in Appendix C.

Based on the information provided in the Encia report and available public domain information LKC consider Radon and specific SVOCs/VOCs from dyeworks, bleach works, and spray booth / vehicle repair, PCBs and mineral oils should be considered as potential contamination sources / types.

For potential receptors, construction workers should be considered separately and outside this assessment under project health and safety requirements as they are a short-term risk. Additional receptors should include adjacent residents, potable water pipes and flora.

The updated potential contamination sources are detailed in Table 2-10.

Source	Contaminants
Onsite Made Ground (infilled reservoirs, general made ground, unrecorded made ground associated with surrounding industries, onsite fly-tipping)	- Ash and clinker (e.g. from hearths and boilers, often historically used for site raising / levelling): Heavy metals, sulphates and PAHs. - Other unknown inorganic / organic contaminants (dependant on fill material source and surrounding industries). - Asbestos-containing material (ACM) may be present on site. - If organic / putrescible material: Hazardous gas (principally carbon dioxide and methane).

Source	Contaminants
Onsite Former Car Park, repair garage / spray booth, tanks.	- Spillages / leakages: petroleum hydrocarbons, oils (source expected to be minimal and localised). - VOCs from spray booth / repair (source expected to be minimal and localised).
Bleach works, tannery, dyeworks including boiler house	- Anthrax (former tannery). - Boiler ash (heavy metals, sulphates and PAHs), Asbestos may have been used within the building as insulation and lagging or as roofing and cladding. - Metals, other inorganic compounds (e.g. cyanides, sodium compounds, sulphide compounds, chloride compounds, mineral acids, alkalis), chlorinated organic solvents, water repellents, soaps and detergents.
Onsite landfill site	- ACM, Heavy metals, sulphate and PAHs (from site demolition rubble, clinker mortar).
Demolished buildings	- Asbestos Containing Material (ACM).
Electricity Sub Station	- Polychlorinated biphenyl (PCBs) and transistor oils.
Surrounding Industries (MOT vehicle garage to the east, industrial estate to the south)	- Spillages / leakages: petroleum hydrocarbons, oils (source expected to be minimal and localised). - Other organic and inorganic contaminants. - Industrial estate to the south not expected to be a significant source due to distance from site.
Underlying Haslingden Flags.	- Radon.

Table 2-10: Potential contamination sources

Potential receptors are detailed in Table 2-11.

Receptors	
Human Health	- Future site users (including residents and visitors). - Offsite land users.
Controlled Waters	- Secondary A Aquifer and surface watercourse.
Buildings and structures.	
Potable water pipes.	
Flora within future gardens/landscaping.	

Table 2-11: Potential receptors

Potential pathways are detailed in Table 2-12.

Pathways		
Soil	Human Health ¹ (residential land use: houses with private gardens)	- Ingestion of soil. - Ingestion of soil-derived indoor dust. - Ingestion of contaminated vegetables. - Ingestion of soil attached to vegetables - Dermal contact with soil. - Dermal contact with soil-derived indoor dust. - Inhalation of soil-derived outdoor dust. - Inhalation of soil-derived indoor dust. - Inhalation of vapours outside. - Inhalation of vapours inside.
		- Windblown dust / fibres to adjacent receptors.
		- Direct contact with receptors (building foundations, services).
		- Root uptake.
Water		- Surface run-off over impermeable surface. - Site is relatively flat and vegetated; therefore, surface run-off will be limited.

¹ EA (2008). "Updated Technical Background to the CLEA Model." Science Report – SC050021/SR3.

	- Infiltration into the ground, through potentially contaminated material (contamination possibly going into solution).
	- Site is predominantly vegetated; therefore, infiltration is likely.
	- Migration through potentially permeable strata and preferential pathways.
	- Superficial (Till) likely to be low permeability.
Gas	- Bedrock (sandstone) likely to variable permeable.
	- Preferential pathways: culverts.
	- Migration through potentially permeable strata and preferential pathways.
	- Superficial (Till) likely to be low permeability.
	- Bedrock (sandstone) likely to variable permeable.
	- Preferential pathways: culverts.
	- Migration into buildings (e.g. via services) and accumulation of gases in confined spaces (potentially causing explosion if methane is present).

Table 2-12: Potential pathways

2.6 LKC Preliminary Contamination Conceptual Model

The preliminary contamination conceptual model in the Encia report has been updated to be in line with LKC current risk assessment methodology (detailed below). The model is based on the contamination sources, pathways and receptors identified in the original report. However, LKC consider additional contamination sources and potential pathways should be considered, which are detailed in Table 2-9 to Table 2-11.

The preliminary contamination conceptual model using contaminant-pathway-receptor linkages based on guidance in CLR11² has been summarised in Table 2-12.

The aim of the conceptual model is to provide a preliminary assessment of the likelihood of a pollutant linkage for each potential combination of contaminant, pathway and receptor. A conceptual model can be used to make an informed decision on the contamination risks associated with the site and determine what site investigation work is required.

The preliminary contamination conceptual model has identified seven generic potential pollutant linkages. Each linkage is described along with an assessment of the risk based upon guidance on probabilities and consequences outlined in CIRIA C552³.

In order to assess the potential risk for each pollutant linkage, an assessment of the magnitude of the potential consequence (severity) of the risk occurring and the magnitude of the probability (likelihood) of the risk occurring has been considered and classified. This is based on the guidance provided in CIRIA C552 and further details including a risk matrix is provided in Appendix D.

Where LKC identified a low to very low risk, limited intrusive investigation work, a watching brief (during construction work) or no investigation work will be recommended. This will be dependent on the nature of the site and the proposed development.

Where the risk falls into the moderate/low risk, LKC will undertake an assessment to establish what category the pollutant linkage will fall into (i.e. moderate or low risk will be chosen).

² EA (2004). "Model Procedures for the Management of Land Contamination." R&D Publication CLR 11.

³ CIRIA (2001). "Contaminated land risk assessment: A guide to good practice". C552.

Where LKC identifies a moderate or higher risk, intrusive work or precautionary remedial measures will be recommended.

The conceptual model is based on the future use of the site (post development), in line with proposed development scheme.

It should be noted that there may be risk from short term exposure from contaminated soil to site workers during development work. The Preliminary Contamination Conceptual Model deals with long term exposure to key receptors associated with the future use of the site. Acute risks can be easily mitigated by good environmental management of the site during site works. Standard health and safety precautions (as per HSE guidance⁴) should be adopted by all workers involved with site enabling and construction works. Therefore, this receptor is not considered in the contamination conceptual model.

⁴ HSE (1991). "Protection of Workers and the General Public During Development of Contaminated Land" London HMSO.

Land at Greenbooth Road, Norden
Geoenvironmental Risk Assessment & Remediation Strategy

PL	Pathway	Receptor	Contaminants of Concern (CoC)	Probability	Consequence	Risk	Recommendations
1	- Dermal contact. - Inhalation of soil, fibres and dust. - Ingestion of soils, dust, vegetables, soil attached to vegetables. - Windblown dust.	- Future site users. - Offsite receptors.	- ACM. - Heavy metals. - PAHs. - VOCs/SVOCs	Likely (given site history, site conditions and proposed end use)	Medium	Moderate	Intrusive investigation required. Soil analysis of CoC.
			- Petroleum hydrocarbons.	Likely (localised around sources such as parking, garage and former fuel tank.	Medium	Moderate	Targeted intrusive investigation required. Soil analysis of CoC, subject to ground conditions encountered.
			- Anthrax - PCBs	Low Likelihood (localised given site history, site conditions and proposed end use)	Medium	Moderate / Low (moderate assumed given sensitivity of end use)	Targeted intrusive investigation required. Soil analysis of CoC.
2	- Inhalation of vapours. - Migration via permeable strata and preferential pathways.	- Future site users. - Offsite receptors.	- Volatile contaminants (TPHCWG, SVOC, VOCs).	Likely	Medium	Moderate	Intrusive investigation required. Soil analysis of CoC.
3	- Inhalation of gas. - Migration via permeable strata and preferential pathways. - Explosion in confined spaces. - Exposure to radon.	- Future site users. - Buildings. - Offsite land users.	- Hazardous gas (carbon dioxide, methane).	Likely (given viable gas source and viable pathway)	Severe	High	Gas monitoring required.
			- Radon	Likely (as 5-10% of homes above action level)	Medium	Moderate	(5-10%) Basic radon protective measures are necessary in the construction of new dwellings or extensions.
4	- Surface run-off. - Migration via permeable strata and preferential pathways. - Perched waters migration.	- Groundwater (Secondary A Aquifer). - Surface watercourses.	- Mobile contaminants such as metals, PAHs, hydrocarbons, volatile compounds.	Likely (mobile contamination anticipated with possible pathway)	Medium	Moderate	Intrusive investigation required. Groundwater and surface water sampling. Analysis for CoC.
5	- Sulphate attack on concrete.	- Building structure.	- Sulphate.	Likely (given site history, site conditions, and direct contact / pathway)	Mild	Moderate / Low (moderate assumed until ground conditions confirmed)	Intrusive investigation required. Soil analysis of CoC.
6	- Ingestion of tainted water supply.	- Future site users. - Water pipes.	- Organic contaminants such as petroleum hydrocarbons, naphthalene, volatile compounds.	Likely (given site history, site conditions and direct contact / pathway)	Medium	Moderate	Intrusive investigation required. Soil analysis of CoC.
7	- Direct contact (plant uptake).	- Flora.	- Phytotoxic contaminants such as heavy metals.	Likely (given site history, site conditions and proposed end use)	Minor	Low	Intrusive investigation required. Soil analysis of CoC.

Table 2-12. Preliminary Contamination Conceptual Model.

3 Ground Investigation

3.1 Site Investigation Design and Methodology

Encia provided a site investigation strategy and this provided in Plate 3-1.

Exploratory holes	Purpose
Hand Excavated Pits	To gather soil samples for chemical analysis in areas which are inaccessible to excavators or drilling rigs (i.e. steep slopes and densely vegetated areas).
Trial Pits	To determine the general nature of near surface soils underlying the western and southern portions of the site (former Tenterhouse Mill area), including the: - Nature, distribution and thickness of Made Ground. - Nature, degree and extent of contamination. - Proportion of undesirable elements e.g. biodegradable matter, relict foundations etc. - Suitability of the ground for founding structures and highways.
Exploratory holes	Purpose
Cable Percussive Boreholes	To determine the nature and depth of deep fill materials across the site and in the former reservoir areas to determine: - Nature, distribution and thickness of Made Ground. - Nature, degree and extent of contamination. - Retrieve geotechnical data from depth for foundation design. - Install monitoring wells across the site in order to determine groundwater levels and monitor for hazardous gas.
Window sample Holes	To determine the general nature of soils underlying the existing buildings located across the central and southern portion of the site and investigate the: - Nature, distribution and thickness of Made Ground. - Nature, degree and extent of contamination. - Proportion of undesirable elements e.g. biodegradable matter, relict foundations etc. - Suitability of the ground for founding structures and highways. - To install gas/groundwater monitoring wells around the site and within infilled reservoirs and around fuel storage tanks.

Plate 3-1: Site investigation strategy.

The investigation was carried out in April and May 2006. The following works were carried out on the study site:

Tack Lea Works

- 3no. hand dug trial pits (HD1, HD5 and HD6).
- 14no. window sample boreholes (WS1, WS4-WS16).
- 2no. cable percussion boreholes (BH1 and BH2).

Shepherd Mill

- 1no. hand dug trial pit (HD7).
- 11no. window sample boreholes (WS17, WS17A, WS18-WS24, WS24A and WS25).
- 3no. cable percussion boreholes (BH10-BH12).

Profile logs are provided in Appendix E. These include details of insitu testing, contamination and geotechnical soil sampling and well installations.

Sampling locations are illustrated on Figure 3.

Certificates of analysis for the soil contamination testing are provided in Appendix F.

3.2 Water Sampling / Leaching Testing

Groundwater and surface water samples were collected, and these are summarised below:

Tack Lea Works

- » Surface water samples were collected from Naden Brook (W1 to W3)
- » Groundwater was collected from WS5 and WS12.
- » Leaching tests were carried out on soil samples from HD1, BH2, WS4, WS6, WS8, WS9, WS11 and WS12.

Shepherd Mill

- » Surface water samples were collected from Naden Brook (W4) and the setline tank / reservoir (W5).
- » Groundwater was collected from BH10, BH12, WS19.
- » Leaching tests were carried out on soil samples from WS17A ,WS19, WS20, WS21 and WS25.

Certificates of analysis for groundwater, surface water and leaching tests are provided in Appendix F.

3.3 Gas Monitoring

Gas monitoring was carried by Encia in selected boreholes. The results are provided in Appendix G and a risk assessment of hazardous gas and ground gas is provided in Section 5.3.

4 Ground Conditions

4.1 Summary

Encia provided a commentary on the encountered ground conditions and this is provided in Plate 4-1 below.

8.2 Hardstandings

- 8.2.1 Concrete hardstanding was encountered in the majority of exploratory hole positions located both internally and externally in the Tack Lea Works and Shepherd Mill areas. Some smaller isolated areas of concrete were also located in the western and southern portions of the site, adjacent to Greenbooth Road.
- 8.2.2 The concrete was generally found to be approximately 0.2m to 0.3m thick and in good condition. However, in WS7, WS13 and WS14 (located beneath the main Tack Lea Works building) the concrete floor slabs were found to vary in thickness from 0.7m to 1.1m.
- 8.2.3 Tarmac hardstanding was encountered in the car parking area to the east of the Shepherd Mill building. The tarmac was typically 0.1m thick.

8.3 Made Ground

- 8.3.1 Made Ground was encountered in all exploratory hole locations, reaching a maximum depth of 5.6m in BH4. It should be noted however that the base of the Made Ground strata could not be determined in a number of positions due to the presence of obstructions. As such, locally deeper Made Ground may present in these areas.
- 8.3.2 The Made Ground soils were generally shallowest (<1.0m) in elevated locations above the valley floor. In and around the buildings of Tack Lea Works in the central portion of the site, the Made Ground deposits were generally between 1.0m and 2.0m thick, although deeper pockets of fill were encountered in the former boiler house and around the filter beds to the east. In these areas, Made Ground was found to range from 2.2m to 5.0m. The deepest Made Ground soils were found in the Shepherd Mill (former reservoir areas) and former Tenterhouse Mill areas (possible former basements) where the fill was typically in excess of 2.5m.
- 8.3.3 The Made Ground on site generally comprised a heterogeneous mixture of materials, however the majority of the Made Ground can be categorised as one of three broad types:
- Made Ground Type 1 - Reworked Natural Soils*
- 8.3.4 Made Ground Type 1 consists typically of granular or cohesive deposits with occasional cobbles of sandstone. Minimal potentially contaminative fragments were noted to be present (i.e. ash or clinker). These deposits were generally found to be present at shallow depth in undeveloped, vegetated and wooded areas in the northern and eastern parts of the site and at depth beneath the southern and western site areas. This fill type is considered 're-worked' natural material.
- Made Ground Type 2 - Mixed Granular and Cohesive Ashy Fill*
- 8.3.5 Made Ground Type 2 comprises both granular and cohesive fill, containing fragments of ash, clinker, brick and concrete etc. This Made Ground type was found to be present at various depths across much of the central, western and southern parts of the site.
- Made Ground Type 3 - General Demolition Material*
- 8.3.6 Made Ground Type 3 comprises predominantly coarse fragments of concrete, brick and

	sandstone with many cobbles and boulders. This fill type has been interpreted as general demolition material and was found to be most extensive in the southern, western and south eastern parts of the site (Tenterhouse Mill and Shepherd Mill areas).
8.3.7	There are a number of infilled ponds/reservoirs at the site which comprise a mixture of Made Ground materials as described above.
8.4	Natural Ground
	<i>Drift Strata</i>
8.4.1	Natural drift strata were encountered in sixteen exploratory holes located across the entire site. In the Shepherd Mill and Tack Lea areas, drift deposits were found to be absent in some locations. Where drift strata were encountered, they typically comprised gravelly clay with cobbles of sandstone and saturated fine to coarse sand and gravel, extending vertically to depths of approximately 2.0m to 4.0m.
8.4.2	Drift deposits were found to be more extensive, both laterally and vertically to the south and west of the Naden Brook (in the Tenterhouse Mill area). In this area, the drift strata comprised interbedded gravelly clay with sandstone cobbles and medium dense saturated fine to coarse sand and gravel overlying 'stiff' to 'very stiff' sandy gravelly clay (Glacial Till). In this part of the site, the drift deposits were found to extend to depths in excess of 15.0m.
	<i>Solid Strata</i>
8.4.3	Bedrock was encountered in nine exploratory hole positions (BH1, BH2, BH9, BH11, WS1, WS2, WS13, WS14 and WS14) at depths ranging from 0.1m to 8.2m.
8.4.4	To the north of the Tack Lea Works, bedrock can be seen outcropping in the hillside. As such, beneath the central and western portions of the Tack Lea site, bedrock was found at shallow depth (typically less than 1.0m).
8.4.5	To the east of the Tack Lea Mill buildings and in the Shepherd Mill area of the site, bedrock was found to be deeper and was encountered at depths ranging from 4.3m (BH11) to 5.0m (BH2).
8.4.6	To the south and west of the Naden Brook (in the Tenterhouse Mill area) bedrock was only encountered in one borehole (BH9) at 8.2m. Two boreholes (BH3a and BH6) drilled in this part of the site were advanced to greater depths in order to determine the depth to bedrock. The boreholes were terminated at 15.0m and 17.6m respectively in very stiff gravelly clay deposits.

Plate 4-1: Extract from Encia report on ground conditions.

4.2 Visual and Olfactory Evidence of Organic Contamination

An extract from the Encia report is provided in Plate 4-2.

Location	Site Area	Material	Depth (m) bgl	Observation
BH10	Shepherd Mill	Mixed Ashy Fill	0.2 to 2.0	Slight hydrocarbon odour in soils
BH10	Shepherd Mill	Demolition	2.0 to 2.5	Strong hydrocarbon odour in groundwater
BH12	Shepherd Mill	Mixed Ashy Fill	0.3	Slight hydrocarbon odour in perched groundwater strike
BH12	Shepherd Mill	Demolition	2.0 to 3.5	Very strong hydrocarbon odour in water strike at 2.0m
WS19	Shepherd Mill	Mixed Ashy Fill	0.2 to 3.5	Strong hydrocarbon odour in soils
WS19	Shepherd Mill	Natural Clay	3.5 to 4.3	Strong hydrocarbon odour in soils
WS21	Shepherd Mill	Mixed Ashy Fill	0.3 to 1.2	Very strong hydrocarbon odour in soils
WS25	Shepherd Mill	Mixed Ashy Fill/Demolition	0.2 to 1.8	Strong hydrocarbon odour in soils
TP106	Tenterhouse Mill	Mixed Ashy Fill	1.4 to 1.8	Strong hydrocarbon odour

Plate 4-2: Extract from Encia report on visual and olfactory evidence of contamination.

4.3 Groundwater

Encia noted perched groundwater within the Made Ground in BH2 during drilling at shallow depth with “true” groundwater struck in WS4 and WS5.

A summary of groundwater levels collected during monitoring visits is provided in Table 4-3.

LOCATION	Borehole Elevation (mAOD)	Water Level (mbgl)	Max. Elevation of GW (MAOD)	Evidence of Contamination?
BH2	164.5	2.7-3.1	161.8	No
WS4	163.55	0.9-1.5	162.65	No
WS5	164.45	2.1	162.35	No
WS6	163.95	DRY	N/A	No
WS12	163.9	1.6-1.8	162.3	No
BH10	161.1	2.2	158.9	Strong odour
BH11	161.4	3.2-4.5	158.2	No
BH12	160.95	1.9-2.0	159.05	Strong odour
WS17A	162.5	4.8	157.7	No
WS19	163.4	1.9-2.2	161.5	In soils

Table 4-2: Summary of water strike depths.

5 Generic Risk Assessment

5.1 Introduction

Current good practice requires that the findings from a site investigation should be evaluated on a site-specific basis, using a risk-based approach. Risk assessment involves identification and evaluation of the hazards presented by the concentrations of contaminants measured followed by an evaluation of the risks which are associated with these hazards (CLR11⁵). Information gathered from the risk assessment has been collated in the revised contamination conceptual model in Section 5.6.

5.2 Soil Risk Assessment

5.2.1 Methodology

With regards to the soil risk assessment LKC will use the following hierarchy:

- Category 4 Screening Levels (C4SLs).
- LQM Suitable 4 Use Levels (S4ULs).
- CL:AIRE Generic Assessment Criteria (GACs).

C4SLs were published in 2013^{6,7}. The recent change to the contaminated land guidance has changed the evaluation of risk from 'minimal' (referred to as Health Criteria values (HCVs))⁸ used to generate Soil Guideline Values (SGVs) to 'low' (referred to as Lowest Level of Toxicological Concern (LLTCs)). The policy companion document and supporting letter by Defra, dated 3rd September 2014, states that C4SLs '*could be used under the planning regime, as well as within Part 2A*'. Based on these comments LKC considers the justifications and assumptions used to generate 'low' risk are suitable for the planning regime.

Where no C4SLs have been generated LKC will use the LQM S4ULs⁹. Similar assumptions and land uses to C4SLs have been used. However, toxicological information has been based on 'minimal risk' as per previous guidelines and assumptions^{10,11,12,13}.

If contaminants are not present as C4SLs and S4ULs then LKC will use ATRISK SSVs or CL:AIRE GACs¹⁴. These follow the 'minimal' risk principle and more stringent exposure parameters and will be conservative.

LKC consider the main risk drivers for PAHs are benzo(a)pyrene (B(a)P) and naphthalene. This is due to B(a)P possibly being a carcinogen and most toxic of the

⁵ EA (2004). "Model Procedures for the Management of Land Contamination." R&D Publication CLR 11.

⁶ Defra (2014). "SP1010: Development of Category 4 Screening Levels and Assessment of Land Affected by Contamination – Policy Companion Document."

⁷ CL:AIRE (2013). "SP1010: Development of Category 4 Screening Levels and Assessment of Land Affected by Contamination – Final project Report."

⁸ EA (2008). "Human Health Toxicological Assessment of Contaminants in Soils." Science Report – SC050021/SR2.

⁹ LQM (2014). "The LQM/CIEH S4ULs for Human Health Risk Assessment."

¹⁰ EA (2008). "Updated Technical Background to the CLEA Model." Science Report – SC050021/SR3.

¹¹ EA (2008). "Human Health Toxicological Assessment of Contaminants in Soils." Science Report – SC050021/SR2.

¹² EA (2008). "A Review of Body Weight and Height Data used within the Contaminated Land Exposure Assessment Model (CLEA)." Project SC050021/Technical Review 1.

¹³ EA (2009). "Compilation of Data for Priority Organic Pollutants for Derivation of Soil Guideline Values." Science report SC050021/SR7.

¹⁴ CL:AIRE (2009). "The Soil Generic Assessment Criteria for Human Health Risk Assessment."

PAHs^{15,16} and naphthalene the most volatile and soluble¹⁷. The new C4SLs indicate B(a)P as a surrogate marker for carcinogenic PAHs, if it falls within appropriate limits, since the risk from other non-carcinogenic PAHs are considered negligible¹⁸. For B(a)P to be used as a surrogate marker it should follow the profile described by the HPA (2008)¹⁹ and CL:AIRE (2013). Naphthalene will be treated separately using the LQM S4ULs.

The proposed development is for residential houses with gardens. LKC consider the assessment criteria for residential with the consumption of homegrown produce to be most appropriate to use.

All criteria have been generated using the CLEA V1.06 model²⁰ based either on 1%, 2.5% and 6% Soil Organic matter (SOM).

It should be noted the Encia investigation did not include SOM or TOC testing, therefore results will be compared to the most conservative criteria of 1% SOM.

A summary of the generic assessment criteria is provided in Appendix H.

B(a)P as Surrogate Marker

Based on the above assumption for PAHs, LKC undertook an assessment of the data for the site with regards to using B(a)P as a surrogate marker for carcinogenic PAHs as per HPA and CL:AIRE guidelines. The primary toxicological study related to Culp *et al.*²¹, which was based on coal tar mixtures (>80,000mg/kg of total PAHs) fed in food to mice over a two-year carcinogenicity study.

Graph 5-1 summarises the study site data with respect to how the ratios of carcinogenic PAHs relate to B(a)P, within the confidence limits provided in the HPA document.

¹⁵ EA (2002). "Contaminants in Soils: Collation of Toxicological Data and Intake Values for Humans. Benzo[a]pyrene." R&D Publication TOX2.

¹⁶ USEPA (1984). "Health Effects Assessment of Polycyclic Aromatic Hydrocarbons (PAHs). EPA 540/1-86-013."

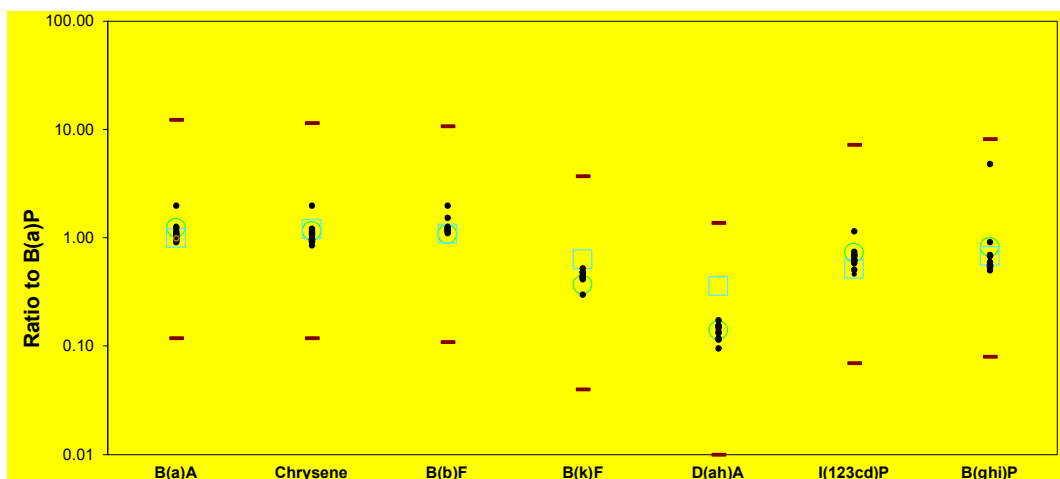
¹⁷ EA (2003). "Review of the Fate and Transport of Selected Contaminants in the Soil Environment." Draft technical report P5- 079/TR1.

¹⁸ CL:AIRE (2013). "SP1010: Development of Category 4 Screening Levels and Assessment of Land Affected by Contamination – Final project Report."

¹⁹ HPA (2010). "HPA Contaminated Land Information Sheet: Risk Assessment Approaches for Polycyclic Aromatic Hydrocarbons (PAHs)." Version 3.

²⁰ EA (2008). "CLEA Software (Version 1.05) Handbook." Science Report – SC050021/SR4.

²¹ Culp, S; Gaylor, D; Sheldon, W; Goldstein, L and Beland, F (1998). "A Comparison of Tumours Induced by Coal Tar and Benzo-a-pyrene in a 2-Year Bioassay." Carcinogenesis. Vol 19, no. 1, pp. 117-124.



Graph 5-1: The ratio of PAH to B(a)P in soil for all available data at the site based on 15 samples (where values were >LOD to allow the calculation of a ratio).

Notes:

B(a)P = Benzo(a)pyrene; D(ah)A = Dibenzo(ah)anthracene; B(a)A = Benzo(a)anthracene; B(b)F = Benzo(b)fluoranthene;

B(k)F = benzo(k)fluoranthene; I(123cd)P = Indeno(123cd)pyrene; B(ghi)P = Benzo(ghi)perylene

● = Ratio to B(a)P for all data ○ = Mean ratio to B(a)P for Culp data △ = Mean ratio to B(a)P from all data at the site

□ = Mean ratio to B(a)P for UK data presented by HPA — = Upper and Lower limits (order of magnitude from Culp data)

All the data points that could be used to calculate ratios fall inside the upper or lower limits.

Based on this distribution of data LKC considers B(a)P can be used as a surrogate marker for carcinogenic PAHs and the C4SL criteria is suitable for this dataset.

Other Contaminants with no C4SLs, LQM S4ULs or CL:AIRE GACs

Where generic assessment criteria have not been derived (mainly due to insufficient toxicological data), the results were compared against contaminants of assumed likely similar toxicity (with some conservatism) as shown below:

- Naphthalene derivatives will be compared to relevant S4UL (1% SOM) for naphthalene. LKC considers this appropriate given that the guidance provided on the ATSDR website²² indicates that the oral toxicity of 2-methylnaphthalene is within an order of magnitude to that of naphthalene, although it was unknown what an appropriate inhalation reference dose is.

5.2.2 Soil Results Comparison against Assessment Criteria

Chemical analysis data from the site investigation undertaken by Encia within the study site have been used for the risk assessment. All analysis sheets are presented in Appendix F. Elevated and pertinent results are presented in Table 5-2.

²² ATSDR (2005). Public Health for naphthalene, 1-methylnaphthalene and 2-methylnaphthalene.

Contaminant	Units	Elevated Results	Sample Location	Criteria (1% / 6%SOM)	Source
Lead	mg/kg	205	HP7 0.25m	200	C4SL
		538	WS5 0.7m		
		4474	WS9 0.5m		
		492	WS10 0.4m		
		220	WS25 0.7m		
PAHs					
B(a)P (used as a surrogate marker)	mg/kg	5.71	BH10 1.0m	2.2 / 3.0 5 (6% only)	S4UL C4SL
		28.19	WS10 0.4m		
		28.16	WS12 0.7m		
		4.877	WS12 0.8m		
		19.71	WS22 0.7m		
		19.905	WS19 0.4m		
		3.03	WS19 0.9m		
		14.27	WS24A 0.3m		
Naphthalene	mg/kg	3.83	WS12 0.7m	2.3 / 13	S4UL
		11.33	WS19 0.9m		
		5.06	WS19 3.7m		
		13.83	WS21 0.5m		
		4.24	WS22 0.7m		
		62.402	WS19 0.4m		
		6.18	WS19 0.8m		
		3.33	WS25 0.5m		
2-methyl naphthalene	mg/kg	30.592	WS19 0.4m		
		4.511	WS25 0.5m		
TPHs					
Aromatic C16-21	mg/kg	282	BH10 1.0m	260 / 930	S4UL
		484	WS19 0.4m		
Aromatic C21-35	mg/kg	2543	WS19 0.4m	1100 / 1700	
VOCs					
1,2,4-Trimethylbenzene	mg/kg	1.704	WS19 0.4m	0.35 / 2.0	GAC
GENERAL					
pH	pH		Range 4.26 to 10.56		
Asbestos	N/A		Detected (see Table 5-4)		
Anthrax	N/A		None detected.		

Table 5-2: Summary of elevated and pertinent analytical results.

Notes:

Only results that exceeded assessment criteria have been shown and results from **all depths** are noted. Results have been compared to the nearest appropriate SOM.

Elevated results have been identified for lead, benzo(a)pyrene (used as a surrogate marker), naphthalene, 2-methylnaphthalene, aromatic TPHs and 1,2,4-trimethylbenzene.

No incidences of volatile TPH fractions, PCBs or anthrax spores were detected.

Asbestos was identified, as detailed in Table 5-3.

Sample Location	ID	Comments
WS18 0.6-0.7m	Amosite	Visible in soil and confirmed by laboratory
WS10	Cement (likely chrysotile)	Noted as visible at surface in profile log. Material not tested.

Table 5-4: Details of asbestos identified and suspected.

5.2.3 Direct Contact Risk – Pollutant Linkage 1

Elevated results have been identified for lead, PAHs (benzo(a)pyrene used as a surrogate marker) and aromatic TPHs.

The source of the contamination is expected to the ash, clinker and demolition materials noted in the made ground.

In addition, asbestos fibres were detected in one location and pieces of suspected asbestos cement were identified at the surface of another sampling location.

At the concentrations identified, the contaminants are considered to pose a potential risk to future site users (residents) in gardens and soft landscaped areas, where made ground may be exposed / in contact with vegetables. The principal pathways are the ingestion pathways (soil, dust and vegetables) and dermal contact.

The probability of metal contamination in the made ground affecting site users is likely. With a medium consequence, the risk is considered to be moderate and remediation is recommended.

PAHs and Petroleum Hydrocarbons

Elevated PAHs (benzo(a)pyrene used as a surrogate marker) were identified in made ground samples across the site.

The elevated aromatic TPH concentrations were located in the Shepherd Mill area where visual and olfactory evidence of hydrocarbons was also noted.

At the concentrations identified (TPH is likely heavy-end), the contaminants are considered to pose a risk to future site users (residents). The principal pathways are the ingestion pathways (soil, dust and vegetables) and dermal contact.

The probability of PAHs and heavy end petroleum hydrocarbons posing a risk to site users is considered to be likely. With a medium consequence, the risk is considered to be moderate and remediation is recommended.

The risk associated with the inhalation of vapours is discussed in Section 5.2.4 below.

Asbestos

Asbestos (chrysotile) was identified in WS18 at 0.6-0.7mbgl and was suspected on the surface at WS10.

The source of the asbestos is likely to be from demolition materials and may be present in other locations on the site.

The probability of asbestos fibres posing a risk to site users is considered to be likely. With a medium consequence, the risk is considered to be moderate and remediation is recommended.

Additional consideration should also be given to the risk to workers and offsite receptors during groundworks and construction. This is discussed further in Section 8.

5.2.4 Risk from Inhalation of Vapours – Pollutant Linkage 2

Elevated naphthalene and 2-methylnaphthalene were identified in a number of samples of the made ground across Shepherd Mill and in one location on Tack Lea works (WS12). In addition, elevated 1,2,4-trimethylbenzene was encountered in the made ground in WS19. This is on a highly conservative assessment of 1% SOM. It is likely the SOM of the site soils is much higher.

Despite the visual and olfactory evidence of contamination in the Shepherd Mill area, no elevated potentially volatile <C16 TPH fractions were identified.

The elevated concentration in WS12 was 3.83mg/kg on an assumed 1% SOM. It is likely the SOM is closer to 6% which has an assessment criterion of 13mg/kg.

The probability of vapours from naphthalene posing a risk to site users is considered to be likely across Shepherd Mill and localised on Tack Lea Works. With a medium consequence, the risk is expected to be moderate and remediation in these parts of the site is recommended.

No remediation with regards to Pollutant Linkage 2 is required elsewhere on site.

5.3 Gas Risk Assessment

Gas monitoring was undertaken by Encia between 10th May 2006 and 19th June 2006. The results are provided in Appendix G and are summarised in Table 5-5 below.

Boreholes	Visit	CH ₄ (%v/v)	CO ₂ (%v/v)	O ₂ (%v/v)	Flow (l/h)	Groundwater (mbgl)	Pressure (mb)
BH2	1	<0.1	<0.1	20.8	0.6	2.85	1001 (f)
	2	<0.1	<0.1	20.5	<0.1	2.76	963 (r)
	3	<0.1	<0.1	20.6	0.2	2.74	1005 (r)
	4	<0.1	<0.1	20.6	0.6	2.79	1006 (r)
	5	<0.1	<0.1	20.7	0.6	2.88	995 (r)
	6	<0.1	<0.1	20.7	<0.1	3.08	984 (r)
WS4	1	<0.1	1.3	16.7	0.3	1.46	1001 (f)
	2	<0.1	0.4	19.3	<0.1	0.86	963 (r)
	3	<0.1	<0.1	20.8	0.1	1.38	1005 (r)
	4	<0.1	2.0	13.5	0.2	1.46	1006 (r)
	5	<0.1	2.9	10.9	<0.1	1.34	995 (r)
	6	<0.1	3.5	10.8	<0.1	1.42	984 (r)
WS5	1	<0.1	0.6	18.0	<0.1	2.07	1001 (f)
	2	<0.1	0.1	20.5	<0.1	2.06	963 (r)
	3	<0.1	0.1	20.6	<0.1	2.08	1005 (r)
	4	<0.1	0.3	19.9	<0.1	2.08	1006 (r)
	5	<0.1	0.5	19.7	0.1	2.10	995 (r)
	6	<0.1	0.6	19.3	<0.1	2.13	984 (r)
WS6	1	<0.1	0.2	20.7	0.2	DRY	1001 (f)
	2	<0.1	0.1	20.1	<0.1	DRY	963 (r)
	3	<0.1	<0.1	20.7	<0.1	DRY	1005 (r)
	4	<0.1	<0.1	20.5	0.1	DRY	1006 (r)
	5	<0.1	<0.1	20.5	0.1	DRY	995 (r)
	6	<0.1	<0.1	20.6	0.2	DRY	984 (r)
WS12	1	<0.1	<0.1	20.8	0.1	1.73	1001 (f)
	2	<0.1	<0.1	20.6	<0.1	1.64	963 (r)
	3	<0.1	<0.1	20.8	<0.1	1.74	1005 (r)
	4	<0.1	<0.1	20.8	<0.1	1.75	1006 (r)
	5	<0.1	<0.1	20.5	0.2	1.77	995 (r)
	6	<0.1	<0.1	20.6	0.2	1.79	984 (r)
BH10	1	<0.1	1.4	18.6	<0.1	2.18	1001 (f)
	2	<0.1	0.6	19.2	0.3	DRY	963 (r)
	3	NO ACCESS					
	4	<0.1	1.8	17.5	0.1	2.21	1006 (r)
	5	NO ACCESS					
	6	<0.1	0.7	18.6	<0.1	2.19	984 (r)
BH11	1	<0.1	1.6	18.2	<0.1	3.93	1001 (f)
	2	<0.1	2.2	16.6	<0.1	3.22	963 (r)
	3	NO ACCESS					
	4	<0.1	1.3	19.3	<0.1	3.73	1006 (r)
	5	NO ACCESS					
	6	<0.1	2.5	15.3	0.1	4.52	984 (r)
BH12	1	<0.1	3.5	13.5	0.2	1.97	1001 (f)
	2	<0.1	0.8	12.2	0.1	1.88	963 (r)
	3	NO ACCESS					
	4	<0.1	2.6	14.4	<0.1	1.99	1006 (r)
	5	NO ACCESS					
	6	<0.1	4.3	9.5	<0.1	1.93	984 (r)
WS17A	1	<0.1	<0.1	20.7	-0.2	DRY	1001 (f)
	2	<0.1	0.6	19.4	0.1	DRY	963 (r)
	3	NO ACCESS					

Boreholes	Visit	CH ₄ (%v/v)	CO ₂ (%v/v)	O ₂ (%v/v)	Flow (l/h)	Groundwater (mbgl)	Pressure (mb)
	4	<0.1	0.5	19.8	<0.1	4.75	1006 (r)
	5	NO ACCESS					
	6	<0.1	0.6	20.2	<0.1	DRY	984 (r)
WS19	1	<0.1	0.6	19.5	<0.1	2.13	1001 (f)
	2	<0.1	3.9	13.1	<0.1	1.89	963 (r)
	3	NO ACCESS					
	4	<0.1	6.8	11.1	<0.1	2.15	1006 (r)
	5	NO ACCESS					
	6	<0.1	6.1	13.4	<0.1	2.21	984 (r)

Table 5-5: Summary of Encia gas monitoring results.

Gas Screening Value

In accordance with CIRIA C665²³, a Gas Screening Value (GSV) may be calculated. Assuming worst-case scenario maximum gas concentrations and flow for each borehole have been used to calculate the GSV. The GSV can be used to determine the characteristic situation (CS).

The maximum GSV is 0.0068l/hr which would be CS1 / Green.

In addition, in accordance with CIRIA C665, if carbon dioxide and methane are recorded above 5%v/v and 1%v/v respectively, you should consider upgrading the characteristic situation from CS1 to CS2.

The monitoring covers a range of atmospheric pressures and is a reasonable characterisation of the gas risk.

Carbon dioxide concentrations were recorded above 5%v/v on 2no. occasions in WS19 only. The levels are only marginally elevated (maximum 6.8%v/v), and the concentrations recorded are relatively consistent. Taking this into account and the very low flow rates recorded, LKC consider that CS1 would be appropriate for the site based upon the monitoring available.

The gas can potentially migrate into buildings, accumulate in confined spaces and cause explosions (methane) and asphyxiation. LKC consider the probability of methane and carbon dioxide affecting site users and buildings as unlikely. Assuming a severe consequence, there is a moderate / low risk. Given the minimal gas concentrations and flow, a low risk is considered most appropriate and no remediation is required with respect to hazardous gas.

However, the PRA indicates that the site is in a Radon Affected Area and that basic protection measures are required for new dwellings. Therefore, at this stage remediation is required with respect to Radon.

5.4 Controlled Water Assessment

The site lies above an unproductive superficial aquifer and a Secondary A bedrock aquifer. There are surface water features within and adjacent to the site.

²³ CIRIA (2007). "Assessing Risks Posed by Hazardous Ground Gases to Buildings." CIRIA C665.

No evidence of significant mobile contaminants was identified on the Tack Lea Works site, whereas visual and olfactory evidence of hydrocarbons were noted in soil and groundwater in Shepherd Mill site.

Although elevated metals and PAHs were identified within the soils, the source is anticipated to be ash and clinker noted within the made ground. Contamination associated with ash and clinker is not anticipated to be mobile due to the residual crystalline nature of the matrix.

It should be noted that leaching tests were undertaken alongside groundwater and surface water testing. The leaching test is aggressive (de-ionised water) and is not in aqueous equilibrium (steady state) with the solid sample. This may cause rapid dissolution and overestimation of the aqueous phase concentrations compared to groundwater in contact with contaminated soils. Although dissolution may be reduced for highly hydrophobic contaminants²⁴, such as B(a)P it is likely that the initial leaching will remove the most readily available hydrocarbons and subsequent flushing would reduce the leachable concentrations²⁵. Traditionally the leaching test was developed for inorganic constituents and the leaching of organics is poorly understood²⁶.

LKC have compared results above Limits of Detection (LOD). Where relevant the review of priority substances takes precedence considering threshold values for groundwater cannot be used '*as part of site-specific investigations*'. The hierarchy is as follows:

- River Basin District Standards²⁷ and updated Water Framework Directive²⁸ for Annual Average / Maximum Allowable Concentration Environmental Quality Standards (AA-MAC-EQS) for priority substances (surface water risk).
- 2001 Environment Agency Values for Environmental Quality Standards (EQS) and UK Drinking Water Standard (UKDWS)²⁹.
- Surface Water Abstraction Directive (SWAD)³⁰ based on A2 treatment (TPH only).

The SWAD criteria is considered appropriate for TPH and would be more realistic criteria than UKDWS. For example, the UKDWS for hydrocarbons (dissolved/emulsified) is 10µg/l, whereas it would be 200µg/l using SWAD for normal physical/chemical treatment (A2 treatment). This standard has been repealed in 2007³¹, but values have not been replaced currently in the Water Framework Directive. A recent document by the EA on risk from petroleum hydrocarbons in groundwater³² has not derived EQS values for emulsified hydrocarbons but state that it must not form distinctive films or produce harmful effect to fish. It is understood that the EA are working on providing guideline values for individual carbon bands. Until this has occurred LKC considers the use of SWAD to be still acceptable for TPH for surface waters.

²⁴ EA (1999). "Methodology for the Derivation of Remedial Targets for the Soil and Groundwater to Protect Water Resources." R&D Technical Report, P20

²⁵ EA (2006). "Remedial targets Methodology: Hydrological Risk Assessment for Land Contamination."

²⁶ EA (2009). "Petroleum Hydrocarbons in Groundwater: Supplementary Guidance for Hydrological Risk Assessment."

²⁷ Defra (2010). "The River Basin Districts Typology, Standards and Groundwater Threshold Values". Water Framework Directive (England and Wales) Directions 2010.

²⁸ Defra (2015). "Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015".

²⁹ EA (2002). "Environment Agency technical advice to third parties on Pollution of Controlled Waters for Part IIA of the Environment Protection Act 1990."

³⁰ Surface Water Directive (EC 75/440/EEC); Water Supply (Water Quality) Regulations 1989, as modified.

³¹ DWI (2008). "The 2009 Periodic Review of Prices – Guidance on Drinking Water Quality Requirements."

³² EA (2009). "Petroleum Hydrocarbons in Groundwater: Supplementary Guidance for Hydrological Risk Assessment."

With regards to hydrocarbon mixtures (TPHCWG) for UKDWS, LKC will use the CL:AIRE guidance on petroleum hydrocarbons in groundwater³³ based on WHO guidelines.

No criteria values have been presented for surface waters (EQS) except the odour, visual evidence and taste test for fish³⁴. However, criteria for each banding has been presented by WHO within the CL:AIRE report for drinking water and will be used in the assessment.

The risk from List 2 compound (EC Dangerous Substance Directive 76/464/EEC) in a freshwater ecosystem is governed by the hardness of the water. As no hardness testing was carried out by Encia then EA guidance stipulates “*where the hardness of the receiving waters is not known, it will be appropriate to use the lowest (most stringent value).*”

Elevated contaminants above limits of detection are presented in Table 5-6 below and all analysis sheets are presented in Appendix F.

Contaminant	Units	Elevated Result	Location	Assessment Criteria	Source of Criteria
Copper	µg/l	<u>WATER:</u> 2 (BH10), 2 (W1), 2 (W3), 3 (W4), 165 (WS12). <u>LEACHING:</u> 2 (HDP1 0.5m), 8 (WS6 1.0m), 4 (WS8 0.4m), 9 (WS9 0.5m), 5 (WS11 0.6m), 4 (WS12 0.7m), 5 (WS17A 4.8m), 7 (WS19 0.9m), 10 (WS20 0.6m), 31 (WS21 0.5m), 3 (WS25 0.7m).		1-28 2000	EQS UKDWS
Lead	µg/l	20L	WS20 0.6m	7.2 10	DSTV (AA) UKDWS
Mercury	µg/l	0.28L	WS8 0.4m	0.07	DSTV (MAC)
Zinc	µg/l	<u>WATER:</u> 16 (BH10), 13 (BH12), 23 (W1), 23 (W3), 25 (W4), 28 (W5), 22 (WS4), 24 (WS5), 26 (WS12), 21 (WS19). <u>LEACHING:</u> 25 (HP1 0.5m), 11 (WS4 0.5m), 10 (WS6 1.0m), 15 (WS8 0.4m), 15 (WS9 0.5m), 19 (WS11 0.6m), 11 (WS12 0.7m), 10 (WS17A 4.8m), 17 (WS19 0.9m), 16 (WS20 0.6m), 9 (WS21 0.5m), 10 (WS25 0.7m).		8-500 5000	EQS DWS
Ammoniacal Nitrogen	mg/l	0.6	W5	0.015	EQS
Sulphate	mg/l	574L	WS6 1.0m	400	EQS
		325L	WS9 0.5m	250	UKDWS
PAHs					
Anthracene	µg/l	14.719	BH12	0.4	DSTV (MAC)
		17.621	WS19		
		10.270L	WS19 0.9m		
		55.655L	WS21 0.5m		
Fluoranthene	µg/l	19.861	BH12	1.0	DSTV (MAC)

³³ CL:AIRE (2017). “Petroleum Hydrocarbons in Groundwater: Guidance on Assessing Petroleum Hydrocarbons Using Existing Hydrological Risk Assessment Methodologies.”

³⁴ EA (2009). “Petroleum Hydrocarbons in Groundwater: Supplementary Guidance for Hydrological Risk Assessment.”

Contaminant	Units	Elevated Result	Location	Assessment Criteria	Source of Criteria
		7.537L	WS19 0.9m		
		7.506L	WS21 0.5m		
Naphthalene	µg/l	3548.807	WS19	2.4	DSTV (AA)
		6518.006L	WS21 0.5m		
Benzo(a)pyrene	µg/l	0.713	BH12	0.1	DSTV (MAC)
		0.120	W4		
		0.284	WS12		
		0.704L	WS21 0.5m		
TPH					
Aro >EC8-EC10	µg/l	515	BH12	300 / 500	WHO
		1569	WS19		
Aro >EC10-EC12	µg/l	1389	BH12	90	WHO
		9811	WS19		
Aro >EC12-EC16	µg/l	837	BH12	90	WHO
		1450	WS19		
Aro >EC16-EC21	µg/l	836	BH12	90	WHO
		608	WS19		
Aro >EC21-EC35	µg/l	502	BH12	90	WHO
		280	WS19		
Ali >EC8-EC10	µg/l	302	BH12	300	WHO
		851	WS19		
Ali >EC10-EC12	µg/l	926	BH12	300	WHO
		6540	WS19		
Ali >EC12-EC16	µg/l	399	BH12	300	WHO
TPH	µg/l	6292	BH12	200	SWAD
		21514	WS19		
General					
pH	pH	Range 7.4 to 8.55 (water) Range 7.04 to 7.90 (leaching)			

Table 5-6: Summary of elevated groundwater, surface water and leaching test results.

Notes:

EQS (2001) and AA / MAC-EQS (2010) = surface water criteria.

UKDWS (2001, 2009) and WHO (2017) = Groundwater criteria (potable supply).

TPH result based on SWAD value. Individual fractions also compared to this value to identify distribution of hydrocarbon contamination.

Where applicable "L" denotes leaching test result.

Based on the above, the made ground across the site appears to be a source of low levels of leachable copper and zinc. Similarly, low levels are present in the groundwater and surface water samples. The absence of hardness testing requires the most conservative EQS criteria to be applied and the likelihood is hardness testing would demonstrate these values are not elevated. The exceptions are copper at 165 µg/l in a water sample from WS12.

There was also sporadic lead and mercury detected in leaching tests. The groundwater and surface water does not appear to be impacted; therefore, the elevated concentrations are considered to be caused by the leaching test preparation.

Limited ammoniacal nitrogen in W5 is likely related to the water sitting and residing filter beds / settling tank and within the area of infilled ground.

The elevated PAH and TPH contamination are generally located in the Shepherd Mill site and co-incident with the visual and olfactory observations of hydrocarbon contamination.

LKC considers the probability of contaminants on site affecting the Secondary A Aquifer and surface watercourses as unlikely in the Tack Lea Works area and likely in the Shepherd Mill area.

Given a medium consequence Pollutant Linkage 4 is considered low risk in Tack Lea Works and a moderate risk in Shepherd Mill site. Therefore, remediation is required in the Shepherd Mill site.

5.5 Additional Risk Assessments

5.5.1 Concrete (Pollutant Linkage 5)

Water soluble sulphate and pH tests were carried out on soil and groundwater samples. Full results are presented in Appendix F and are summarised in Table 5-7.

Strata	pH		Sulphate	
	Soil	Groundwater	Soil (g/l)	Groundwater (mg/l)
Made Ground	4.26-10.56	7.4-8.55	<0.032-0.219	13-168
Natural	7.16-8.61		0.025-0.117	

Table 5-7: Summary of pH and sulphate results.

The concentrations of soluble sulphate in the soil when contrasted to BRE Digest 2005³⁵ categorise the concrete requirement as DS-1 AC-3z in the made ground and DS-1 AC1 in the natural strata.

Based on the above, the probability of sulphate concentrations affecting buildings is likely if concrete is laid in contact with made ground. Given the consequence is considered to be mild, the risk (pollutant linkage 5) is anticipated to be moderate and remediation (sulphate resistant concrete) is required. This should be confirmed with the structural engineer.

5.5.2 Potable Water Supply (Pollutant Linkage 6)

Soil results were compared to United Utilities (UU) guidelines for the selection of potable water pipes in land potentially affected by contamination³⁶. Only contaminants of concern, based on the preliminary conceptual model and ground conditions encountered, were analysed by Encia.

Therefore, the following contaminants are not considered to be a risk and therefore not included in the analysis suites: cresols, ethers, nitrobenzene, ketones, aldehydes and amines.

The following elevated contaminants were identified in the made ground:

- Elevated petroleum hydrocarbons in the east of the site.
- Elevated TVOCs (inc. naphthalene) in made ground across the site.

³⁵ BRE (2005). "Concrete in Aggressive Ground." Special Digest 1.

³⁶ UU(2011). "United Utilities Water Supplementary Guidance for the Selection of Water Pipes in Land Potentially Affected by Contamination."

It should be noted typical pipework depths are 0.75mbgl to 1.35mbgl. The pipework will likely be laid into the underlying made ground across the site.

Once details of the pipeline location and depths are known a UU Risk Assessment should be undertaken.

At this stage, the probability of organic contaminants affecting potable water pipes is likely. Given the consequence is considered to be medium, the risk (pollutant linkage 6) is anticipated to be moderate and remediation (i.e. barrier pipe) is likely to be required (subject to further risk assessment).

5.5.3 *Phytotoxicity (Pollutant Linkage 7)*

Soil results were compared to phytotoxic guideline values as outlined in BS3882³⁷.

Sporadic elevated zinc concentrations (HD1 0.5m, WS5 0.7m and WS9 0.5m) were identified. The probability of phytotoxic contaminants affecting vegetation is considered to be likely.

With a minor consequence, the risk (pollutant linkage 7) is anticipated to be low. Although the risk is low, some remediation is recommended. The remediation associated with PL1 (cover system) will be more than sufficient for PL7.

5.6 **Revised Contamination Conceptual Model**

The preliminary contamination conceptual model (Table 2-12) has been revised following the risk assessments undertaken in Sections 5.1-5.5. The revised contamination conceptual model follows the same methodology and guidance used in the preliminary contamination conceptual model. The risk matrix is provided in Appendix D.

The revised contamination conceptual model is presented in Table 5-8.

Where a very low risk is identified no specific remediation is required.

Where a low risk is identified, some form of remediation may be required depending on the pollutant linkage, the type and concentration of contaminants present and the proposed development.

Where there is a moderate/low risk is identified, an assessment will be undertaken to establish what category the pollutant linkage will fall into.

Where LKC identifies a moderate or higher risk, remediation or further investigation work is recommended.

Further details of the remedial proposals are given in Section 8.

³⁷ BS (2015). "Specifications for Topsoil and Requirements for Use." BS3882:2015.

PL	Pathway	Receptor	Contaminants of Concern (CoC)	Probability	Consequence	Risk	Recommendations
1	- Dermal contact. - Inhalation of soil, fibres and dust. - Ingestion of soils, dust, vegetables, soil attached to vegetables. - Windblown dust.	- Future site users. - Offsite receptors.	- ACM. - Heavy metals. - PAHs.	Likely (elevated concentrations in made ground)	Medium	Moderate	Remediation required.
			- Petroleum hydrocarbons.	Likely (Elevated concentrations in Shepherd Mill)	Medium	Moderate	Remediation of hydrocarbon impacted soils required.
				Unlikely (no elevated concentrations in Tack Lea Works)	Medium	Low	No remediation required.
			- Anthrax - PCBs	Unlikely (none detected)	Medium	Low	No remediation required.
2	- Inhalation of vapours. - Migration via permeable strata and preferential pathways.	- Future site users. - Offsite receptors.	- Volatile contaminants (TPHCWG, SVOC, VOCs).	Likely (Elevated concentrations in Shepherd Mill)	Medium	Moderate	Remediation of hydrocarbon impacted soils required and / or provision of vapour protection measures in housing.
				Unlikely (no elevated concentrations in Tack Lea Works)	Medium	Low	No remediation required.
3	- Inhalation of gas. - Migration via permeable strata and preferential pathways. - Explosion in confined spaces. - Exposure to radon.	- Future site users. - Buildings. - Offsite land users.	- Hazardous gas (carbon dioxide, methane).	Unlikely	Severe	Moderate / Low (low assumed due to low flow rates and slightly elevated carbon dioxide).	No remediation required.
			- Radon	Likely (as 5-10% of homes above action level)	Medium	Moderate	(5-10%) Basic radon protective measures are necessary in the construction of new dwellings or extensions.
4	- Surface run-off. - Migration via permeable strata and preferential pathways. - Perched waters migration.	- Groundwater (Secondary A Aquifer). - Surface watercourses.	- Metals	Low	Medium	Moderate / Low (low assumed as slight exceedances due to absence of hardness testing)	No remediation required. Confirmatory testing to include hardness in surface water and groundwater testing.
			- Petroleum Hydrocarbons & PAHs	Likely (Elevated concentrations in Shepherd Mill)	Medium	Moderate	Remediation of hydrocarbon impacted soils and groundwater required.
				Unlikely (no elevated concentrations in Tack Lea Works)	Medium	Low	No remediation required.
5	- Sulphate attack on concrete.	- Building structure.	- Sulphate.	Likely (given site history, site conditions, and direct contact / pathway)	Mild	Moderate / Low (moderate risk in contact with made ground).	Sulphate resistant concrete required where in contact with made ground. To be determined by the structural engineer.

PL	Pathway	Receptor	Contaminants of Concern (CoC)	Probability	Consequence	Risk	Recommendations
6	- Ingestion of tainted water supply.	- Future site users. - Water pipes.	- Organic contaminants such as petroleum hydrocarbons, naphthalene, volatile compounds.	Likely (elevated concentrations of hydrocarbons and TVOCs)	Medium	Moderate	Barrier pipe required. To be agreed with United Utilities.
7	- Direct contact (plant uptake).	- Flora.	- Phytotoxic contaminants such as heavy metals.	Likely (elevated zinc)	Minor	Low	Remediation required as part of PL1.

Table 5-8: Revised Contamination Conceptual Model.

Notes

The conceptual model only takes into consideration the future use of the site and long-term exposure. Consideration should also be given to the short-term exposure of construction workers and nearby land users to ACM containing soils during groundworks. This is discussed further in Section 7.

6 Summary Conclusions

6.1 Contamination Assessment

A revised contamination conceptual model has been produced by LKC which is summarised in Table 6-1 below (more detailed model provided in Section 5).

Pollutant Linkage		Risk	Recommendations
PL1: Contaminants posing a risk to future site users via dermal contact, ingestion and inhalation (of soil, dust, fibres and vegetables).	ACM, heavy metals, PAHs Petroleum hydrocarbons (Shepherd Mill)	Moderate	Remediation required in garden and soft landscaping areas.
	Petroleum hydrocarbons (Tack Lea)	Low	No remediation required.
	Anthrax, PCBs	Low	No remediation required.
PL2: Volatile contaminants posing a risk to future site users via the inhalation of vapours.		Moderate (Shepherd Mill)	Remediation of hydrocarbon impacted soils required and / or provision of vapour protection measures in housing.
		Low (Tack Lea)	No remediation required.
PL3: Gas posing a risk to buildings and future site users via the migration of gas into building causing explosion and asphyxiation.	Carbon dioxide & methane	Low	No remediation required.
	Radon	Moderate	(5-10%) Basic radon protective measures are necessary in the construction of new dwellings or extensions.
PL4: Mobile contamination posing a risk to controlled waters via the migration through permeable strata.		Moderate (Shepherd Mill)	Remediation of hydrocarbon impacted soils and groundwater required.
		Low (Tack Lea)	No remediation required. Confirmatory testing to include hardness in surface water and groundwater testing.
PL5: Sulphate posing a risk to building via direct contact (sulphate attack).		Moderate / Low	Sulphate resistant concrete required where in contact with made ground. To be determined by the structural engineer.
PL6: Organic contaminants posing a risk to water pipes.		Moderate	Barrier pipe required. To be agreed with United Utilities.
PL7: Phytotoxic metals posing a risk to flora via root uptake.		Low	Remediation required as part of PL1.

Table 6-1: Summary Risk Table.

Remedial recommendations are presented in Section 7.

6.2 Geotechnical Assessment

A geotechnical assessment is outwith the scope of this assessment. The Encia report details the insitu and laboratory testing carried out at the site and also provides an initial geotechnical appraisal for foundations and land stability.

7 Recommendations and Remedial Strategy

The recommendations provided below are considered appropriate for the site based on the site investigation work undertaken. LKC should stress that no remediation, enabling works or designing works should take place until Regulatory approval has been obtained.

7.1 Remediation and Validation Recommendations

Table 7-1 details the further works and remedial recommendations / requirements. The table shows work required post-demolition of building(s), pre-construction (i.e. during earthworks) and during / post construction.

Phase	PL	Remediation Requirements	Validation Requirements
Pre-Construction	ALL	<u>Earthworks Inspections / Unexpected Contamination</u> The relevant contractors should be briefed that during development works at the site should any unusual ground conditions and / or visual or olfactory evidence of contamination (including asbestos containing material) be encountered at the site, LKC and the Local Authority should be informed, and further assessment of the material may be required. It would be advisable to introduce an asbestos management strategy in line with CIRIA C733 ³⁸ . In the construction Health and Safety plan.	Log of work undertaken including photographs. Details of any sampling undertaken and validation of any potential additional remedial work.
	1,2,4	<u>Hydrocarbon Removal / Treatment (Shepherd Mill)</u> The hydrocarbon contaminated soil and groundwater in the Shepherd Mill area will be remediated. This may include source removal, on site chemical and / or biological treatment or stabilisation. This will also address the PAH and VOC contamination in this area of the site.	Details of work undertaken including photographs, validation testing and appropriate LA / EA permits and licence have been obtained and complied with. Consignment notes confirming the removal of impacted soil.
	4	<u>Heavy metals risk to Controlled Waters</u> LKC recommend that further testing is undertaken to include hardness in order to confirm no remediation is required.	Certificates of analysis and further generic risk assessment to be carried out.

³⁸ CIRIA (2014). "Asbestos in Soil and Made Ground: A Guide to Understanding and Managing Risks". C733.

Phase	PL	Remediation Requirements	Validation Requirements
Build-Phase Construction	1 and 7	<u>Environmental Cover System</u> As made ground is relatively deep, it is unlikely to be viable to remove the contaminated soils. Therefore, an environmental cover system is recommended. The environmental cover system should be as follows: Private Back Gardens: 600mm thick environmental cover system comprising: Either 100mm physical break layer (MOT type 1 material, 20-30mm, minimal fines) and at least 500mm comprising clean inert fill and sufficient topsoil for a growing medium. Or geotextile membrane and at least 600mm comprising clean inert fill and sufficient topsoil for a growing medium. Private Front Garden / Shared Landscaping: 300mm thick environmental cover system comprising: Either 100mm physical break layer (MOT type 1 material, 20-30mm, minimal fines) and at least 200mm comprising clean inert fill and sufficient topsoil for a growing medium. Or geotextile membrane and at least 300mm comprising clean inert fill and sufficient topsoil for a growing medium. A diagram of a typical environmental cover system is shown in Appendix I.	Measuring depth of environmental cover system using a staff and providing photographic evidence. Photographic evidence of the granular physical break or geotextile layer will also be collected. Chemical validation of imported soils: See Table 7-2.
	3	<u>Radon</u> Basic radon protection measures required.	Approval of foundation cross sections with LA. Inspection and photographic evidence of the required measures.
	5	<u>Sulphate Resistant Concrete</u> Sulphate Resistant Concrete required to structural engineer specifications.	N/A
	6	<u>Potable Water Pipes</u> Barrier pipe is required for the site.	Delivery Notes of Pipe Material. Photographs of the Installed Pipe.

Other Considerations	<u>Grubbing Out of In-Ground Structures</u> It is recommended that in-ground structures are grubbed out as part of the groundworks.
	<u>Re-use of site won material</u> To ensure material is compliant with appropriate waste regulations, any site won material re-used onsite should be in recourse to appropriate exemptions. A U1 and T5 exemption should be registered. This will allow the following to be used onsite or brought in for use onsite (refer to guidance for types of waste that can be used ³⁹): 5,000 tonnes (c. 2,500m³) <u>treatment of</u> crushed concrete / stone. 1,000 tonnes (c. 500m³) <u>use of</u> non-hazardous soil 5,000 tonnes (c. 2,500m³) <u>use of</u> clays, sand, gravel, brick, concrete, stone etc. 50,000 tonnes (c. 25,000m³) <u>use of</u> bituminous material to be used in roadways. A Materials Management Plan (MMP) with recourse to the CL:AIRE Code of Practice may be required if volumes exceed exemption limits. This must be registered before material movement starts onsite. If an MMP is required, this needs to be registered by a Qualified Person (QP) and there must be 'certainty of use' for any material re-used onsite or exported to site to ensure there is no 'sham recovery'. For all the above material will need to be tested at the rate and analytical suites presented in Table 7-2.
	<u>Asbestos Management Plan</u> Due to the presence of asbestos containing material, it is recommended that additional precautions are taken during site clearance, earthworks and construction in the area of concern. The presence of asbestos in the made ground at the site presents a potential risk of generation of airborne fibres if this material is disturbed, such as for excavations to construct new foundations. This risk can be managed by careful procedures and site monitoring to reduce the risk of airborne fibres, and it is recommended that an appropriate 'Asbestos Management Strategy' is developed in the Construction Health and Safety plan and adopted for all intrusive ground works which disturb the made ground in the area of concern. This should be carried out in line with CIRIA C733⁴⁰. This may include asbestos awareness training for all site staff, provision of suitable personal and respiratory protective equipment and air monitoring. With regards to cement bound asbestos, this can be handpicked, doubled bagged and disposed of appropriately to a licenced landfill. Guidance on removing asbestos cement is described in HSE (2012)⁴¹. If ACM is identified in soil arisings then soil should be placed directly into covered skips and disposed of at a suitable licenced landfill, after further testing to quantify the extent of asbestos contamination of the soils. It should be considered that blue asbestos is notifiable and must be removed by a licenced contractor.

³⁹ <https://www.gov.uk/guidance/waste-exemptions-using-waste>

⁴⁰ CIRIA (2014). "Asbestos in Soil and Made Ground: A Guide to Understanding and Managing Risks". C733.

⁴¹ HSE (2012). "Removing Asbestos Cement (AC) Debris." A11 Asbestos Essential – Non-licenced Tasks.

	Health and Safety Considerations In working with, removing or treating any contaminating material it is important that any potential risks associated with the actual site works are mitigated by good environmental management of the site during the remedial phases. Standard health and safety precautions (as per HSE guidance⁴²) should be adopted by all workers involved with site enabling and construction works.
	Piling in Contaminated Land Given the depth of made ground, it is expected that some buildings may be piled into the bedrock. This may provide a preferential pathway for any mobile contaminants not previously identified to the Secondary A Aquifer. Once the method of piling has been determined, good practice for the drilling of piles on contaminated sites should be adhered to, such as guidance provided by the Environment Agency⁴³.

Table 8-1: Further work, remediation and validation requirements

Notes: See Table 5-8 for pollutant linkage (PL) details.

7.2 Validation of Subsoil / Topsoil

Chemical validation of all imported soils to be used on site in gardens and soft landscaping areas should be undertaken. Imported soils should be accompanied by a certificate of analysis and source details.

A summary of the required imported material sampling requirements is presented in Table 7-2. Ideally, the material should be sampled at source to prevent double handling if soil fails, with confirmatory sampling undertaken on importation to site. However, where this is not possible then material imported should be segregated based on source and soil type. Validation samples should be taken prior to placement in gardens to ensure suitability for use.

Material Type	Source	Suite of Analysis	Sampling Rate*
Topsoil	Greenfield	Suite A	1 sample per 50m³
	Brownfield / Unknown	Suite B	
Subsoil	Brownfield / Unknown	Suite B	1 sample per 150m³
	Site won natural material / greenfield	Suite A	
	Physical Stone Break Layer	First Generation i.e. quarried sand (subsoil) or stone (break layer)	
	Recycled Stone (6F2 / screened)	Suite B	1 sample per 500m³

Table 7-2: Sampling requirements for imported soils.

Notes:

Suite A - Heavy metals, pH, water soluble sulphate, speciated PAH, soil organic matter and asbestos screen.

Suite B - Heavy metals, pH, water soluble sulphate, speciated PAH, phenol, total and free cyanide, soil organic matter, asbestos screen, banded petroleum hydrocarbons (TPH CWG), BTEX, MTBE.

*Minimum sampling rate of 3 samples per source.

Any soil with visual or olfactory evidence of hydrocarbons should be rejected.

⁴² HSE (1991). "Protection of Workers and the General Public During Development of Contaminated Land" London HMSO.

⁴³Environment Agency (2001) Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination: Guidance on Pollution Prevention.

In addition, it should be ensured that the matrix of the topsoil is suitable as a growing medium and no undesirable material is present (in line with BS3882⁴⁴). LKC advise this information is provided by the supplier before material is imported onto site.

Imported material to be used in gardens will be compared against residential with plant uptake criteria (as used in the contamination risk assessment (Section 5-1)). Appropriate remedial target criteria are presented in Appendix H.

7.3 Site Completion Report

It is recommended that any remediation carried out on the site is validated by a third party and suitable documentary evidence provided in a Site Completion Report, such as photographs, consignment documents and analytical results. This should include as a minimum:

- » Validation of the remediation of hydrocarbon (and PAH and VOC) impacted soils in the Shepherd Mill area of the site.
- » Provision of waste transfer documents.
- » Validation of environmental cover system depths.
- » Verification testing of all imported soil for garden and soft landscaping areas.
- » Information on the installation of protective pipes.

The aim of the Site Completion Report will be to demonstrate to the Local Authority that the site has been suitably remediated to the extent that construction works may commence and, in accordance with the National Planning Policy Framework (NPPF)⁴⁵:

- » The site is suitable for its new use taking account of ground conditions and land instability, including from natural hazards or former activities such as mining, pollution arising from previous uses and any proposals for mitigation including land remediation or impacts on the natural environment arising from that remediation;
- » After remediation, as a minimum, land should not be capable of being determined as contaminated land under Part IIA of the Environmental Protection Act 1990⁴⁶; and,
- » Adequate site investigation information, prepared by a competent person, is presented.

Once the above is satisfied the Local Authority should be able to discharge all the relevant contaminated land conditions.

⁴⁴ BS (2015). "Specifications for Topsoil and Requirements for use." BS3882:2015.

⁴⁵ DCL (2019). "National Planning Policy Framework." Department of Communities and Local Government.

⁴⁶ Defra (2006). "Environmental Protection Act 1990: Part 2A Contaminated land." Defra Circular 01/2006.

Figures

Appendix A

Historical Maps

Risk Evaluation

The method for risk evaluation is a qualitative method of interpreting the output from the risk estimation stage of the assessment, based on CIRIA 552⁴⁷. It involves the classification of the:

- » Magnitude of the potential consequence (severity) of the risk occurring (Table A).
- » Magnitude of the probability (likelihood) of the risk occurring (Table B).

Consequence (Severity)		
Classification	Definition	Example
Severe	- Short term (acute) risk to human health likely to results in 'significant harm' as defined by the Environment Protection Act 1990, Part IIA. - Short term risk of pollution (note: water Resources Act contains no scope for considering significance of pollution) of sensitive water resource. - Catastrophic damage to buildings/properties. - A short-term risk to a particular ecosystem, or organism forming part of such ecosystem (note: the definition of ecological systems within the Draft Circular on Contaminated Land, DETR, 2000).	- High Concentrations of cyanide on the surface of an informal recreation area. - Major spillage of contaminants from site into controlled waters. - Explosion, causing building collapse (can also equate to short term human health risk if buildings are occupied).
Medium	- Chronic damage to Human Health ('significant harm' as defined in DETR, 2000). - Pollution of sensitive water resources (note Water Resources Act contains no scope for considering significance of pollution). - A significant change in a particular ecosystem, or organism forming part of such ecosystem.	- Concentrations of a contaminant from site exceed generic, or site-specific assessment criteria. - Leaching of contaminants from a site to a major or minor aquifer (Principal and Secondary). - Death of a species within a designated nature reserve.
Mild	- Pollution of non-sensitive water resources. - Significant damage to crops, buildings, structures and services ('significant harm' as defined in DETR, 2000). - Damage to sensitive buildings/structures/services or the environment.	- Pollution of non-classified groundwater. - Damage to building rendering it unsafe to occupy (e.g. foundation damage resulting in instability).
Minor	- Harm, although not necessarily significant harm, which may result in a financial loss, or expenditure to resolve. - Non-permanent health effects to human health (easily prevented by means such as personal protective clothing etc). - Easily repairable damage to buildings, structures and services.	- The presence of contaminants at such concentrations that protective equipment is required during site works. - The loss of plants in a landscaping scheme. - Discoloration of concrete.

Table A. Classification of Consequence

Probability (Likelihood)	
Classification	Definition
High Likelihood	- There is a pollutant linkage and an event that either appears very likely in the short term and almost inevitable over the long term, or there is evidence at the receptor of harm or pollution.
Likely	- There is a pollutant linkage and all the elements are present and in the right place, which means that it is probable that an event will occur. - Circumstances are such that an event is not inevitable, but possible in the short term and likely over the long term.
Low Likelihood	- There is a pollutant linkage and circumstances are possible under which an event could occur. - However, it is by no means certain that even over a longer period such event would take place and is less likely in the shorter term.
Unlikely	- There is a pollutant linkage, but circumstances are such that it is improbable that an event would occur in the very long term.

Table B. Classification of Probability.

⁴⁷ CIRIA C552 (2001) Contaminated Land Risk Assessment - A Guide to Good Practice.

These classifications are then compared to indicate the risk presented by each pollutant linkage (Table C). It is important that this classification is only applied where there is a possibility (which can range from high likelihood to unlikely) of a pollutant linkage existing.

		Consequence			
		Severe	Medium	Mild	Minor
Probability	High Likelihood	Very High Risk	High Risk	Moderate Risk	Moderate / Low Risk
	Likely	High Risk	Moderate Risk	Moderate / Low Risk	Low Risk
	Low Likelihood	Moderate Risk	Moderate / Low Risk	Low Risk	Very Low Risk
	Unlikely	Moderate / Low Risk	Low Risk	Very Low Risk	Very Low Risk

Table C. Comparison of Consequence against Probability

Once the risk has been determined the corresponding action can be assessed (Table D).

Risk	Action Required
Very High Risk	- There is a high probability that severe harm could arise to a designated receptor from an identified hazard, OR, there is evidence that severe harm to a designated receptor is currently happening. - This risk, if realised, is likely to result in a substantial liability. - Urgent investigation (if not already undertaken) and remediation are likely to be required.
High Risk	- Harm is likely to arise to a designated receptor from an identified hazard. - Realisation of the risk is likely to present a substantial liability. - Urgent investigation (if not undertaken already) is required and remedial works may be necessary in the short term and are likely over the longer term.
Moderate Risk	- It is possible that harm could arise to a designated receptor from an identified hazard. However, it is either relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that the harm would be relatively mild. - Investigation (if not already undertaken) is normally required to clarify the risk and to determine the potential liability. Some remedial works may be required in the longer term.
Low Risk	- It is possible that harm could arise to a designated receptor from an identified hazard, but it is likely that this harm, if realised, would at worst normally be mild.
Very Low Risk	- There is a low possibility that harm could arise to a receptor. In the event of such harm being realised it is not likely to be severe.

Table D. Description of the Classification and Likely Action Required.

Where a very low risk is identified no specific remediation is required.

Where a low risk is identified, some form of remediation may be required depending on the pollutant linkage, the type and concentration of contaminants present and the proposed development.

Where there is a moderate/low risk identified, an assessment will be undertaken to establish what category the pollutant linkage will fall into.

Where LKC identifies a moderate or higher risk, remediation or further investigation work is recommended.

Appendix B

Environmental Factual Information

Appendix C

Encia Diagrammatical Preliminary Conceptual Model

Appendix D

Risk Matrix

Appendix E

Profile Logs

Appendix F

Certificates of Analysis

Appendix G

Gas Monitoring

Appendix H

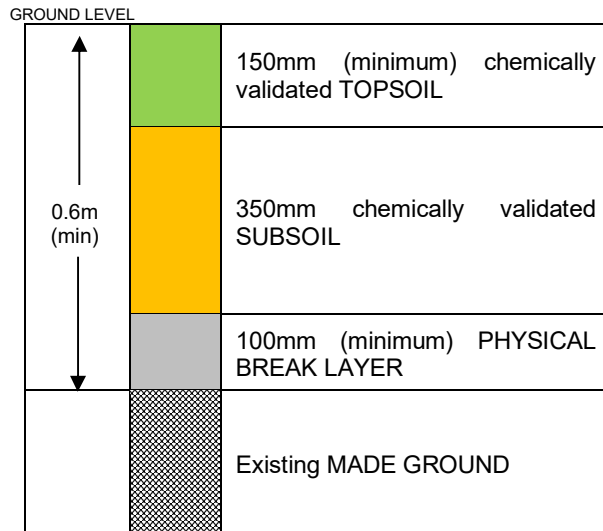
Generic Assessment Criteria

Appendix I

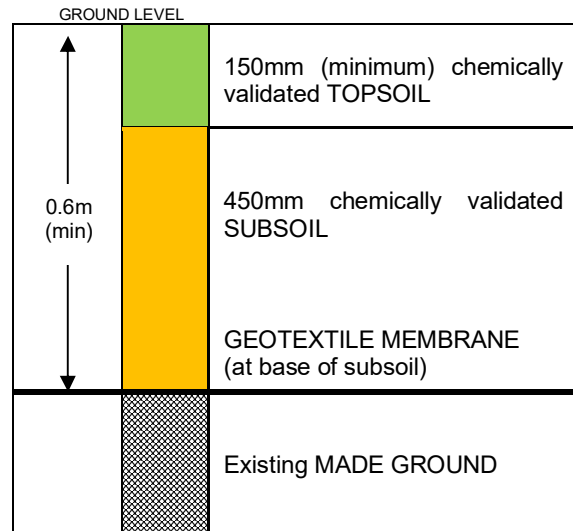
Environmental Cover System Construction

PRIVATE BACK GARDENS:

Either (physical break layer)

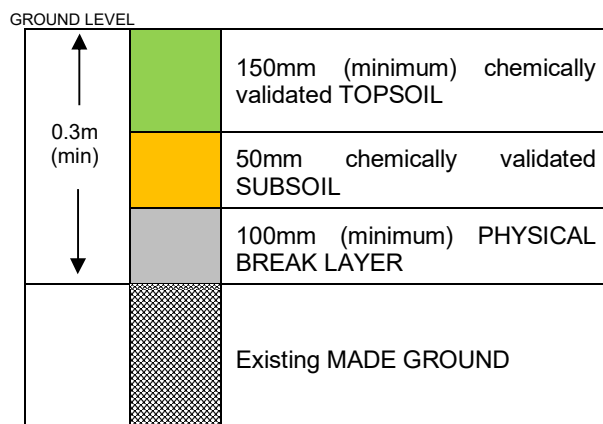


Or (geotextile membrane)

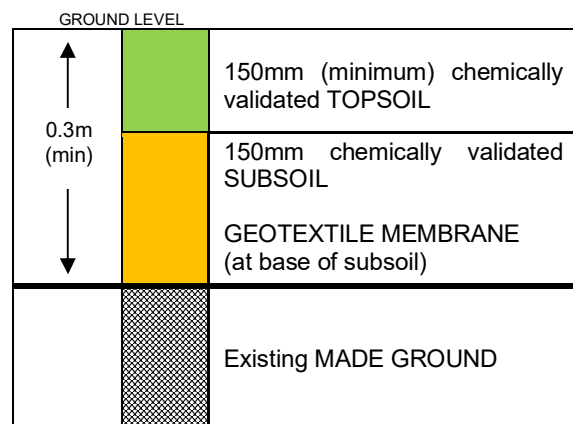


PRIVATE FRONT GARDENS / SHARED LANDSCAPING:

Either (physical break layer)



Or (geotextile membrane)



Hardstood Areas – No Remediation Required