University College London

Astor College, 99 Charlotte Street

Ground Contamination Assessment and Remediation Strategy

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1 Introduction

1.1 Background

Ove Arup and Partners Limited (Arup) has been commissioned by University College London (UCL) to prepare an interpretative ground contamination assessment and remediation strategy report for the proposed redevelopment of Astor College, Charlotte Street, London (the site).

Planning permission for the development was granted by London Borough of Camden (LBC) on 27th May 2015 (Ref: 2015/1139/P):

'for refurbishment of existing student accommodation comprising 2 storey upper ground floor front extension, 8 storey rear extension and front central bay extended forward to provide 60 additional bedrooms, provision of ground floor cafe and pedestrianisation of Bedford Passage'.

Previous ground investigation reports prepared by Albury S.I. Ltd in 2014 [1] and Soil Mechanics in 2011 [1] were submitted in June 2016 to LBC to discharge Condition 11a (Ref: 2016/3094/P). However, the LBC Environmental Health Officer (EHO) requested further information in order to discharge the condition. On 3rd November 2016, Arup spoke with the LBC EHO. It was agreed to submit an interpretative ground contamination assessment and remediation strategy report, based on the previously submitted factual information.

1.2 Objectives

This report has been prepared to support the partial discharge of Condition 11 of planning permission Ref. 2015/1139/P, as outlined below:

"At least 28 days before development commences:

(a) a written programme of ground investigation for the presence of soil and groundwater contamination and landfill gas shall be submitted to and approved by the local planning authority in writing; and,

(b) following the approval detailed in paragraph (a), an investigation shall be carried out in accordance with the approved programme and the results and a written scheme of remediation measures [if necessary] shall be submitted to and approved by the local planning authority in writing.

The remediation measures shall be implemented strictly in accordance with the approval scheme and a written report detailing the remediation shall be submitted to and approved by the local planning authority in writing prior to occupation.

Reason: To protect future occupiers of the development form the possible presence of ground contamination arising in connection with the previous industrial/storage use of the site in accordance with policy CS5 of the London Borough of Camden Local Development Framework Core Strategy and policy

DP26 of the London Borough of Camden Local Development Framework Development policies."

This report is intended to address parts a) and b) above which represent the 'pre-commencement part of the condition.

The full discharge of the condition requires a report, summarising the remediation measures implemented, to be submitted to the local planning authority for approval, prior to occupation. Further details are presented in Section 5.2.3.

1.3 Scope of works

The scope of the ground contamination assessment and remediation strategy report is summarised below:

- Review existing reports for contamination information pertinent to the site (see below).
- Undertake a site walkover and meet with the principal contractor (Galliford Try).
- Assessment of potential contamination risks.
- Present a site specific remediation strategy.

The following ground contamination related documents have been reviewed by Arup as part of the interpretative ground contamination assessment:

- Albury S.I. LTD (2014) Report on a Site Investigation at UCL, Astor College, Charlotte Street [1]. The ground investigation report was prepared for the Astor College site.
- Soil Mechanics (2011) Final Report on Ground Investigation [2]. The ground investigation report was prepared for the adjacent UCL Sainsbury Wellcome Centre (former Windeyer Building), which also assessed the ground conditions within the Astor College site.
- Arup Geotechnics (2011) University College London, Project Glimmer Geotechnical and Contamination Desk Study [3]. This desk study report was prepared for the adjacent Sainsbury Wellcome Centre which also assessed the Astor College site.
- Soiltechnics (2016) Proposed development Astor College University College London [4]. The ground investigation report was prepared for the Astor College site, on behalf of Galliford Try.

1.4 Limitations

This report has been prepared by Arup for use by the client in connection with their proposed development of the site. It takes into account our client's particular instructions and requirements and addresses their priorities at the time. It is not intended for, and should not be relied upon by any third party and no responsibility is undertaken to any third party in relation to it, except as provided in Arup's agreement with the client.

This report provides an assessment of the potential for contamination in the ground. Arup has based this assessment on the sources of information detailed within the report text and believes them to be reliable, but cannot and does not guarantee the authenticity or reliability of this third party information. Notwithstanding the efforts made by the professional team in undertaking this contamination assessment it is possible that ground conditions and contamination other than those potentially indicated by this report may exist at the site.

The findings and conclusions presented in this report are based on the proposed development as described in Section 2.2. If the proposed layout or land-uses for the site are altered, then the findings of this report may need to be reviewed and reassessed where appropriate.

This report has been prepared based on current legislation, statutory requirements, planning policy and industry good practice prevalent at the time of writing. Any subsequent changes or new guidance may require the findings, conclusions and recommendations made in this report to be reassessed in the light of the circumstances.

The report does not provide an assessment of the potential for hazardous materials (including asbestos) in the building fabric and the implications of those hazardous materials. A geotechnical assessment (including unexploded ordnance) did not form part of the agreed scope of works.

2 The site

2.1 Site location and description

The site is located at the intersection of Charlotte Street and Howland Street in central London (approximate National Grid Reference 529280 181860). A site location plan showing the redline boundary is presented as drawing 2869-L047 (Appendix A). The boundary of the adjacent UCL owned land (Sainsbury Wellcome Centre) is also shown.

The site is irregularly shaped and is approximately 1500m^2 is area. The site currently comprises Astor College, which was constructed in the 1960s. The current building footprint occupies the majority of the site area and includes:

- A sub-basement with plant room and gymnasium (refer to drawing Ref. 2869 L48, Appendix B).
- Lower ground floor with plant room, laundry stores and gymnasium, changing room and shared amenity rooms (refer to drawing Ref. 2869 L49, Appendix B). The lower ground floor forms a basement adjacent to the Charlotte Street boundary, but is at ground level to the rear (refer to Section A and Section C drawing Refs. 2869 L198 and L200, Appendix B).
- Upper ground floor with main entrance, offices, student accommodation, bike stores and terrace (refer to drawing Ref. 2869 L50, Appendix B).
- Floors 1 to 7 with student accommodation (refer to drawing Refs. 2869 L51 and L57, Appendix B) and roof level (refer to drawing Ref. 2869 L58, Appendix B).

The site is surrounded by office and retail buildings, including the Sainsbury Wellcome Centre to the northwest and Middlesex Hospital to the southwest.

Arup visited the site on 15 November 2016. No obvious evidence of potentially contaminative land-uses activities or features were observed. There are no fuel oil tanks currently on site.

2.2 Proposed development

The proposed development includes the refurbishment of existing student accommodation comprising a two-storey upper ground floor front extension and eight-storey rear extension:

- Retaining of the existing sub-basements uses, including plant room and gymnasium as shown on drawing Ref: 2869 L098 (Appendix C).
- Lower ground floor: Retaining of existing plant room, laundry, lounge and changing rooms, with new kitchens and bedrooms to the rear (including an extension), new café and cycle stores adjacent to Bedford Passage, as shown on drawing Ref. 2869-L099 (Appendix C).
- Upper ground floor: Mostly new student accommodation as shown on drawing Ref. 2869-L0100 (Appendix C).

- Floors 1 to 7: Existing student accommodation as shown on drawing Ref. 2869-L0101 & 103 (Appendix C).

The proposed cross sections are show on drawings 2869-L201 and L203 (Appendix C). No basements are proposed for the rear extension, although ground levels will have to be reduced by approximately 600mm to 700mm to allow for the slab and sub-base construction. Slightly deeper excavations (~1.1m) will be required to allow the pile cap construction. The building extensions will be constructed on continuous flight auger (CFA) piled foundations which are 22m in depth.

It is not proposed to significantly alter the existing basement and lower ground floor layout or uses. Galliford Try has confirmed that there will be a combination of passive and mechanical (e.g. kitchen) ventilation and that the development will be constructed in accordance with the Building Regulations Approved Document C, in consultation with the Building Control Officer.

The rear extension will have a ground bearing reinforced concrete slab (200mm thick) with 50mm blinding and 150mm minimum of sub-base. Above the slab, a Visqueen 2000 gauge damp proof membrane (with joints lapped and taped) will be installed with insulation and then screed.

New landscaping is proposed to the rear of the building and Bedford Passage, as shown on drawings Ref. 2869 L900 and 901 (refer to Appendix C). The majority of the area will be hard landscaped. There will be small soft landscaped areas will consist of raised planting beds and two Chinese Birch trees in tree pits. Both the beds and pits will be underlain by a drainage layer. The design drawings indicated that the raised planting areas will typically have a minimum of 450mm depth of topsoil, minimum 100mm depth of free draining gravel and a geotextile at the base. The tree pits will extent to a greater depth.

The form of development has a low sensitivity with respect to potential contamination, construction and the end-use and environment, for example:

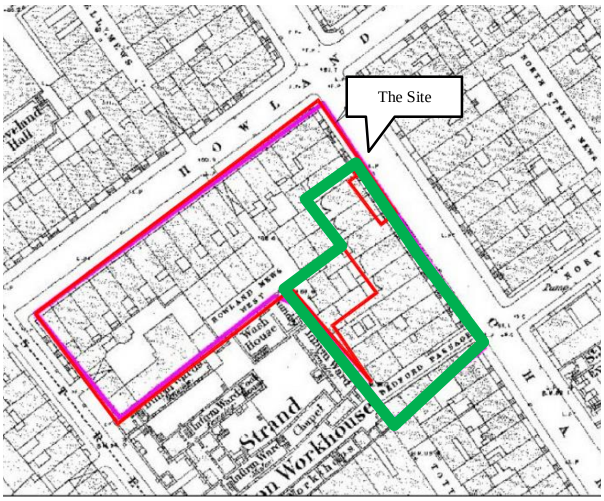
- The proposed end-uses will be university students (>18 years old) and site workers (office and maintenance), which are considered low risk receptors.
- The majority of the site will be capped with buildings, with small external space consisting of mostly hard landscaping. There is some small areas of soft landscaping is in raised bed or tree pits. In both cases this will require a suitable thickness of imported topsoil (growing medium) and will be underlain by a drainage layer. This will prevent potential contaminant exposure (e.g. via ingestion and dermal contact).
- The floor slabs and ventilation both in the existing building and proposed extensions will provide some protection against potential ground gas.
- The small areas of soft landscaping to the rear of the building will be managed and maintained by UCL. Galliford Try will undertake appropriate verification (e.g. chemical testing) of any imported topsoil.
- CFA piles are proposed which are considered to present a low risk to groundwater, as they minimise the creation of contaminant pathways.

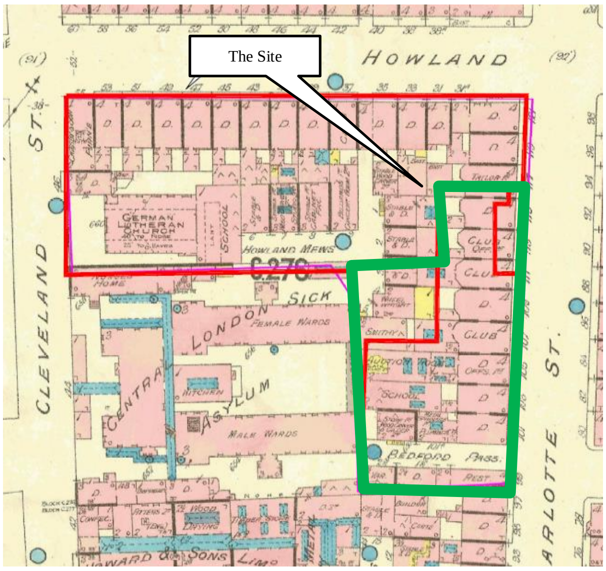
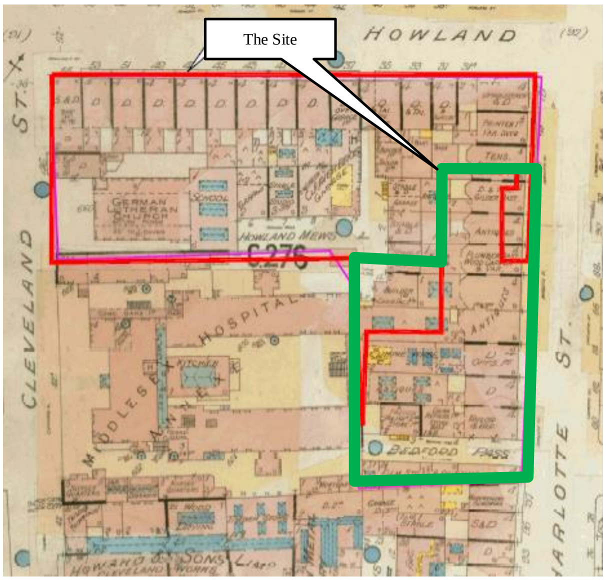
- There will be limited excavations at the site, with no deep excavations. Therefore groundwater is not expected to be encountered.
- The development is a continued used which has operated as a student halls of residence for 50 years.
- Services and construction materials will be appropriately designed where appropriate for the ground conditions.

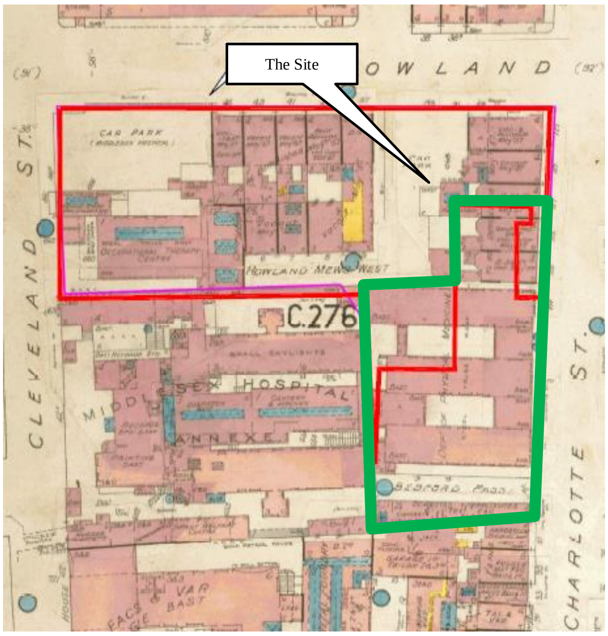
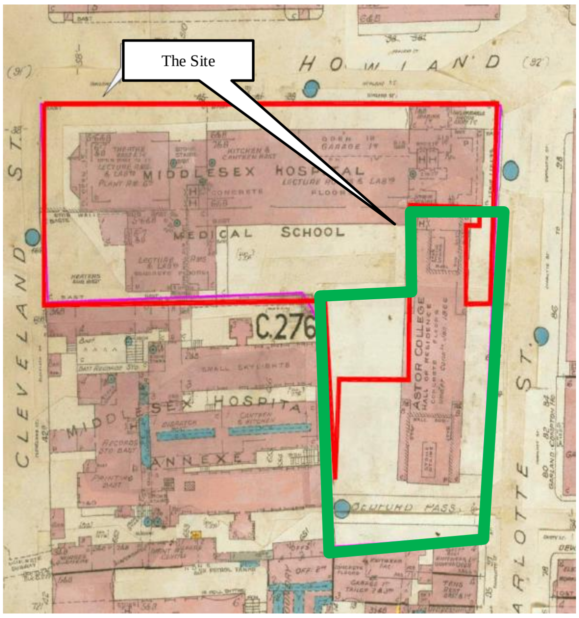
2.3 Site history and potential for contamination

Table 1 summarises the history of the site and the immediate surrounding area from a review of the historical maps, Goad Fire Insurance Plans and aerial photographs obtained from Landmark and Arup's own archive as contained in the Arup desk study [3].

Table 1 Summary of site history

Date	Map Extract **Green Boundary – Astor College (i.e. site)** **Red/Purple – UCL land**	On and off-site features
1746[a)]		The site comprises open agricultural fields. Possible gravel pits are shown in the wider area, including to the northeast. Subsequent historical mapping between 1746 and 1765 [b)] indicates that the site (and area to the south) had been redeveloped. The gravel pits are no longer shown. The Greenwood map [c)] (1827) indicates that the area had been fully developed.
1872[d)]		The present day road layout is shown, as well as Bedford Passage. The site (green boundary) is fully developed with unlabelled buildings. No potentially significant contaminative land-uses are identified at the site. Ground levels may have been raised prior to development, including any gravel pits in the wider area.

Date	Map Extract Green Boundary – Astor College (i.e. site) Red/Purple – UCL land	On and off-site features
1900 d) (Goad Fire Insurance plan)		The site (green line) is occupied by a number of small scale commercial, retail and educational units, including stables and a small smithy in the northwest corner. Within the immediate surrounding area (i.e. within 50m), there are a number of commercial and medical facilities which include the 'Central London Sick Asylum' and a 'Brass Gun and Metal Foundry'. No potentially significant contaminative land-uses are identified at the site.
1927 d) (Goad Fire Insurance plan)		The site (green boundary) has remained in broadly the same configuration. Uses now include, for example, a plumbers, antique shops, wood carving works and film store and printing. The 'Central London Sick Asylum' now forms an annex of the 'Middlesex Hospital'. A number of small scale land-uses such as printers, varnish works and garages are shown in the surrounding area (within 50m). A small plating and polishing works is shown just to the northwest of the site on the 1947 plan.

Date	Map Extract Green Boundary – Astor College (i.e. site) Red/Purple – UCL land	On and off-site features
1957 d) (Goad Fire Insurance plan)		The site (green line) has been completely redeveloped as the 'Department of Physical Medicine'. The 1948 Goad Fire Insurance Plan (not reproduced) shows that most of the site had been cleared. The Bomb Damage Map e) indicated that most buildings on the site had been damaged beyond repair. The area to the north (Sainsbury Wellcome Centre) is in the process of being cleared (and used as car parking) or is shown as being vacant.
1966 d) (Goad Fire Insurance plan)		Astor College (green line) is shown to be under construction. The site is shown in the current configuration and is labelled as a hall of residence. The area immediately to be north has been completely redeveloped and now forms part of the Middlesex Hospital Medical School. The remainder of the surrounding area has remained broadly in the same configuration. Since 1966 (to present) the site has remained broadly in the same configuration.

Note

a) John Rocque Survey of London (1746)

b) British Library Online Gallery http://www.bl.uk/onlinegallery/onlineex/crace/a/007zzz000000019u00018000.html

c) Greenwood Map of London, 1827, British Library Online Gallery: http://www.bl.uk/onlinegallery/onlineex/crace/m/007000000000006u00225000.html

d) Map extracts taken from the Envirocheck Report Ref: 30940311_1_1 included with the Arup desk study [3]. Copyright Landmark Information Group.

e) London Topographical Society (2005). The London County Council Bomb Damage Maps 1939-1945. London Topographical Society and London Metropolitan Archives. LTS Publication No. 164.

There have been no significantly contaminative industries on site. Activities in or close to the site that may have resulted in localised contamination are summarised below.

Made Ground of unknown origin is commonly present at most sites, which could be a potential source of contamination. The infilled gravel pits in the wider area may also be a potential source of contamination. Any raising of levels or infilling is likely to have occurred in the mid-18th Century and therefore is unlikely to have been significantly contaminated.

The known historical and current site land-uses have been either small scale, low risk activities or limited in duration and unlikely to have used significant volumes of chemicals or other pollutants (although small scale uses may have occurred). Therefore, the site activities are unlikely to have resulted in significant and/or widespread contamination, given that many of these land-uses occurred over 60 years ago.

The buildings at the site were damaged during World War 2 (WW2) and then demolished, and then redeveloped in the 1950's, which was in turn demolished during the early to mid-1960's prior to construction of the current building. It is possible that these phases of development may have deposited contaminated fill (e.g. metals, asbestos and hydrocarbon). Conversely, the 1960's Astor College development would have removed Made Ground across the building footprint as part of the basement and lower ground floor construction.

Various small scale potentially contaminative land-uses were identified in the surrounding area, which could have resulted in localised contamination (e.g. metals, hydrocarbons, and solvents). However, these land-uses are considered unlikely to have significantly impacted the Astor College site. For example, the neighbouring Sainsbury Wellcome Centre Building to the northwest (where many of the previous small scale activities were noted) has a basement which is likely to have partially removed Made Ground (and potential contamination).

Former fuel oil tanks are known to have been located in the surrounding area which have resulted in localised ground contamination due to leaks. This is considered unlikely to have resulted in significant contamination on the site itself.

2.3.1 Geology, hydrogeology and hydrology

From Arup's knowledge of the local geology, the anticipated ground conditions at the site is summarised in Table 2 below.

Table 2 Summary of anticipated geology

Stratigraphy	**Stratum thickness (m)**
Made Ground	2.4 - 5.5
Lynch Hill Gravel / River Terrace Deposits (RTD)	1.5
London Clay	19.0
Lambeth Group	15
Thanet Formation	3.0

Stratigraphy	Stratum thickness (m)
Chalk	>100 (base not proven)

For Arup's experience of the area, alluvium (or peat deposits) are unlikely to be present at the site. These deposits are a natural potential source of ground gases such as methane and carbon dioxide.

The Environment Agency designates the underlying RTD, Lambeth Group and Thanet Formation as secondary 'A' aquifers. There are no significant surface water features (e.g. rivers) within close proximity of the site.

The Chalk Formation encountered at a depth of around 45m below ground level is designated as a principal aquifer. The lower granular beds of the Lambeth Group, the Thanet Formation and Chalk deposits are often referred to as the Chalk-basal sands aquifer (or lower or deep aquifer). The site does not lie within a groundwater source protection zone (SPZ) for public water supply abstraction and there are no SPZs within 1km of the site.

2.3.2 Environmental database search report

A review of the Envirocheck environmental database report included with the Arup desk study [3] has indicated the following pertinent information for the Astor College site:

- There are no registered groundwater abstractions recorded on or near the site. The nearest surface water feature is located approximately 700m south east of the site and will not be affected by the proposed works.
- The site is not in a radon affected area as less than 1% of properties are above the action level defined by the Health Protection Agency (HPA). Therefore radon protection measures are unlikely to be required for new properties.
- Ten contemporary trade directory entries recorded within 100m of the site. The closest of which is located approximately 8m south east of the site and relates to an auto garage, which is inactive.
- There are no landfills recorded within 250m of the site.
- There are no registered radioactive substances licences for the site. Due to the medical use of the site and surrounding area (between 1940's and 1966), it is possible that radioactive substances may have been used. It is understood that a neutron generator was located in the former Windeyer Building.
- There are no ecological receptors as the site, with surrounding area being fully developed.

3 Ground investigation

3.1 Scope of works (contamination)

The site area is approximately 1500m^2 which is mostly occupied by the Astor College building. There has been 20 pits and two boreholes which represents a significant amount of investigation on a small site. The various phases of investigation are described below:

Soil Mechanics (2011) [2]

- Two boreholes (BH1 and BH3) to 48.3m and 11.95m below ground level (bgl) respectively with gas monitoring standpipes installed with response zones in the Made Ground and RTD. BH1 was located in Bedford Passage and BH3 in the courtyard to the rear of Astor College.
- Soil sampling with chemical testing of seven samples (three Made Ground, three RTD and one London Clay) for a suite of metals, asbestos, speciated total petroleum hydrocarbons (TPH), volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC) including polyaromatic hydrocarbons (PAH).
- Ground gas monitoring (one round) for carbon dioxide, methane, and oxygen and gas flow.
- Groundwater level monitoring and sampling of groundwater from BH3 with chemical testing for a suite of metals, TPH, VOC and SVOC.

The factual ground information has been reproduced in Appendix D and discussed in the sections below. The exploratory hole locations are shown on Figure 1.

Albury S.I. Ltd (2014) [1]

- Four trial pit locations (TP1, TP3, TP3a and TP4) located in the proposed rear extension area.
- Soil sampling with chemical testing of two Made Ground samples for a suite of metals, asbestos, TPH and PAH.

The factual ground information has been reproduced in Appendix E and discussed in the sections below. The exploratory hole locations are shown on Figure 1.

Soiltechnics (2016) [4]

- 16 hand excavated trial pits (TP05 to TP20) across the external areas to the rear to the Astor College building and in Bedford Passage.
- Soil sampling with chemical testing of six Made Ground samples for a suite of metals, asbestos and PAH.
- Waste acceptance criteria (WAC) testing of one sample, including leachability.

The factual ground information has been reproduced in Appendix F and discussed in the sections below. The exploratory hole locations are shown on Figure 1.

3.2 Ground conditions

A summary of the ground conditions encountered on site from the three phases of investigation is presented in Table 3 below

Table 3 Summary of geology

Stratigraphy	Depth to top of Strata (m BGL)	Elevation at Top of Stratum (mOD)	Stratum Thickness (m)
Hardcover (Asphalt/concrete)	Ground level	+24.78 to +26.33	Up to 0.25
Made Ground	0.25	+24.53 to +26.08	1.85 to 3.45
Lynch Hill Gravel River Terrace Deposits (RTD)	2.1 to 3.7	+22.63 to +22.68	2.6 to 3.8
London Clay	5.9 to 6.3	+18.88 to +20.03	18.6
Lambeth Group	24.9	+0.33	18.1
Thanet Formation	43.0	-16.67	3.6
Chalk	46.6	-20.27	>1.7m [a)]
a) Base not proven.			

3.2.1 Made Ground

Hardcover consisting of asphalt and concrete (and associated sub-base) was observed in external areas up to a depth of approximately 0.25m. Made Ground was then observed at all locations which consisted of:

- Up to 1m of sandy gravelly clay or clayey sand and gravel, with gravel of brick, tile, concrete and flint, metal, glass, plastic, ash and rare clinker. This fill is probably associated with the 1950/60's phases of development. The more recent fill is locally deeper adjacent to building footings, which also includes reworked natural sand and gravel (RTD) soils.
- Up to 2.7m of sandy gravelly clayey silt or silty clay, with gravel of brick, concrete, flint, rare clinker, oyster shells, pottery and clay pipe fragments. This fill is probably associated with the mid-18th Century land-raise which occurred prior to the original development of the site.

Obstructions were observed up to 1.8m bgl, which may be related to previous phases of development (e.g. building foundations).

No obvious visual or olfactory indicators of contamination such as stains or odours were observed to the Made Ground across the site. In addition, no evidence of visual fragments of asbestos containing material (ACM) were noted on the exploratory hole logs. The Made Ground was also observed to be free of any significant deleterious material or organic material which could act as a potential source of ground gas.

A localised pocket of ‘peaty silty sand’ was noted at TP4 (Appendix E) which is in the area of the proposed extension and which should largely be removed as part of the 600mm to 700mm reduction in levels.

3.2.2 Lynch Hill Gravel

Where encountered, the RTD was observed to be an orangish brown gravelly sand or sandy gravel. Locally, the top of RTD was observed to be an organish brown sandy, gravelly clay. The full depth of the RTD was proved in the 2011 boreholes in the northern (BH3) and southern (BH1) areas of the site.

No obvious visual or olfactory indicators of contamination such as discolouration, stains or odours were observed to the RTD across the site. The presence of RTD supports the site history, which indicated that gravel extraction did not occur at the site. From the available information, there is no indication that the site is being impacted by potential offsite sources of contamination, for example via groundwater migration.

The water level was recorded between 2.33m and 4.2m bgl (22.1m to 22.45m OD), which indicates that the RTD is not fully saturated.

3.2.3 London Clay and Lambeth Group

The London Clay deposits consisting of low permeability grey clay was identified at the site. The London Clay was in turn underlain by the Lambeth Group, which mostly consisted of clay deposits. No obvious visual or olfactory indicators of contamination were observed.

The shallow (RTD) and deep aquifers are separated by over 35m of low permeability clay deposits, which effectively eliminates any plausible contaminant linkage between the site and the lower aquifer. The CFA piles are proposed to terminate near the base of the London Clay. Therefore, there will be approximately 20m of clay deposits between the pile toe and the top of the Thanet Formation. Therefore, there is no a plausible contaminant pathway between the site and the deep aquifer.

3.2.4 Thanet Formation and Chalk

The Thanet Formation and Chalk was observed at BH1 (2011). No obvious visual or olfactory indicators of contamination were observed.

3.3 Soil gas conditions

One round of ground gas monitoring was completed at BH1 and BH3 on the site during 2011 (Appendix D), which consisted of up to 10 separate readings at each location. In summary, the ground gas monitoring indicated:

- Methane concentrations of <0.1%.
- Peak carbon dioxide concentration of up to 3.3%.
- Gas flow of <0.1 l/hr.

- Oxygen concentrations of between 14.6% and 20.1%.
- Hydrogen sulphide and carbon monoxide concentrations of <1ppm.

The calculated Gas Screening Value (GSV) of 0.003 l/h is significantly below the GSV threshold of 0.07 for a gas characteristic situation (CS) 1 [5]. A CS1 indicates that there is a low gas risk and that no specific gas protection measures are necessary for the site.

The low gas risk for the site is supported conceptually, as:

- No alluvium (including peat) or organic rich Made Ground were encountered.
- No obvious evidence of visual or olfactory indicators of contamination were recorded.
- Made Ground below Astor College (i.e. potential source) would have been partially removed during the basement construction in the 1960's.
- The development affords a certain level of protection, such as ventilation in the basement and lower ground floor area and proposed floor slab and DPM in the extension.
- The existing Astor College building including basement and lower ground floor were constructed approximately 50 years ago. The proposed end-use (and receptors) associated with the redevelopment remains unchanged (i.e. student halls of residence).

The risks to human health from ground gas are further assessed in Section 4.2.

3.4 Soil chemical results

3.4.1 Assessment approach

There will be limited pathways applicable due to the nature of the development. After development there will be no dermal and ingestion pathway for students and building users as the site will be covered by the building and hardcover, with tree pits and planters (with a minimum depth of around 550mm in planters and likely deeper in tree pits). The main pathway applicable to the development will be from indoor vapour of volatile contaminants such as benzene and naphthalene. It is also necessary to consider maintenance works if more substantial groundworks are undertaken in the future, which are likely to be infrequent and short term.

There are two human health receptors applicable to the proposed development with respect to assessing risks to end users:

- Workers (office and maintenance) who may be on site for 40 hours a week over their working life.
- Students residents (>18 years) who will be living on the lower ground floor, during term-time for the duration of their university education.

Commercial end-use generic assessment criteria (GAC) have used to benchmark the results in the context of the proposed development for the site workers. The key receptor in the commercial exposure model is a female office worker exposed via some limited direct contact with soil in soft landscaping, some tracking back of soil and dust and exposure via soil vapour pathways, for the duration of her working life. Results above the commercial GAC in this case will not necessary represent significant contamination as there is no direct exposure with residual Made Ground (dermal contact and ingestion). In that case further conceptual assessment is presented.

To assess the potential risks to students, residential GAC (without consumption of home-grown produce) have been used to initially assess the indoor vapour risk from volatile contaminants. This is an initial screen of the results. Residential GAC are based on a female 0-6 year child and take account of a range of exposure pathways. Results above the residential GAC do not necessarily indicate a potential risk and will be subject to further assessment of the conceptual model and/or refinement of the assessment criteria.

LQM 'Suitable 4 use levels' (S4UL) (Copyright Land Quality Management Limited reproduced with permission (Publication Number S4UL3227)) [6] have been used in the assessment where available. In addition Category 4 screening levels (C4SLs), released by Defra for some determinands, have been considered in the assessment where appropriate (for instance for lead for which there is no S4UL). The S4ULs use C4SL exposure parameters but maintain the traditional minimal risk toxicological benchmarks whereas the C4SL are based on a new toxicological benchmark described as 'acceptable low' rather than minimal risk.

There are no published generic assessment criteria for asbestos in soils in the UK and currently it is not possible to generate them. Any positive asbestos results from the site have been assessed using multiple lines of evidence as to the potential significance during and after construction based on the latest guidance from CIRIA [7] and JIWG CAR SOIL™ [10].

3.4.2 Human health assessment

The certificates of chemical analysis from the three phases of investigation have been reproduced in Appendix D (2011), Appendix E (2014) and Appendix F (2016) and summarised in Table 4 below:

Table 4 Summary of soil chemical data

Determinant	No. of samples	Commercial End-use GAC	Residential End-use GAC	Concentration		> GAC commercial / residential
				Min	Max	
Arsenic (mg/kg)	15	640 a)	40 d)	3.8	26	0 / 0
Cadmium (mg/kg)	15	190 a)	85 d)	<0.1	0.97	0 / 0
Chromium total (mg/kg)	15	8600 a)	910 d)	10.4	42.8	0 / 0
Copper (mg/kg)	15	68000 a)	7100 d)	5.8	250	0 / 0
Lead (mg/kg)	15	2300 b)	310 e)	7.4	2100	0 / **5**
Mercury inorganic (mg/kg)	15	1100 a)	56 d)	<0.1	12	0 / 0
Nickel (mg/kg)	15	980 a)	180 d)	11.2	35.5	0 / 0
Zinc (mg/kg)	15	730000 a)	40000 d)	14.8	270	0 / 0
Acenaphthene (mg/kg)	15	84000 a)	3000 d)	<0.1	<0.2	0 / 0

Determinant	No. of samples	Commercial End-use GAC	Residential End-use GAC	Concentration		> GAC commercial / residential
				Min	Max	
Acenaphthylene (mg/kg)	15	83000 [a)]	2900 [d)]	<0.1	<0.2	0 / 0
Anthracene (mg/kg)	15	520000 [a)]	31000 [d)]	<0.1	0.45	0 / 0
Fluoranthene (mg/kg)	15	23000 [a)]	1500 [d)]	<0.1	4.2	0 / 0
Pyrene (mg/kg)	15	54000 [a)]	3700 [d)]	<0.1	3.4	0 / 0
Benzo(a)anthracene (mg/kg)	15	170 [a)]	11 [d)]	<0.1	1.2	0 / 0
Chrysene (mg/kg)	15	350 [a)]	30 [d)]	<0.1	2.7	0 / 0
Benzo(b)fluoranthene (mg/kg)	15	44 [a)]	3.9 [d)]	<0.1	6.9	0 / **1**
Benzo(k)fluoranthene (mg/kg)	15	1200 [a)]	110 [d)]	<0.1	1.2	0 / 0
Benzo(a)pyrene (mg/kg)	15	35 [a)]	3.2 [d)]	<0.1	7.4	0 / **1**
Indeno(1,2,3-c,d)Pyrene (mg/kg)	15	500 [a)]	45 [d)]	<0.1	7.0	0 / 0
Dibenz(a,h)anthracene (mg/kg)	15	3.5 [a)]	0.31 [d)]	<0.1	0.76	0 / **1**
Benzo(g,h,i)perylene (mg/kg)	15	3900 [a)]	360 [d)]	<0.1	7.0	0 / 0
Fluorene (mg/kg)	15	63000 [a)]	2800 [d)]	<0.1	0.7	0 / 0
Naphthalene (mg/kg)	15	190 [a)]	2.3 [d)]	<0.1	0.2	0 / 0
Phenanthrene (mg/kg)	15	22000 [a)]	1300 [d)]	<0.2	2.2	0 / 0
Total 16 PAHs (mg/kg)	15	N/A	N/A	<0.2	35	0 / 0
TPH (C8-C10) (mg/kg)	7	3500 [a, c)]	27 [c, d)]	<4	<4	0 / 0
TPH (C10-C12) (mg/kg)	9	3800 [a, c)]	130 [c, d)]	<2	<4	0 / 0
TPH (C12-C16) (mg/kg)	9	36000 [a, c)]	1100 [c, d)]	<2	8.27	0 / 0
TPH (C16-C21) (mg/kg)	9	28000 [a, c)]	1900 [c, d)]	<2	25.9	0 / 0
TPH (C21-C35) (mg/kg)	9	28000 [a, c)]	1900 [c, d)]	28	85	0 / 0
TPH (C35-C40) (mg/kg)	9	28000 [a, c)]	1900 [c, d)]	19	150	0 / 0
Benzene (μg/kg)	7	27000 [a)]	380 [d)]	<1	2	0 / 0
1,3-Dichlorobenzene (μg/kg)	7	30000 [a)]	440 [d)]	<1	1	0 / 0
1,2-Dichlorobenzene (μg/kg)	7	2000000 [a)]	24000 [d)]	<1	1	0 / 0
1,4-Dichlorobenzene (μg/kg)	7	4400000 [a)]	61000 [d)]	<1	2	0 / 0
Trichloroethene (μg/kg)	7	1200 [a)]	17 [d)]	1	3	0 / 0
1,2,4–Trichlorobenzene (μg/kg)	7	220000 [a)]	2600 [d)]	4	10	0 / 0

Notes:

a) LQM S4UL for a commercial end-use (1% soil organic matter)

b) Defra C4SL for a commercial end-use (1% soil organic matter)

c) Lowest criterion for aliphatic or aromatic carbon band used.

d) LQM S4UL for a residential end-use (1% soil organic matter)

e) Defra C4SL for a residential end-use (1% soil organic matter)

Overall, the available chemical results do not indicate any significant widespread contamination, which supports the conclusions based on the site history. All concentrations were below their respective commercial end-use GAC.

PAH and TPH concentrations were observed at either generally low concentrations or below the laboratory limit of detection (LOD). A locally elevated benzo[a]pyrene concentration of 7.4mg/kg was observed at TP7-0.4m

(2016). VOC/SVOC concentrations were also observed either at low concentrations (up to 12µg/kg) or below the LOD.

Most determinants were also below their respective residential end-use GAC, except for lead, benzo[a]pyrene, benzo(b)fluoranthene and dibenz(a,h)anthracene. These are not considered to present a significant risk to the development as these contaminants are non-volatile and the form of development (e.g. buildings, hardcover, and thick imported growing medium with underlying drainage layer) will break the potential contaminant pathway. All volatile contaminants (e.g. benzene, naphthalene), were observed to be below the residential assessment criteria.

The metal concentrations were observed to be generally low, except for lead, where concentrations up to 2,100mg/kg were observed. The elevated lead concentrations were restricted to the top 1m (i.e. 1950/60's fill) which is consistent with that type of fill.

Out of 15 soil samples (11 Made Ground and 4 natural) screened for asbestos, only one sample was observed to contain asbestos (TP05 0.5m, 2016). The asbestos was recorded as amosite lagging, although the amount was not quantified. This will principally be addressed with enhanced health and safety during construction, and apart from significant maintenance works there is no pollutant linkage after development.

The risks to human health are further assessed in Section 4.2.

3.4.3 Controlled waters assessment

The certificates of chemical analysis from the three phases of investigation have been reproduced in Appendix D (2011), Appendix E (2014) and Appendix F (2016).

As part of the 2016 investigation, a soil sample was also submitted for soil leachate (2:1) analysis as part of the WAC suite. In summary, the soil leachate concentrations were generally low and below their respective freshwater Environmental Quality Standard, as summarised below:

- Arsenic: 9.8µg/l which is below the EQS of 50µg/l.
- Cadmium: <0.1µg/l which is below the EQS of 5µg/l.
- Copper: 12µg/l which is below the EQS of 28µg/l.
- Mercury: <0.5µg/l which is below the EQS of 1µg/l.
- Nickel: 1.6µg/l which is below the EQS of 200µg/l.
- Lead: <1µg/l which is below the EQS of 20µg/l.
- Selenium: 11µg/l is marginally above the EQS of 10µg/l.
- Zinc: <1µg/l which is below the EQS of 125µg/l.

The groundwater chemical results for the RTD (BH3, 2011) indicated very low concentrations, with many determinants observed below the LOD, including TPH, VOC and SVOC and below their respected EQS.

The available soil, leachability and groundwater chemical results (which are generally low) and lack of obvious visual and olfactory evidence of significant contamination, indicate that the site does not presents an unacceptable risk to controlled waters. The risks to controlled waters are further assessed in Section 4.3.

4 Risk assessment

4.1 Methodology

The potential risks to various receptors have been considered in the context of a conceptual model of the site and development in accordance with the current UK approach to contaminated land assessment.

The method for risk evaluation has been based on a qualitative assessment taking into consideration the magnitude of the potential severity of the risk as well as the probability of the risk occurring. The risk characterisations provided below have been assessed on a scale from very high to very low and negligible based on the CIRIA guidance C552 [8]. A brief summary of each risk classification is provided in Table 5 below.

Table 5 Risk classifications

Risk classification	Description of risk
Very high	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. The risk, if realised, is likely to result in substantial liability. Remediation is likely to be required.
High	Harm is likely to arise to a designated receptor from an identified hazard. Realisation of the risk is likely to present a substation liability. Remedial works may be necessary.
Moderate	It is possible that harm could arise to a 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. Some remedial works may be required.
Low	It is possible that harm could arise to a receptor from an identified hazard but it is likely that this harm, if realised, would typically be mild.
Very low	There is a low possibility that harm could arise to a receptor. In the event of such harm being realised the consequence would at worst be mild.
Negligible	There is no plausible pollutant linkage due to the absence of a pathway or receptor (without any intervention).

4.2 Human health risk assessment

4.2.1 During construction

The groundworks associated with the development will be limited in nature, consisting of the removal of hardcover and obstructions, a small reduction in ground levels (to allow for the slab and hardcover construction) and then pile construction will take place. The majority of the groundworks will occur to the rear of Astor College, which is surrounded by buildings on all sides.

Overall, the available ground investigation informations did not identify any significant contamination which would normally result in unacceptable risks during construction, with the possible exception of some asbestos lagging. One sample indicated the presence of asbestos as lagging, which are commonly found in Made Ground soils.

The potential risks during construction will be reduced by the Principal Contractor (Galliford Try) through good construction practices, use of appropriate personal protection equipment (PPE) and site welfare/hygiene facilities. Further details are presented in Section 5.2.

There is a potential for further asbestos contaminated soils being present at the site. Additional precautions will be required to mitigate potential exposure to asbestos fibres during construction in accordance with the principle of ‘as low as reasonably practicable’ (ALARP), CAR 2012 [9] and CAR-SOIL^{TM} [10].

It is considered that the potential risks to human health receptors during the intrusive groundworks without mitigation will be **low** (for general contaminants, such as lead and PAH) and **moderate** (due to the low concentrations of asbestos).

Providing appropriate risk management and mitigation procedures are implemented during the groundworks, the potential risk of harm to human health (i.e. construction workers and neighbours) during construction will reduce to **very low**. Further recommendations are provided in Section 5.2.

4.2.2 During operation

The level of contamination was observed to be low, with any non-volatile contamination (e.g. lead, asbestos) capped by the building (including proposed extension) and cover layers. The ground investigations did not identify any significant volatile contamination. All concentrations were recorded below the respective commercial end-use criteria, with all volatile contaminants (which could present an indoor vapour risk) also below the residential assessment criteria.

There are small soft landscaping proposed to the rear of the Astor College building which will consist of raised planters with at least 450mm of imported topsoil and 100mm drainage layer. The external areas will be subject to maintenance by UCL. The two proposed trees will be planted in pits with clean soil. Imported topsoil will be chemically tested to ensure that it is uncontaminated, free of asbestos and suitable for use. The requirements for verification of the imported soils are presented in Section 5.2.2.

Based on the identified ground conditions and low risk development/end-use, the site is considered not to present an unacceptable risk from contamination (i.e. a **negligible** risk).

The risk of harm to human health of future maintenance workers during groundworks are considered to be **very low** if appropriate mitigation is put in place.

Although the amount of gas monitoring completed is limited, based on the available ground investigation information (e.g. descriptions of Made Ground in the logs and relatively low organic content) and the form of development (refer to Section 2.2), there is not considered to be an unacceptable risk to human health from ground gas. The form of development will afford a certain level of protection. The proposed development (including refurbishment of existing building and extensions) will be undertaken in accordance with the Building Regulations Approved Document C, including consultation with the Building Control Officer. This consultation and agreement should be included in the verification report.

4.3 Controlled waters risk assessment

The ground investigations did not identify any significant level of soil or groundwater contamination at the site, with no obvious visual or olfactory evidence of contamination observed, such as free product or staining.

The development consists of buildings and hardcover which will continue to act to limit potential infiltration and contaminant leaching. The continued use as a student halls of residents, represents a low risk. In addition, no sensitive controlled waters receptors were identified in the close proximity to the site.

The risk of pollution of controlled waters from ground conditions at the site is considered to be **very low.**

4.4 Conceptual site model

Based on the findings of the ground investigations and the risk assessment presented above, Table 6 presents the conceptual site model and assessment of plausible pollutant linkages (PPL).

Table 6 Conceptual site model

PPL	Active	Risk	Mitigation measures	Residual risk
Human health - construction				
Site workers (including visitors) during construction. Site neighbours during construction via inhalation of dust and fibres.	Yes: Generally low levels of contamination. Sporadic low levels of lead, PAH and asbestos in the Made Ground. Potential windblown dust containing low level asbestos.	Low (lead, PAH) Moderate (asbestos fibres)	Good construction practices, PPE. Reduction of potential asbestos exposure via measures described in Section 5.	Very low
Human health - operation				
Future site visitors, residents (students), and office workers via dermal contact, ingestion and inhalation of soils and dust.	No: Based on identified ground conditions. No direct contact with underlying soils as site will be capped. Small areas of soft landscaping with 450m of topsoil and	Negligible	N/A. Form of development is considered sufficient mitigation. Imported topsoil will be tested.	Negligible

PPL	Active	Risk	Mitigation measures	Residual risk
	100mm of drainage layer.			
Maintenance workers, via dermal contact, ingestion and inhalation of soils and dust during excavation works.	Yes (but limited): Generally low levels of contamination identified. Potential for low levels of asbestos in the Made Ground.	Low to moderate	Good construction practices, PPE. Asbestos control measures described in Section 5.	Very Low
Future site visitors, residents (students), office and maintenance workers via inhalation of ground gases and vapours.	Yes: No significant sources of potential ground gas and vapour identified. Development is low risk and mostly remains unchanged.	Very Low	Development in accordance with the Building Regulations in consultation with the Building Control Officer.	Very Low
Controlled waters				
Secondary A Aquifer (RTD) via infiltration and leaching.	Yes (but limited): Low levels of contamination, no sensitive receptors and limited infiltration. CFA piling.	Very low	N/A	Very low

5 Conclusions and recommendations

5.1 Summary and conclusions

Based on the known history, the site is considered to have a low potential for ground contamination. This was confirmed by the three phases of intrusive ground investigation, which indicated generally low levels.

Occasional elevated lead and PAH concentrations and one detection of asbestos were identified in the shallow Made Ground. It is not unusual to encounter similar conditions in London Made Ground and this is consistent with the historical phases of development, including the 1950/60's.

The identified ground conditions and contamination are not considered to be significant with respect to human health and controlled waters receptors assuming mitigation is in place during development and future maintenance. The form of development will further reduce any potential risk to the end-uses. No specific ground or groundwater remediation is required for the site.

Good construction practices (e.g. health and safety and environmental controls) should be implemented to effectively manage any potential risk associated with groundworks. Further details are presented in Section 5.2.

5.2 Remediation strategy and verification plan

5.2.1 Site safety and control, including watching brief

Galliford Try will implement necessary risk assessments, method statements and plans to manage and control environmental and health and safety risks during the construction project. Galliford Try has assessed the risk to be low and as a precautionary approach will implement the following measures:

- Operatives to wear protective clothing particularly gloves to minimise ingestion from soil to contaminated hands.
- Avoiding dust by dampening soils during works.
- Provide shower room/hygiene facilities, which is designated for operatives that are working in and with ground.
- Staff are adequately trained (and experienced) with respect to potential health and safety and environmental risks and requirements. This should include asbestos awareness.
- A watching brief will be undertaken for potential ground contamination.
- Imported topsoil will be tested (refer to Section 5.2.2)

The works should be undertaken in a pro-active manner to prevent the creation of dusts (and potential release of asbestos fibres) with the use of PPE and good control of arisings undertaken as necessary.

The requirements described in the Control of Asbestos regulations (CAR) 2012 [9] and CAR SOIL[10] should be adhered to. All work with asbestos, including asbestos in soils, is regulated under CAR 2012. Asbestos in soils may not necessarily be visible to the naked eye. If encountered it may not be practical to identify and segregate some asbestos containing materials (ACM). However, should pieces of ACM including asbestos hotspots be encountered, the ACM should be segregated, stored and disposed of were practical to do so. The contractor should have the appropriate asbestos expertise (or appoint a specialist) to advise on the works (and associated risks and control measures) before and during the construction period. This a legal requirement under CAR 2012. The recommendations of the specialist should be implemented and documented.

A recent guide was published by CL:AIRE referred to as Interpretation for managing and working with asbestos in soils CAR-SOIL™ [10], which is currently the most authoritative guide on working with asbestos in soils and should be followed. CAR-SOIL™ confirms that all work with asbestos in soil should be carried out under a 'plan of work' and defines the contents of that plan. The plan should consider whether air monitoring is required to confirm the absence of respirable fibres above the CAR 2012 action levels or at the site boundary as recommended by CIRIA C733 [7] .

During the course of the excavation, Galliford Try's site management team will ensure a watching brief is carried out. All operatives will be briefed on what to do if anything unexpected or additional is found, including ACM. All works will be suspended in the area and a competent consultant will advise on a strategy for the assessment and removal (if necessary) of contamination. This will be documented in the verification report (refer to Section 5.2.3).

The Principal Contractor will be responsible for ensuring that the necessary Duty of Care requirements are undertaken when disposing material offsite. Galliford Try will follow their in house waste management and disposal procedure and may undertake further waste classification testing, if deemed to be required.

The development (design and construction) will be undertaken in accordance with the Building Regulations Approved Document C, in consultation with the Building Control Officer. The relevant correspondence and sign off should be included in the verification report.

5.2.2 Import of material

Limited volumes of material will be imported onto site, which is likely to consist of topsoil and 'product' material.

Based on the proposed soft landscaped areas and depth, less than 30m^3 of topsoil material will be imported. Topsoil used shall be general purpose grade in accordance with BS3882:2015, unless specified by the landscape architect. Topsoil testing will be carried out to demonstrate that the material is clean and suitable for use. Based on this small volume, it is proposed that the topsoil will be certified by the supplier and then an additional sample will be taken on delivery and tested for metals, TPH, PAH and asbestos.

'Product' material, such as concrete and natural quarry materials which may include drainage shingle, bedding sands and sub-base quarry aggregate will not be chemically tested.

Upon arrival to site, all materials should be visually inspected to ensure that it is free of any obvious visual or olfactory evidence of contamination or deleterious material and is consistent with the expected material type. If suspect material is identified, any lorry loads should either be rejected or chemically tested (and confirmed as clean) prior to any placement.

Delivery notes should be kept confirming the source of where the material originates from.

5.2.3 Verification report

Condition 11 of the planning permission states that a 'written report detailing the remediation shall be submitted to and approved by the local planning authority in writing prior to occupation'. Therefore upon completion of the works, a brief verification / closure report should be prepared by the Principal Contractor (or their appointed consultant) which should be in line with CLR11 [11] and include the following information where appropriate:

- Details of parties involved and summary of works carried out, including method of works, health and safety and environmental control measures implemented, as-built records and photographs of key stages of the ground works.
- Records of the watching brief undertaken, for example, during excavations and piling, including any ground contamination encountered and how it was dealt with.
- Evidence of communication with the regulators (if/where undertaken), such as the Local Authority Environmental Health Officer (EHO) and Building Control Officer.
- Descriptions of asbestos control measures and relevant CAR 2012 assessment.
- Verification of imported soils, including placed thicknesses, volumes and material sources and chemical testing, where appropriate, with assessment against the relevant import criteria.
- Waste management details and records, such as volumes / tonnage, destinations, waste disposal licence/permit details (e.g. haulage contactors and disposal sites), laboratory results for waste classification and summary of waste disposal records, including conveyance tickets and evidence of compliance with the relevant waste regulations.
- Description of final site conditions and as built drawings for small landscaped areas.

The verification report should form part of the Health and Safety File in accordance with the Construction Design and Management (CDM) Regulations 2015 and the development operations & maintenance (O&M) manual or maintenance plan. This is to allow occupiers and owners to address any residual ground contamination risks associated with future operations and maintenance, including residual asbestos where relevant.

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