

WS111	G	GL-0.5	0.5-1	0.2-0.5
WS113	G	GL-0.9	0.9-1.9	0.2-0.9
WS115	G	GL-1	1-2	0.2-1
WS116	G	GL-0.5	0.5-1.5	0.2-0.5
WS118	G	GL-0.5	0.5-1.5	0.2-0.5

12.2.6 Monitoring Well Development

The deep monitoring wells were developed on 5th February 2021 using a submersible electric pump. A minimum of three well volumes were removed from BH101 and BH103. A full three well volume purge was not completed on BH102, BH104, BH105 and BH106 despite several attempts to do so using the available equipment. Low flow sampling methods as described in Section 12.4 were employed to collect representative groundwater samples from the deep standpipes for analysis.

12.3 Field Tests

12.3.1 Standard Penetration Tests

Standard penetration tests were undertaken in the rotary coring boreholes within the overburden or where core recovery was poor. Uncorrected blow counts, 'N values', are recorded on the borehole logs in Appendix D. Where core recovery was good, SPTs were not undertaken in the rotary cored boreholes.

SPTs undertaken in the windowless boreholes at 1m centres in granular soils in accordance with BS EN ISO 22476-3;2005. Uncorrected blow count 'N values' and SPT hammer energy ratios are recorded on the borehole logs in Appendix D.

12.3.2 Perth Penetration Tests

Hand held perth penetrometer tests were undertaken in trial pits at depths between 1.0 m to 1.5m bgl. Uncorrected blow counts, 'N values', are recorded on the trial pit logs in Appendix D.

12.3.3 In-situ California Bearing Ratio Test – Dynamic Cone Penetrometer

6 No. in-situ CBR tests have been undertaken on undisturbed ground where it was deemed safe to do so (i.e. away from known below ground services) using a Dynamic Cone Penetrometer (DCP), recording blow counts over 900mm of penetration from test level. The test method and interpretation of the results have been undertaken in accordance with DMRB HD 29/08¹² using a modified DCP. The results are presented in Appendix D.

¹² HD22/08 Data for Pavement Assessment. Design Manual for Roads and Bridges; Volume 7 Pavement Design and Maintenance; Section 3 Pavement Maintenance Assessment Part 2

12.3.4 BRE365 Soakage Tests

3 No. soakage tests have been carried out in trial pits TP147, TP126A and TP138 in general accordance with BRE Digest 365¹³. However, due to site conditions (high groundwater) it was not possible to fill and test each location three times.

12.4 Ground Gas and Groundwater Monitoring

12.4.1 Groundwater sampling

Three rounds of groundwater sampling were undertaken during this investigation. The visits were completed on 8th-9th, 22nd-23rd February, and 8th-9th March 2021. Groundwater monitoring wells were inspected for the presence of water using an electronic dipmeter.

Following well development groundwater samples were recovered using low flow sampling equipment i.e. a bladder pump attached to a multiparameter probe with a through flow cell. Water samples were collected when physio-chemical parameters (pH, dissolved oxygen, REDOX, and electroconductivity) were deemed stable on site.

Samples were collected in laboratory supplied containers and placed in cooled insulated boxes for transport to The Environmental Laboratory Ltd for analysis. The results of the groundwater monitoring visits are provided in Appendix I and summarised in Section 13.3.

12.4.2 Land gas monitoring

Six rounds of land gas monitoring have been undertaken on 8th February, 22nd February, 8th March, 15th March, 22nd March and 6th April 2021. A seventh gas monitoring visit was undertaken on 16th April 2021, as one monitoring round was missed at BH106, for completeness shallow monitoring wells in the vicinity of BH106 were also measured (WS103 and WS106). The wells were monitored for methane, carbon dioxide, oxygen, hydrogen sulphide and carbon monoxide using a GA2000 portable gas analyser. The results of the land gas monitoring visits are presented in Appendix I and summarised in Section 32.

The wells were monitored for volatile organic compounds using a PhoCheck+ portable Photo-ionisation Detector (PID).

12.5 Laboratory Analysis

12.5.1 Chemical Soil Analysis

Selected samples of soil have been subjected to laboratory testing. Sampling techniques and storage have been undertaken as per BS 10175:2011+A2:2017 Code of Practice for Investigation of Potentially Contaminated Sites. The laboratory testing has been carried out

¹³ Building Research Establishment DG365 Digest Soakaway Design (2016)

by The Environmental Laboratory Ltd at its laboratories in East Sussex. Where available, the tests procedures are UKAS and MCERTS accredited.

The following analyses were completed on selected samples:-

- LEAP standard Soil suite (metals, speciated PAHs, asbestos);
- Speciated Petroleum Hydrocarbons (CWG-TPH);
- Volatile Organic Compounds;
- Semi Volatile Organic Compounds;
- Asbestos Quantification; and
- Waste Acceptance Criteria tests.

The full laboratory test results are presented in Appendix E.

12.5.2 Chemical Water Analysis

Groundwater from deep monitoring wells have been subjected to laboratory testing. Sampling techniques and storage have been undertaken as per BS 10175:2011+A2:2017 Code of Practice for Investigation of Potentially Contaminated Sites. The laboratory testing has been carried out by The Environmental Laboratory Ltd at its laboratories in East Sussex. Where available, the tests procedures are UKAS and MCERTS accredited.

The following analyses were completed on selected samples:-

- LEAP standard water suite (metals, pH, sulphate, sulphide, phenol, boron, total cyanide and basic petroleum hydrocarbon analysis);
- Petroleum Hydrocarbons including speciated banding via TPH CWG method including BTEX compounds; and
- Speciated PAHs.

The full laboratory test results are presented in Appendix E.

12.5.3 Geotechnical Laboratory Testing

Selected samples of the soils have been classified by laboratory analysis for geotechnical design purposes. The laboratory testing has been carried out by Geolabs Ltd at its laboratories in Watford, in accordance with BS1377¹⁴ and BS EN ISO17892¹⁵. The sampling technique, type, storage and transport and the number of laboratory tests have been undertaken where

¹⁴ BS1377 Parts 1-9:1990 Methods of test for Soils for Civil Engineering Purposes

¹⁵ BS EN ISO 17892 Parts 1-12 Geotechnical Investigation and Testing. Laboratory testing of soil

possible in accordance with BS EN 1997-2:2007 and BS EN ISO 22475¹⁶. Undisturbed Class 1 (Category A) samples have been obtained where possible from the rotary coring boreholes using UT100 thin walled samplers. Full laboratory test results are provided in Appendix F.

13 Ground Conditions

Made ground conditions encountered were noted to vary between the land west and east of Building 3/36. On this basis the ground model summarised below, describes these two sections separately. Figure 5, Appendix B shows exploratory hole location relating to each area. The stratigraphy encountered is described on the trial hole logs in Appendix D.

13.1 Western Area

Table 5: Summary of soils encountered within the western half of the site

Depth From (m)	Depth To ¹⁷ (m)	Soil Type	Description
GL (56.58 / 57.52)	0.15 / 0.4 (56.18 / 57.12)	TOPSOIL	Dark brown silty clay TOPSOIL.
GL (56.18 / 57.83)	0.2 / 1.0 (55.38 / 57.53)	MADE GROUND	Variable MADE GROUND generally comprising grey demolition fill of fine to coarse and cobbles of brick and concrete and occasional blacktop and areas of red sandy gravelly fill with gravel of fine to coarse brick and concrete.
GL / 2.7 (57.03 / 54.36)	0.5* / 2.9 (56.73 / 53.41)	REWORKED SOIL¹⁸	Reworked soils comprising grey to brown clayey silt and silty clay with occasional fragments of fine to coarse brick or concrete.

¹⁶ BS EN ISO 22475 Parts I-3 Geotechnical Investigation and Testing. Sampling methods and groundwater measurements

¹⁷ Average strata thicknesses have not been quoted due to the variability across the site.

¹⁸ 'Reworked' is a generic term used by LEAP to describe soils that are predominantly formed from the 'natural' superficial or bedrock deposits, but may have minor inclusions of anthropogenic material such as glass or brick/concrete gravels. These minor inclusions may have been introduced into underlying stratum during construction or demolition works. They are visually different from 'made ground' soils which are predominantly formed of construction or demolition waste, waste material, or clearly definable 'natural' soils that have been placed to an engineered specification e.g. above a marker layer or a chalk capping layer above a made ground layer.

0.3 / 1.7 (57.12 / 55.88)	1.1 / 3.7 (55.30 / 55.36)	Interbedded CLAY and SILT	Interbedded firm to stiff mottled grey and brown and orangish brown and silty CLAY and clayey SILT.
1.1 / 3.1 (55.30 / 53.21)	3.35 / 3.7 (52.96 / 53.86)	Interbedded MUDSTONE, SILTSTONE & SANDSTONE	Extremely weak to very weak reddish brown to dark grey interbedded occasionally laminated ferruginous MUDSTONE, SILTSTONE and SANDSTONE. Occasionally thin lignite layers encountered within the sandstone strata.
3.35 / 3.7 (52.96 / 53.86)	20.3* (37.26*)	Interbedded MUDSTONE, SILTSTONE & SANDSTONE	Weak reddish brown to dark grey interbedded laminated ferruginous MUDSTONE, SILTSTONE and SANDSTONE. Occasionally thin lignite layers encountered within the sandstone strata.

* - full depth of excavation

Figures 6, 7 and 8 show geological cross-section for the western part of the site. In general, the ground conditions encountered comprised either topsoil or made ground to depths between 0.40m to 1.0m over interbedded firm becoming stiff silty clays and clayey silts to between 1.1m and 3.7m bgl. The silts and clays were underlain by extremely weak to very weak interbedded mudstone, siltstone and sandstone to between 1.1m and 3.5m bgl below which the rock was classified as very weak becoming weak.

Topsoil was encountered within TP101, TP102, TP103, TP104, TP105, TP106, TP113, WS101 and WS118 only. These positions were generally located in the north western area where little previous development had taken place and in areas outside the footprint of the demolished structures (Building 18 and 38).

TP112, WS102 and WS105 were undertaken within the existing car park areas and blacktop hardstanding was present from ground level to 0.10m bgl. The blacktop within TP112 was underlain by a 100mm thick reinforced concrete slab. A fine to coarse gravel of crystalline rock was identified in WS102 from 0.1 to 0.40 m bgl.

Made ground, where present was relatively shallow <1.2m, However, areas of deeper made ground / reworked soil to depths between 0.50 to 2.90 m was encountered within BH105, BH106, TP111, TP113, TP115, WS103 and WS106 as shown in Figure 5 Appendix B. The deeper made ground typically coincided former building footprints (Buildings 18 and 38). The north-western portion of Building 18 recorded deeper made ground than the eastern half. TP115 located outside of a known building footprint (west of Building 17 former solvent store) recorded made ground to 1.90 m depths.

Concrete was encountered in BH105 from 2.50m to 2.70m bgl, this was thought likely to be a relict footing, as BH105 was located to the edge of a building footprint and TP147 located in the centre of the building footprint reported natural soils from 0.80 m bgl. WS104, located on

the southeastern edge of the building refused at 0.80 m, this was also thought likely to be a relict footing due to the position of the trial hole¹⁹.

Based on BH105, BH106 and one historical borehole record (KDC Contractors Ltd BH05) the depth to rock head appears to be slightly shallower in the northern part at 53.86 m AOD relative to the southern boundary at 53.21-53.67 m AOD. A number of the window samplers refused at shallower depths in the northern area namely, WS102 at 55.93 m AOD and WS105 at 55.27 m AOD.

13.2 Eastern Area

Table 6: Summary of soils encountered within eastern half of the site

Depth From (m AOD)	Depth To ¹⁷ (m)	Soil Type	Description
GL (56.58 / 57.52)	0.15 / 0.4 (56.18 / 57.12)	TOPSOIL	Dark brown silty clay TOPSOIL.
GL / 1.2 (57.28 / 56.01)	0.2 / 4.05 (56.14 / 52.88)	MADE GROUND	Variable MADE GROUND generally comprising grey demolition fill of fine to coarse and cobbles of brick and concrete and occasional blacktop with localised pockets of black gravel of crystalline rock and areas of red sandy gravelly fill with gravel of fine to coarse brick and concrete
GL / 1.2 (56.42 / 56.08)	0.5 / 2.0* (55.92 / 54.36*)	REWORKED SOIL¹⁸	Reworked soils comprising grey to brown clayey silt or silty clay occasionally with fragments of fine to coarse brick or concrete pockets containing frequent reworked sandy siltstone or silty sandstone fine to coarse gravel was noted in locations TP118, TP132 and TP136.
0.15 / 2.0 (57.68 / 54.70)	0.6* / 3.1* (57.23* / 54.52*)	Interbedded CLAY & SILT	Interbedded firm becoming very stiff mottled grey to brown and silty CLAY and clayey SILT.
0.8 / 4.05 (56.51 / 52.88)	6.0 / 13.55 (51.37 / 43.38)	Interbedded MUDSTONE, SILTSTONE & SANDSTONE	Extremely weak to very weak reddish brown to dark grey interbedded occasionally laminated ferruginous MUDSTONE, SILTSTONE and SANDSTONE. Occasionally thin coal beds and minor deposits encountered within the sandstone strata.

¹⁹ Although we understand that slabs / footings to 1.0 m bgl should have been removed as part of the demolition works in 2015/16.

2.6 / 7.3 (54.77 / 49.12)	20.5* (36.63*)	Interbedded MUDSTONE, SILTSTONE & SANDSTONE	Weak reddish brown to dark grey interbedded laminated ferruginous MUDSTONE, SILTSTONE and SANDSTONE. Occasionally thin coal beds and minor deposits encountered within the sandstone strata.
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* - full depth of excavation

Figures 9 and 10 show geological cross-section of the eastern part of the site. In general, the ground conditions encountered in the eastern portion of the site were similar to those in the west i.e. made ground over interbedded silts and clays of the mudstone, siltstone and sandstone of the Tunbridge Wells Sands at depth. The made ground encountered on the eastern portion of the site (and to the south of Building 3/36) was generally thicker than in the west extending to depths of <2.0m over large parts.

Areas of deeper made ground were observed in the footprints of the larger demolished Buildings 15 and 42 in the central eastern area of the site, reaching 2.1m and 2.2m bgl at WS111 and TP128 respectively. Deep made ground was also encountered within TP136 and TP132 to the full depth of the excavation at 2.3m and 2.1m respectively. Deeper made ground may be present in these areas where the base depth of made ground was not proven.

The base of a water storage reservoir (for the fire suppression system) was proven in BH101 with a concrete slab recorded from 3.45 to 4.05 m bgl. Sample recovery was not achieved in WS107 between 1.0m to 2.4m, a brick or concrete fragment may have obstructed the window sampler liner rather than the presence of a void. WS107 refused at 2.4m on a concrete obstruction. WS107 was located in the footprint of the former boiler house. A concrete footing was encountered in TP118 at 1.40-1.60 m bgl.

Made ground shallower than 1m bgl was generally found outside of the former building footprints and was generally near to the sites eastern margin. Concrete hardstanding was encountered at or near surface within TP116, TP132, TP149 and TP151.

Additionally, one location, WS108 located ~40 m to the southeast of Building 3/36 encountered soft to firm slightly organic smelling clay. This clay extended to 1.8m bgl in WS108. Organic odours were also noted in firm clays in TP116 from 1.20 to 2.00m and WS106 from 0.47 to 0.52 m. Stiff blue clay was noted in TP123. These may be related to historical drainage features from the early 20th Century and/or the fact that the site was historically low lying.

Made ground was absent on the crest of the slope on the eastern boundary in locations B1, B2, B4 and TP139 and along the only machine accessible area on the northern boundary at TP130.

The desk study highlighted possible below ground tunnels and large service ducts, although these were not encountered during this phase of investigation.

The depth to rock head was shallowest in the northeast corner at ~55.70 m AOD (BH103) falling to ~54.60 m AOD in the central areas (BH102, BH104). Where encountered, the mudstone, siltstones and sandstones of the Upper Tunbridge Wells Sands were generally extremely weak to very weak at shallow depths, but generally strengthened to weak from depths below ~6.0m bgl, although localised bands of extremely weak mudstones were also noted at depth.

13.3 Groundwater

Groundwater strikes were recorded in the following trial holes:-

Table 7: Groundwater Strikes in Western Area

Trial Hole	Depth to Groundwater strike mbGL (m AOD)	Stratum	Comments
TP108	0.2 (57.32)	Made ground	Surface water ingress from northern face of trial pit.
TP108	1.3 ((56.22)	Interface between made ground and reworked SILT	Significant water inflow
TP110	0.6 (54.50)	Base of made ground	Moderate water seepage
TP147	0.3 (55.86)	Made ground	Slight water seepage encountered from northern face of pit
WS102	0.4 (57.53)	Base of made ground	Groundwater seepage encountered.
WS103	0.25 (57.33)	Made ground	Groundwater seepage encountered.
WS104	0.7 (55.48)	Made ground	Water seeping in obstructing view of the bottom of the borehole.
BH105	9 (47.31)	Upper Tunbridge Wells Sand Formation	Groundwater observed during drilling
BH105	14.9 (41.4)	Upper Tunbridge Wells Sand Formation	Groundwater recorded at 14.9m rising to 12.3 after 30 minutes.
BH106	19 (38.56)	Upper Tunbridge Wells Sand Formation	Groundwater observed at 19m and rising to 16.2m after 30 minutes.

In the Western Area a perched water body was encountered in made ground within the footprints of the demolished buildings. Outside of these areas, the exploratory holes were recorded as dry and stable. This was also after a period of heavy rainfall. The clayey silts in these areas may limit water percolation. Groundwater strikes were recorded in the bedrock generally at depths below 9 m. These appear to correlate to siltstone in both BH105 and BH106, where fractures may facilitate groundwater movement.

Table 8: Groundwater Strikes in Eastern Area

Trial Hole	Depth to Groundwater strike mbGL (m AOD)	Stratum	Comments
TP116	1.2 (55.2)	Base of made ground	Moderate water seepage
TP117	1.4 (54.85)	Reworked sandy silty CLAY	Significant water seepage
TP118	1.2 (56.08)	Interface between made ground and reworked gravelly CLAY	Moderate water seepage
TP122	1.2 (55.65)	Made ground	Significant water seepage
TP125	1.2 (54.77)	Made ground	Moderate water seepage
TP126A	2.1 (54.45)	Upper Tunbridge Wells Sand Formation	Slight water seepage encountered at the bottom of the pit
TP126B	1.3 (55.77)	Upper Tunbridge Wells Sand Formation Interface between CLAY and SILTSTONE	Moderate seepage encountered.
TP127	0.6 (55.92)	Base of made ground	Slight water seepage encountered
TP128	1.2 (55.8)	Made ground	Moderate seepage encountered
TP128	1.85 (55.15)	Made ground	Significant water ingress encountered
TP131	2.9	Upper Tunbridge Wells Sand Formation. In SANDSTONE	Slight water seepage encountered at the bottom of the pit
TP132	1.0 (56.21)	Reworked SILTSTONE	Water ingress and standing water encountered. Water level rose from base of pit at 2.1m to 1.6m after 15 minutes
TP135	0.4 (56.19)	Made ground	Major water ingress encountered
TP136	1.6 (55.45)	Made ground	Moderate water seepage encountered. Water level rose from base of pit at 2.3m to 1.8m after 20 minutes
TP137	1.1 (55.26)	Made ground	Moderate water seepage encountered at 1.1m. Water level rose from base of pit at 1.6 m to 1.4m after 20 minutes
TP138	0.3 (56.04)	-	Slight surface water seepage encountered from northern face of pit
TP140	0.7 (56.00)	Made ground	Moderate water seepage encountered
TP142	1.0 (55.36)	Made ground	Moderate water seepage encountered
TP146	0.6 (56.68)	Made ground	Moderate water seepage encountered
TP148	1.1 (56.21)	Upper Tunbridge Wells Sand Formation. In SILTSTONE	Moderate water seepage encountered
TP150	1.0 (56.63)	Upper Tunbridge Wells Sand Formation. In SANDSTONE	Moderate water seepage encountered
TP152	1.0 (55.52)	Made ground	Significant water ingress
WS107	1.4 (54.78)	Made ground	Groundwater encountered
WS110	0.2 (56.63)	Made ground	Water seepage

WS111	0.9 (56.25)	Made ground	Water seepage
WS116	0.3 (56.33)	Made ground	Water seepage
WS117	0.8	Made ground	Water seepage
BH101	5.5 (51.43)	Upper Tunbridge Wells Sand Formation. In SILTSTONE	Steady groundwater level upon completion.
BH103	1.3 (56.07)	Made ground	Groundwater seepage at base of hand-dug pit prior to drilling.
	3.2 (54.17)	Upper Tunbridge Wells Sand Formation.	Groundwater recorded at 3.2m upon completion and at 2.2m after 30 minutes.
BH104	16 (40.42)	Upper Tunbridge Wells Sand Formation.	Groundwater recorded at 16m upon completion and at 13.7m after 45 minutes.

The Eastern Area also recorded a perched water within made ground soils, although in some trial pits where Upper Tunbridge Wells Sand Formation was encountered seepages were recorded and these typically related to siltstone and sandstone fractions. The deeper boreholes also encountered groundwater within the Upper Tunbridge Wells Sand Formation, which appear to be at shallower depths than that in Western Area.

Table 9: Groundwater Monitoring Results

Location	Response Zone	Depth to groundwater m bgl (m AOD)						
		8-9	22-23	8-9	15	22	6	16
		Feb-21	Feb-21	Mar-21	Mar-21	Mar-21	Apr-21	Apr-21
BH101D (56.93)	UTW	7.0 (49.93)	7.85 (49.08)	8.0 (48.93)	-	-	-	-
BH101S (56.93)	MG	0.95 (55.98)	1.20 (55.73)	1.35 (55.58)	1.3 (55.63)	1.2 (55.73)	1.2 (55.73)	-
BH102 (57.13)	UTW	14.6 (42.53)	14.1 (43.03)	14.3 (42.83)	-	-	-	-
BH103D (57.37)	UTW	14.4 (42.97)	14.4 (42.97)	14.5 (42.87)	-	-	-	-
BH103S (57.37)	MG/UTW	1.05 (56.32)	1.25 (56.12)	DRY	1.55 (55.82)	1.55 (55.82)	1.5 (55.87)	-
BH104 (56.42)	UTW	10.3 (46.12)	10.35 (46.07)	10.55 (45.87)	-	-	-	-
BH105 (56.31)	UTW	Not taken – equipment failure	12.15 (44.16)	12.15 (44.16)	-	-	-	-
BH106 (57.56)	UTW	16.5 (41.06)	16.4 (41.16)	16.65 (40.91)	16.6 (40.96)	16.53 (41.03)	16.65 (40.91)	16.8 (40.76)
WS102 (57.93)	UTW	1.05 (56.88)	1.00 (56.98)	1.7 (57.68)	1.3 (56.63)	1.6 (56.33)	1.8 (56.13)	-
WS103 (57.58)	MG/UTW	0.20 (57.28)	0.10 (57.38)	0.75 (56.83)	0.5 (57.08)	0.75 (56.83)	1.6 (55.98)	1.8 (55.78)

WS105 (57.16)	UTW	-	0.90 (56.26)	1.07 (56.15)	0.93 (56.23)	0.99 (56.17)	1.3 (55.86)	-
WS106 (57.23)	UTW	1.40 (55.82)	1.40 (55.82)	1.50 (55.72)	1.45 (55.58)	1.5 (55.53)	1.6 (55.43)	1.6 (55.43)
WS108 (55.91)	UTW	0.85 (55.05)	0.90 (55.00)	1.05 (54.95)	0.9 (55.01)	1.07 (54.84)	1.15 (54.76)	-
WS109 (56.79)	UTW	-	1.10 (55.68)	1.30 (55.48)	1.05 (55.74)	1.4 (55.39)	1.5 (55.29)	-
WS111 (57.15)	MG	0.70 (56.55)	1.10 (56.15)	1.20 (56.05)	Detected base ~ 1.25 (55.9)	DRY	DRY	-
WS113 (56.69)	UTW	0.95 (55.79)	1.25 (55.46)	1.65 (54.81)	1.32 (55.37)	1.6 (55.09)	1.8 (54.89)	-
WS115 (56.31)	UTW	0.30 (56.01)	0.70 (55.61)	1.50 (54.81)	0.67 (55.64)	0.86 (55.45)	1.2 (55.11)	-
WS116 (56.62)	MG/UTW	0.30 (56.32)	0.45 (56.17)	0.70 (55.72)	0.4 (56.22)	0.4 (56.22)	0.7 (55.92)	-
WS118 (56.51)	UTW	0.50 (56.01)	0.70 (56.50)	0.85 (56.35)	0.7 (55.81)	0.82 (55.69)	0.96 (55.55)	-

MG = Made ground; UTW = Upper Tunbridge Wells Sand Formation

It should be noted that groundwater monitoring was undertaken during a period of wet weather and the winter months when groundwater levels can be expected to be at their highest.

The differences in groundwater levels between the deep and shallow monitoring well locations suggest that shallow and deep aquifers are not connected.

Based on groundwater elevations within the deep monitoring wells, groundwater within the Tunbridge Wells Sand Formations is indicated to flow towards the north-east. The hydrogeological characteristics of the Upper Tunbridge Wells Sand Formation are complicated by geological fault lines present within 800 m to the east and west of the site, and regionally the geology dips to the southwest and northwest, which may influence local groundwater flow.

13.4 Visual and Olfactory Evidence of Contamination

Visual and olfactory evidence of contamination noted during the investigation works is summarised in the following table.

Table 10: Summary of Visual and Olfactory Evidence

Hole ID	Depth (m)	Olfactory Evidence	Visual Evidence

TP111	0.3-0.5		Black staining of natural clayey silt arisings
TP112	0.2-0.4		Black stained sand and gravel made ground fill
TP115	0.9-1.9	Moderate to strong organic 'manure' odour	
TP115	1.9		Partially black stained natural silt at surface of strata
TP116	1.2-1.5	Faint organic odour	Black staining within natural clay
TP124	0.8-1.4		Black staining of reworked clay soils
TP126A	0.9	Moderate to strong organic 'manure' odour within natural silt soils	
TP126B	0.8		Black staining encountered within the made ground
TP146	0.45-0.6		Black staining encountered within the made ground
WS106	0.47-0.52	Slight organic odour within reworked clay soils	
WS108	0.3-1.6	Slight organic odour within natural clay soils	
WS115	0.3	Slight organic odour encountered within made ground soils	

Non-aqueous phase product (NAPL) / strong hydrocarbon odours were not encountered in any of the trial holes.

13.5 Other Observations

On the 19th January 2021 ground gas was observed to be 'bubbling' from around the headworks of BH106 (the internal section of the cover was flooded during a period of heavy rain), and an audible flow could be heard when the valve was opened. A 'spot' reading was undertaken to initially characterise the gas concentrations emanating from the borehole. A flow rate of 104L/hr with 13.6% carbon dioxide, 0% methane and 1.0% oxygen concentrations were recorded. The gas flow rate was high for at least 24 hours, but was found to gradually decrease over 7 days, as the borehole was visually and acoustically monitored.

The high flow rates were only observed after a period of very heavy rain. The borehole was located away from known services and no voids were recorded when the borehole was drilled. The response zone for the monitoring well extended from 11.3 m to 20.3 m within the Upper

Tunbridge Wells Sand Formation. A relatively thin layer of made ground ~0.50 m thick was encountered in BH106. An additional ground gas monitoring well (WS106) was installed within 2.0 m of BH106 to characterise the shallow ground gas conditions at this position.

During the Phase III site investigation the two lodge houses at the site entrance were demolished. The demolition included grubbing out of below ground foundations and a brick wall using heavy plant and machinery. This caused disturbance to otherwise natural ground.

Boggy soft wet ground was encountered at the surface within the footprint of former Building 12.

Table 11 below summarises obstructions encountered during this phase of investigation.

Table 11: Summary of obstructions encountered during investigation

Hole ID	Depth (m)	Comment
TP116	2.0	No further progress due to concrete slab obstruction encountered. Possible remnant foundation.
TP118	1.4-1.6	Concrete foundation footing encountered within the northern wall of the trial pit.
TP125	1.4	No further progress due to encountered obstruction within the made ground.
TP132	2.1	No further progress due to hard ground. Base of trial pit obscured by groundwater, not possible to confirm if due to concrete or refusal on natural ground.
TP136	2.3	No further progress due to hard ground. Base of trial pit obscured by groundwater, not possible to confirm if due to concrete or refusal on natural ground.
WS104	0.8	Borehole refused on an assumed concrete obstruction. Bottom of the pit not visible due to water ingress.
WS107	2.4	Borehole refused on an obstruction.

Tunnels or voids were not encountered during this phase of investigation, however the presence of tunnels or voids across the site cannot be discounted.

The record of obstructions encountered during previous investigations by others is outlined below, and a summary of historical exploratory hole locations is provided as Figure 4, Appendix B.

Table 12: Summary of obstructions encountered during previous investigations

Hole ID	Investigation	Depth (m)	Comment
WS19A	SKM July 2013	0.55	Terminated due to concrete at base of inspection pit.
WS20	SKM July 2013	1.0	Terminated due to obstructions in sides and base of inspection pit.
WS22	SKM July 2013	0.65	Terminated due to dense gravel and obstruction at the base.
WS24	SKM July 2013	0.4	Terminated due to concrete obstruction.
WS25	SKM July 2013	0.55	Terminated due to concrete obstruction.
WS29	SKM July 2013	0.6	Terminated due to concrete obstruction.
WS39	SKM July 2013	0.6	Terminated due to brick and concrete obstructions.
WS39A	SKM July 2013	0.9	Terminated due to brick and concrete obstructions. Second attempt at WS39,
WS45	SKM July 2013	0.7	Concrete obstruction recorded across base of the inspection pit. Pit extended but the obstruction continued.
WS60	Jacobs October 2014	0.3	Concrete with rebar noted across the base of the inspection pit.
WS60A	Jacobs October 2014	0.5	Concrete with rebar noted across the base of the inspection pit.
WS61	Jacobs October 2014	0.75	A metal obstruction encountered.
WS70	Jacobs October 2014	1.0	Concrete noted across the base of the pit.
TP35	KDC June 2016	3.7	Trial pit terminated due to two concrete sidewalls encountered causing restricted excavator bucket movement.
TP47	KDC June 2016	0.8	Trial pit terminated upon reaching an obstruction visually described as a concrete slab. Potential cover of a rainwater drain.
TP-CP1	KDC June 2016	1.2-1.5	Encountered an obstruction noted as rows of bricks, possible former oil storage tank foundation.

E GEOTECHNICAL INFORMATION

14 Strata Encountered

The encountered conditions of the natural soils of the Upper Tunbridge Wells Sand was largely uniform across the site. However, the made ground encountered was noted to vary between the eastern and western site of the site. On this basis the ground model for the made ground is split between the two sections, as per below. The following laboratory geotechnical tests have been undertaken:-

Table 13 Geotechnical Laboratory Testing

Test	Number of tests						
	Clay	Silt	Sand	Siltstone	Mudstone	Sandstone	Made Ground
Moisture Content	12	13					
Atterberg Limit Test	12	13					
Particle Size Distribution Test	1	4					1 reworked ¹⁸ silt
Sulphate Determination	6	5		1			1 reworked ¹⁸ silt, 1 reworked clay and 1 made ground fill
pH	6	5		1			1 reworked ¹⁸ silt, 1 reworked clay and 1 made ground fill
Undrained Triaxial Test	1						
Point Load Strength Test				11	27	33	
Uniaxial Compressive Strength Test				2	13	9	
California Bearing Ratio		1					

14.1 Made Ground – Western Area

The made ground soils encountered on the western side of the site comprised blacktop hardstand areas and underlying fill, building demolition rubble and ‘reworked’ soils occasionally with anthropogenic inclusions of fine to coarse brick and concrete. The

demolition fill on the western side of the site was encountered up to 1.0m within previous footprints of buildings 18 and 38, comprising fine to coarse brick and concrete with occasional fragments of vinyl flooring, plastic and ceramic. The central blacktop hardstand area was encountered to be underlain by red fine to coarse brick sandy gravelly fill up to 0.4 m. The deepest area of made ground on the western side was encountered towards the south west as reworked clayey gravelly silts in BH105 up to 2.9m.

Table 14: Summary of the limited Geotechnical Testing on the Western side made ground

Test	Range
SPT 'N value'^	9 - 28
Undrained shear strength (kN/m ²) – Hand Penetrometer Field Test within reworked made ground	58 - 115

^SPT-N Values are uncorrected

14.2 Made Ground – Eastern Area

Much of the eastern side of the site is underlain by made ground generally comprising demolition rubble fill made up of brick and concrete with occasional anthropogenic inclusions of ceramic, plastic, vinyl flooring, rare wood, cables, scrap metal, rebar, wire, fragments small metal and plastic pipes. The made ground was generally deepest within the footprint of the demolished buildings, extending to depths generally between 1-2m and up to 4.05 m in the south eastern corner.

Made ground or fill is by nature highly variable in both composition and bearing capacity and can be subject to large differential settlements when loaded. It is therefore generally unsuitable for use as a bearing stratum. In addition, made ground may contain contaminated and/or putrescible material. It can therefore be potential source of contamination and landfill gas.

Table 15: Summary of the limited Geotechnical Testing on the Eastern side made ground

Test	Range
Sulphate Content (g/l)	0.15 - 0.89
pH	8.1 – 11.7
SPT 'N value'^	4 - 66
Undrained shear strength (kN/m ²) – Hand Penetrometer Field Test within reworked made ground	15 - 158

^SPT-N Values are uncorrected

14.3 Clay and Silt – Weathered Upper Tunbridge Wells Sands

The clays and silt soils encountered extended to depths up to 3.7m in the eastern section and to depths up to 3.1m in the western section and were underlain by extremely weak interbedded mudstone, siltstone and sandstone. The results of the geotechnical laboratory testing are summarised in Table 16 below.

Table 16: Summary of Geotechnical Test Results for the clays and silts

Test	Range
SPT 'N value'^	6 – 64
Moisture Content (%)	13.3 - 36.4
Liquid Limit (%)	26 - 49
Plastic Limit (%)	16 - 27
Plasticity Index (%)	7 - 25
Undrained shear strength (kN/m ²) – Hand Penetrometer Field Test	35 - >300
Undrained shear strength (kN/m ²) – Undrained Triaxial Test	16
California Bearing Ratio (%)	6.2 – 7.1
Sulphate Content (g/l)	<0.010 – 0.34
pH	5.7 – 10.7

^SPT-N Values are uncorrected

The results of Atterberg limit testing completed on the shallow soils indicate they comprise low to intermediate plasticity clays and silts. The full plasticity testing results are illustrated in an A line plot in Figure 11 Appendix B.

One undisturbed sample of the clay was recovered from BH102 at 1.50m and undrained triaxial testing was undertaken. The results returned an undrained shear strength of 16 kPa indicative of soft clay. Discussions with the testing laboratory regarding the low shear strength suggested that the sample was fissured and that the low strength related to failure along one of these pre-existing planes rather than failure of the intact soil matrix. Furthermore, it should be noted that the sample was at ~ 300mm below the base of the overlying made ground. As such the shear strength recorded may also relate to slight disturbance/reworking of the soil from placement of the overlying made ground. It is therefore considered that the recorded shear strength from the triaxial testing is not indicative of the wider soil strengths on site.

Uncorrected SPT N values recorded within the shallow soils ranged from N = 6 to N = 64 indicative of firm to very stiff/hard clays and silts. It was noted that the test yielding the lowest SPT value was completed at 1.0m bgl within WS108, described as a grey clay and recorded firm (indicative) N values and a soft i(ndicative) undrained shear strength of 35 kPa, which was also the lowest reading recorded using a hand penetrometer test.

This test was completed within soft becoming firm grey clays which were noted in only two locations on site, namely WS108 and BH102. Stroud (1974)²⁰ found that a good correlation exists between the undrained shear strength of over-consolidated clays and their corresponding SPT blow count N value, where:

$$C_u = f_1 \times N$$

f_1 = factor between 4-6 relating to the plasticity of the clay.

SPT blow counts of N=6 to 64 were recorded within the shallow soils. Using Stroud's factor $f_1 = 5$ for the soils encountered, the corresponding undrained shear strengths vary from 35-495kPa, indicative of soft to very stiff soils. Disregarding the low results from WS108 this range reduces to 55kPa to 495kPa indicating firm to very stiff soils.

Table 17: Summary of PSD test results for the clays and silts

BH/TP Ref	Depth (m)	Clay (%)	Silt (%)	Sand (%)	Gravel (%)	Cobbles (%)
TP102	1.8	10.5	85.8	2.4	1.3	0
TP111	1.7	44.1	54	1.3	0.6	0
TP124	2.3	18.7	62.7	3.3	15.3	0
TP135	1.6	25.6	67.7	5.9	0.8	0
WS106	1.9	18.5	68.4	5.9	7.2	0

The results of particle size distribution testing indicate that the shallow weathered portion of the Upper Tunbridge Wells Sand deposits comprise slightly gravelly slightly sandy clayey silts.

14.4 Interbedded Siltstone, Mudstone and Sandstone - Upper Tunbridge Wells Sand

The clays and silts were underlain by interbedded grey mudstones and siltstones and sandstones to the full depth of investigation. The results of laboratory and *insitu* testing undertaken on the rocks at depth are summarised below.

²⁰ Stroud M A "The Standard Penetration Test in Insensitive Clays and Soft Rocks" Proceedings of European Symposium on Penetration Testing, Stockholm 1974

Table 18: Summary of Geotechnical Test Results for interbedded Upper Tunbridge Wells Sand formation units

Test	Range
SPT 'N value'	29 - >50
Uniaxial Compressive Strength (MPa)	0.377 – 27.3
Point Load Index $I_{s(50)}$ (MPa)	0.01 – 2.54
Sulphate Content (g/l)	<0.010
pH	6.6

The results of Uniaxial Compression Strength (UCS) testing ranged from 0.377 MPa to 27.3 MPa indicating that the intact Upper Tunbridge Wells Sand units on site range from extremely weak to moderately strong. However, only one sample recorded UCS values indicative of moderately strong sandstone namely BH106 at 17.8m. It is also noted that just three samples, BH101 at 11.7m, BH102 at 3.5m and BH106 at 9.0m recorded UCS values indicative of extremely weak rock. Furthermore, all three of these samples were taken from the mudstone, whilst all samples of the siltstone and sandstone tested exhibited very weak to weak compressive strengths. A plot showing the UCS results vs depth is available in Figure 12 Appendix B.

Point load testing was also completed on samples of the intact Upper Tunbridge Wells strata. The results ranged from 0.01 MPa to 2.54 MPa. Using a conservative factor of $C = 10$ then the approximate UCS can be estimated using the following conversion:

$$UCS = L_{s(50)} \times C$$

Using the above conversion the $L_{s(50)}$ results equate to an approximate UCS range 0.3 MPa to 9.7 MPa for the mudstones and 0.1 MPa to 25.4 MPa for the sandstone. These point load testing results are in general accordance with the UCS testing and indicate that the mudstones are extremely weak to weak and the sandstones range from extremely weak to weak with one sample verging on moderately strong.

F GEOTECHNICAL APPRAISAL

The foregoing geotechnical appraisal does not constitute a Geotechnical Design Report in accordance with BSEN1997. The following recommendations are for preliminary design purposes only.

For the detailed design, the short-term and long-term design situations must be considered. Where relevant, the following limit states should be considered:-

- Loss of equilibrium of the structure or the ground, considered as a rigid body, in which the strengths of structural material and the ground are significant in providing resistance (EQU)
- Internal failure or excessive deformation of the structure or structural elements in which the strength of structural materials is significant in providing resistance (STR)
- Failure or excessive deformation of the ground, in which the strength of soil or rock is significant in providing resistance (GEO)
- Loss of equilibrium of the structure or the ground due to uplift by water pressure or other vertical actions (UPL)
- Hydraulic heave, internal erosion and piping in the ground caused by hydraulic gradients (HYD)

The following factors should also be considered.

- Overall stability and ground movements
- Nature and size of the proposed construction including the design life
- Conditions with regards to the surroundings (e.g. neighbouring structures, traffic, utilities, vegetation, contamination etc.)
- Ground and groundwater conditions
- Influence of the environment

15 Swelling and Shrinkage

Based on the laboratory test results in Section E, an overall classification of NHBC **MEDIUM** Volume Change Potential (VCP) is recommended for the clay soils.

Foundations will therefore require deepening in accordance with NHBC Chapter 4.2 where shallow clay soils are encountered near trees. Foundation depths should be calculated based on the mature height of the tree, however, the existing height is relevant for trees which are to be removed. Deepening may be terminated where the mudstone, siltstone or sandstone are encountered at depth.

16 Sulphates

16.1.1 Made Ground Soils

Three made ground soil samples were tested for sulphate content and pH. The limited geotechnical testing carried out on the made ground soils classified the material as sulphate design class DS-2, and, assuming a mobile groundwater table, the ACEC class is AC-2 (using approaches described by BRE).

16.1.2 Tunbridge Wells Sand Formation

One siltstone sample at depth and eleven samples of silts and clays were tested for sulphate content and pH. In accordance with the BRE²¹ methodology and the number of samples tested, the site has been classified on the mean of the highest 20% of the measured sulphate content.

Based on the results detailed in Section E and the above, the natural clays and silts and the Upper Tunbridge Well Sandstone Formation are classified by the BRE as sulphate design class DS-1, and, assuming a static groundwater table, the ACEC class is AC-1.

16.1.3 Groundwater

Based on the pH and sulphate results gathered from the groundwater monitoring programme detailed in Section 12.4, the deep groundwater of the site is classified by the BRE as sulphate design class DS-1, and, assuming a static groundwater table, the ACEC class is AC-1.

17 Groundwater

A total of 41 No. groundwater strikes / seepages were reported during this phase of investigation. The majority of these occurred at depths ranging from 0.60m to 1.2m bgl and generally coincided with the contact between the base of the made ground and the natural clay/silt soils below. Deeper groundwater strikes were recorded within the rotary boreholes at depths ranging from 1.3m to 19m bgl. Groundwater monitoring has recorded the groundwater table within the deep monitoring wells at between 7.0 to 16.80 m bgl (49.93 to 40.76 m AOD) with shallower depths to groundwater recorded on the southern side of the site. The groundwater within the shallow monitoring wells was encountered from 0.10 to 1.80 m bgl (57.38 to 54.89 m AOD) with shallowest depths in areas of made ground.

The full groundwater monitoring results/observations are given in Section D. On the basis of these results, groundwater within the Tunbridge Wells Sand is anticipated to be at below 9-10m depths across the majority of the site, but is shallower in the south east (BH101) of the

²¹ Building Research Establishment Special Digest I: 2005. Concrete in aggressive ground. Part I: Assessing the aggressive chemical environment.

site at around ~7m. However, significant quantities of shallow perched water should be anticipated within the made ground across much of the site. As such allowance should be in place for pumping of excavations with side support where excavation in granular, reworked or made ground material is required. It is advised that a more comprehensive dewatering long term strategy of the made ground soils is considered as opposed to a method where pumping out is undertaken in a single excavation.

It is noted that the large volume of made ground in the east could be acting as a sump for infiltration and may also be collecting surface water run-off from historic channels and/or damaged surface water drains. It is recommended that the surface water drainage system is camera surveyed to confirm its integrity and to ensure that no historic connections are feeding water into the made ground. Following that, and any necessary repairs, it is may also be necessary to undertake more extensive control of perched groundwater in the made ground (e.g. by recompacting existing made ground to reduce pore space and protecting the surface) in order to allow excavations to be safely constructed in the made ground soils.

18 Soakage Potential

18.1 Test Results

3 No. soakage tests were undertaken on site in accordance with BRE365²². Given the time restrictions, it was only possible to fill and test each pit once. TP126A and TP147 soakage test pits were installed within natural and reworked clays and silts, which were underlying the demolition made ground present at surface, whereas TP138 was installed mainly within clay and siltstone. The results are attached in Appendix G and are summarised in Table 19 below:

Table 19: Summary of soakage tests

Test Location	Soakage Rate		Comments
	m/s	l/m ² /min	
TP126A	1.67E-07	0.0088	Water level did not fall to 75% of the maximum water depth and as such the results are not compliant with BRE DG365 requirements.
TP138	-		Water level remained unchanged for 5 hours at which point the test was abandoned.

²² Building Research Establishment DG365: 2016. Digest Soakaway Design

TP147	-	Water level remained unchanged for 5 hours at which point the test was abandoned.
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Prior to testing standing water was noted in all tests pits at depths ranging from 0.37m bgl in TP147 to 1.8m bgl in TP126A. Due to the elevated water levels recorded within TP138 and TP147 it was not possible to fill the pits with a sufficient input volume to undertake a representative test. However, water levels within the pits were recorded over a 5-hour period during which no level changes were recorded.

In order to complete the testing in TP126A the pit was filled to 1.0m bgl with the intention to monitor water levels until they returned to resting water levels at ~1.8m bgl. The soils encountered at the monitored depth range were recorded slightly gravelly clayey silts. The test was undertaken over a period of 6 hours and a soakage rate of $1.47\text{E-}07$ m/s (0.0088 l/m²/min) was recorded.

18.2 Recommendations

Based on the results of soakage testing completed to date along with the shallow groundwater levels recorded across the site it is considered that the soils on site are not suitable for soakaway drainage and allowance should be in place for surface water to be piped off site.

19 Bearing Capacity and Foundations

19.1 Shallow Foundations

19.1.1 Eastern Area - Commercial

Based on the consistent thicknesses of made ground >2.0m on the eastern half of the site it is considered that shallow foundations are not suitable and that piled foundations would be required in this area. Vibro compaction may be a viable foundation solution, although some of the made ground may be difficult to penetrate and foundation trenches difficult to excavate where groundwater levels are very shallow.

19.1.2 Western Area - Residential

Except for the area of previous footprints of buildings 18 and 38 and land south of Building 3/36 (including WS103, WS107, TP107, TP108 and BH105) made ground on the western portion of the site was found to either not be present or only extend to ~1.20m bgl. As such it is considered that traditional strip foundations would be appropriate in this portion of the site for structures up to 3-4 storeys. All loads should be transferred beneath any topsoil, made ground, loose, soft, low strength, desiccated or disturbed soils and transferred onto the stiff

clays at depth. For low rise housing, based on local experience and BS8103²³ Table 8, an allowable bearing capacity of 100 kPa is recommended for shallow foundations on the stiff clays below about 1.2m. However, foundations will require deepening in the clay soils near trees to NHBC Medium VCP precautions.

Where foundations are stepped or span different soil types, allowance should be made for nominal reinforcement.

19.1.3 Construction Supervision

Foundation excavations should be inspected by a suitably qualified engineer prior to pouring concrete to ensure competent soils, most notably to ensure made ground is fully penetrated and that no soft grey silty clays or any other low strength soil is present at the bases of foundation formations.

19.2 Piling

Piled foundations are likely to be required for taller residential structures and all buildings on deeper made ground. For the ground conditions encountered on site, driven, bored or continuous flight augered (cfa) piles may be considered. However, given the proximity of adjacent buildings and railway surrounding the site, driven piles may be excluded due to the vibrations induced during installation and the effect these may have on existing buildings. Therefore, conventional bored or cfa piles may be more suitable. Discussions with previous site users indicate that several, below ground structures including services ducts and drainage culverts were previously present on site. Significant loss of concrete can occur where cfa piles encountered voids. Therefore, if cfa piles are to be adopted, probing of the proposed pile locations is recommended and allowance may need to be made for casing.

Given the potentially unstable nature of the made ground at depth, particularly below the water table, careful monitoring of the bored piles will be required when withdrawing temporary casings or the flight auger, to prevent necking of the pile shafts. This problem should be discussed with the specialist contractor and a program of integrity testing may be required.

Mudstone, siltstone and sandstone should be anticipated underlying the made ground and the clays and allowance should be made for drilling through layers of rock.

BS8103-1:2011 Structural design of low-rise buildings. Code of practice for stability, site investigations, foundations, precast concrete floors and ground floor slabs for housing

Discussions should be held with the specialist piling contractors to assess the technical and financial merits of their various systems for the ground conditions encountered, and the depth and size of pile required, with an adequate safety margin.

The final pile design will be determined by the selected piling contractor as the method of pile formation will affect the bearing capacity. For the purpose of preliminary design, the following soil model may be adopted:

Table 20: Soil model for preliminary pile design

Depth to base (m)	Soil Type	Characteristic Shear Strength (kPa) / angle of shearing resistance (°) / UCS (MPa)
3.45	Made Ground	Ignore Skin Friction
4.0	Clay / Silt	150 kPa
6.0	Mudstone/Sandstone/Siltstone	1 MPa
>20	Mudstone/Sandstone/Siltstone	10 MPa

Given the ground conditions on site and the presence of mudstone/sandstone at depth, rock socketed piles may be considered. The final design must be carried out by the specialist contractor in accordance with their preferred method of formation. Piling schemes which limit or negate the need for subsurface ground beams may also be considered beneficial in areas where groundwater levels are very shallow.

20 Floor Slabs

With reference to NHBC Standard 5.2, suspended floor slabs are recommended for residential properties (west of site) where:-

- Where the depth of fill exceeds 600mm
- Where foundations are deepened below 1.5m in accordance with NHBC Standards Chapter 4.2
- Where desiccated soils are encountered
- Where vibratory ground improvement techniques have been used
- Where foundations have been piled

In the east of the site, given the thickness of the made ground encountered, the medium VCP of the cohesive soils and the recommendation for piled foundations, suspended floor slabs are also recommended for the proposed commercial properties. Should larger storage /

warehouse buildings be proposed, consideration could be given to ground bearing slabs supported on vibro-compacted or re-engineered made ground.

21 Roads

CBR testing across much of the site was considered impractical given the thickness and variability of the made ground, which would prohibit road formation level founding on the natural soils. As such the limited laboratory CBR testing and DCP CBR testing were focussed on the western portion of the site, where natural soils appeared to be at surface and where made ground thicknesses were shallower.

21.1.1 Test Results

A single laboratory CBR test was undertaken on samples of the shallow clayey silts from TP127 on the eastern half of the site and returned CBR values in the range of 6.2% to 7.1%. The results are attached in Appendix F.

A series of 6 No. dynamic cone CBR tests were carried out in the north western portion of the site (where natural soils had been encountered at shallow depths). The results ranged from 0.3% to 126.8%. However, this very high CBR value was only encountered within one location DCP 1 and it is considered that this represents the probe impacting an obstruction (likely a flint, brick or concrete cobble) at depth rather than a true representation of the bearing ratio of the soils. Away from this anomalous result the CBR values recorded ranged from 0.3% to 13.1%. Assuming nominal formation depth of between 400mm and 600mm bgl the tests results range from 2.9% to 13.1%.

Based on the results of the plasticity testing (see Section E) along with the high silt content recorded during PSD testing, the soils on site are considered potentially frost susceptible.

21.1.2 Recommendations

A design CBR value of 3% is recommended for a silty clay / clay silt subgrade.

Made ground soils are by nature highly variable. Where such soils are encountered at formation level or where soft soils occur at formation level, over excavation to at least 1m below ground level, proof rolling and then engineered filling to formation level with a suitable granular fill is recommended in accordance with an appropriate specification such as The Specification for Highways Works Series 600. It is possible that the granular fill may be able to be sourced from the existing made ground subject to screening and confirmatory classification testing.

Further confirmatory testing may be required if the proposed roads are to be adopted.

22 Excavations

Excavations in the made ground and reworked natural soils are likely to be unstable and subject to collapse even over the short term. Furthermore, abundant shallow groundwater seepages were recorded in the made ground, especially at the interface between the made ground demolition fill and the underlying low permeability clays, silts or the interbedded mudstones and siltstones. As such excavations in made ground and any granular soils will be unstable. Excavations in the silty clays should be stable in the short term. However, they will be unstable in the long term and should be backfilled as soon as possible. Excavations are likely to require dewatering especially during the winter months.

Appropriate Health and Safety precautions must be adhered to where man entry into excavations is required. Even stiff clay soils at shallow depth can collapse, particularly following wet weather. Alternative foundation methods may need to be adopted where trench footings cannot be safely or satisfactorily constructed.

23 Filling

The preliminary recommendations contained within this report assume that ground levels are to remain at a similar level across the site for the proposed development, and that no significant changes in level are proposed. In the event that ground levels are to be raised, this may induce significant settlement, particularly across the areas of deep made ground and soft clays, which could adversely affect foundation design, drainage etc. Where significant changes in ground levels are proposed then further investigation may be required, particularly in areas of the infilled clays pits, to assess the impact of such earthworks on the above recommendations.

24 Slope Stability

As described in Section B the north-eastern and eastern parts of the site appears to have undergone a previous cut to create a level platform for the pharmaceutical works. Overall, the site is currently relatively gently sloping. However, there are steep slopes (circa 20°) in the vicinity of the railway line to the east of the site, and on the boundary with Parsonage Road along the north-eastern side of the site. Detailed consideration of these slopes is outside of the brief of this investigation and will be required as part of final design. It is broadly assumed that the existing slopes will either be part retained, or reduced in height and slope as part of any landscaping design of the eastern part of the site. At this stage, and in the absence of detailed assessment, the following preliminary parameters could be adopted for initial slope stability assessment in the natural tunbridge wells sands, to be confirmed as part of any final design where slopes greater than say 7 ° are to remain.

$$\gamma_b = 19 \text{ kN/m}^2 \quad \varphi' = 26^\circ \quad c' = 0 \text{ kN/m}^2$$

Provided no significant level changes are proposed, no further **site wide** slope stability issues are anticipated.

25 Retaining Walls

LEAP has not been made aware that any retaining walls are proposed on site, although noting the above comments some consideration may need to be given to parts of the north eastern and eastern boundaries.

A 2m high retaining crib wall was noted on part of the eastern boundary of the site during the walkover. This structure will require further consideration if it is to be incorporated into the final design. In the meantime, care must be taken to ensure that on site activities do not have a destabilising effect on this structure. Activities with the potential to destabilise the wall include, loading of the retained soils, excavation of the soils in front of the wall and introduction of water into the retained soils.

It is noted that existing retaining walls are present on site therefore assessment of the effect of the new development on these structures may be necessary. For this assessment, the use of the earth pressures for design is recommended based on the following equation:

$$K_0 = 1 - \sin \varphi'$$

For the natural tunbridge wells sands, a φ' of 26° can be used for preliminary design purposes.

26 Settlement

Based on the allowable bearing capacity given in Section 19, settlements of traditional foundations should be within typical tolerable limits for the low-rise development proposed. Significant settlement should be anticipated where made ground soils are loaded, and consideration should be given to pre-treatment or re-engineering of made ground where loads are to be applied.

If soft clays are encountered at formation level or below, significant settlement should be anticipated and serviceable limit state analyses will be required. Where foundations are stepped or span different soil types, differential settlement should be anticipated and allowance should be made for nominal reinforcement.

G GEO-ENVIRONMENTAL APPRAISAL

27 Conceptual Site Model

The site has historically been used for the research and development of pharmaceuticals and has been the subject of numerous investigations, which were undertaken both pre and post demolition of the buildings. The reports were summarised in depth in the LEAP Phase1 desk study. The resulting site conceptual model is summarised below:

Identified as potential risks to human health:

- Petroleum hydrocarbons were found by others in former areas of storage and use and these were compared to conservative assessment criteria and in some cases, excavated and removed from site. Resulting excavations were backfilled with either site won or imported clean materials. Residual petroleum hydrocarbons may still be present in these areas or in areas not yet investigated.
- Heavy metals. Elevated concentrations of arsenic and lead were recorded in made grounds soils across the site pre demolition. Post demolition, arsenic, lead, beryllium and copper have been recorded at concentrations above residential land use screening criteria.
- Asbestos was identified in soils pre and post demolition – although generally limited in extent.
- Ground gas generation. There is the potential for backfilled material on site (former clay pit backfilled areas) to generate gas, although the evidence to date suggests the site backfill is not significantly organic or subject to degradation. However off-site sources of backfill have been identified and whilst the risk is considered to be low, there is still the potential for off-site gas to migrate to site.
- Potential asbestos, metals, PAHs, petroleum hydrocarbons, BTEX, VOCs and SVOCs from site use for pharmaceutical production in areas not previously identified.

Identified as potential risks to controlled waters:

- Contaminants that have the potential to compact controlled waters include metals, PAHs, petroleum hydrocarbons, BTEX, VOCs and SVOCs. Previous investigations have included groundwater risk assessment and concluded that the risk to controlled water is very low. However, this assessment may need revising to consider continuity between perched and deeper aquifer if further contamination is identified.

Section C, above notes that the risk to offsite controlled water receptors (groundwater and surface water) from onsite groundwater is low. The only plausible source pathway linkage to

offsite controlled water receptors is via a preferential pathway from site drains that extend through the site and connect to the Horsham Pond 800 m to the southwest.

28 Testing Strategy

28.1 Soil Sampling

Given that previous investigations have targeted potential sources, their findings and the areas not covered previously, it was considered appropriate to spread exploratory hole locations across the site to provide even, non-targeted coverage. The trial hole spacing on a ~30 m grid is consistent with the recommended density of 25 to 50m for an exploratory investigation after BS10175 Section 7.7.

Samples have been tested for the presence of the identified contaminants of concern (heavy metals, PAH compounds, petroleum hydrocarbons, SVOCs, VOCs and asbestos as detailed in section 12.5.

Selected samples have been tested for waste classification purposes.

Whilst not specifically targeting historical sources of contamination, due to the density of the grid system trial holes have been located on or close to many of the previously identified sources of contamination. We note that access to some areas was restricted (particularly in areas north and south of the retained building) due to physical constraints (soft strip activities / vehicle movements) and presence of potential below ground utility services.

28.2 Groundwater monitoring/sampling

Six deep (14m to 20.3m) monitoring wells and 11 shallow (1.0 m to 3.0 m) were installed during this investigation to allow determination of the groundwater regime beneath the site, including groundwater flow direction and groundwater quality.

Six groundwater level monitoring rounds have been completed on all well installations and three groundwater sampling visits have been undertaken on the six deep monitoring wells. A single groundwater sampling round has also been completed at BH101S.

28.3 Land gas / vapour monitoring

The land gas investigation strategy has been designed generally in accordance with BS8576:2013²⁴ and NHBC²⁵ guidance.

The investigation strategy makes reference to Section 8 of BS8576:2013 in regard to the location, extent and sensitivity of proposed new buildings; ground conditions at the site (geology and hydrogeology); and the gas generation potential of source(s).

The placement of gas monitoring wells has been considered based on the following potential areas of concern:

- Deep made ground (where identified);
- To provide a general coverage, based on a preliminary non-targeted investigation of ground gas risks at the site to include boundary monitoring of potential off site sources.

At the end of the monitoring period an assessment of the sufficiency of data will be undertaken with reference to Annex F of BS8576:2013. Further monitoring may be required.

29 Assessment Criteria

29.1 Human Health Assessment Criteria

The generic quantitative risk assessment (GQRA) for human health compares the analytical results from the current investigation to Generic Assessment Criteria (GAC). These were selected using the following rationale and assumptions.

Defra and the EA have published a limited number of Soil Guideline Values (SGVs)²⁶ that represent minimal chronic risk to human health. CL:AIRE has published a limited number of Category Four Screening Levels (C4SLs)²⁷ which represent a low but still strongly precautionary

²⁴ BS8576:2013 Guidance on investigations for ground gas. Permanent gases and Volatile Organic Compounds ()

²⁵ Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present, incorporating “traffic lights”, Report I0627-R01-(02) for NHBC 2006 Boyle, R and Witherington, P

²⁶ Environment Agency Science Report SC050021 series.

²⁷ CL:AIRE Final Project Report. SPI010 – Development of Category 4 Screening Levels for assessment of land affected by contamination. CL:AIRE, December 2013

level of chronic risk to human health. Both the SGVs and C4SLs have both been derived for a Soil Organic Matter (SOM) content of 6%, which is not always representative of the low SOM that are encountered within Made Ground on brownfield sites.

LQM responded to the demand for a more comprehensive set of screening values for a wider range of SOM and produced Suitable for Use Levels (S4ULs)²⁸ which are a hybrid of SGVs and C4SLs. The S4ULs have been endorsed by the Chartered Institute of Environmental Health (CIEH).

LEAP uses C4SLs where they are available as generic assessment criteria to quantitatively assess the potential chronic risks to human health. Where C4SLs are not available, the S4ULs are used. It is noted that S4ULs are not equivalent to C4SLs in all their exposure assumptions but are generally more conservative in their assumptions. For benzene and benzo(a)pyrene, LEAP has calculated equivalent C4SLs for 1% and 2.5% SOM. This does not affect the inorganic contaminants.

In accordance with current Public Health England (PHE) guidance²⁹, the assessment of PAHs has been carried out using a surrogate marker approach, whereby the assessment of risk from benzo(a)pyrene also captures potential risks from other carcinogenic PAHs that may be present. The alternative S4ULs for PAHs using the Toxic Equivalent Factor (TEF) approach have not been used because this approach is likely to under predict the true carcinogenicity of PAHs and is not advocated by PHE. The threshold PAHs have been assessed similarly, by using naphthalene as a marker compound due to its high volatility relative to other PAHs.

Sets of GACs have been generated for SOMs of 1%, 2.5% and 6%. In this case the TOC in the Made Ground samples that were analysed averaged 1.6%. Using the conversion of SOM = TOC x 1.72, this equates to a SOM of around 2.7% therefore 2.5% SOM was considered to be appropriate to maintain conservatism.

Whilst the details of the development proposals are not yet finalised, it is clear from the outline proposals that part of the site, mostly likely the western side, will include low rise residential development with private gardens and apartment blocks and the eastern side will be a commercial land use. Soil data will be initially screened against residential with homegrown produce generic assessment criteria (GAC) to maintain conservatism for the outline development. Where potential contaminants are identified at concentrations above

²⁸ The LQM/CIEH S4ULs for Human Health Risk Assessment, Nathaniel P et al, 2015. Copyright Land Quality Management Ltd, reproduced with permission: Publication Number S4UL3509

²⁹ HPA Contaminated Land Information Sheet. Risk Assessment Approaches for Polycyclic Aromatic Hydrocarbons (PAHs). Public Health England, 2017.

this GAC in samples collected from the proposed commercial areas the results will also be compared to commercial land use GACs as an informative.

29.2 Groundwater and Surface Water Assessment Criteria

The generic controlled waters risk assessment was conducted in accordance with the principles of EA '*Remedial Targets Methodology: Hydrogeological Risk Assessment for Land Contamination*' 2006 (EA 2006) and the 'prevent and limit' approach of the Water Framework Directive (2000/60/EC). Generic controlled waters risk assessments compare directly measured concentrations with standard assessment criteria.

Appropriate Water Quality Standards (WQS) are selected based on both a hierarchy of relevance to England and Wales and the receptor. In this case, the controlled water receptor identified in the CSM was the Upper Tunbridge Well Sand Secondary A Aquifer and the Horsham Pond and so the following hierarchy of WQS were considered to be appropriate:

Groundwater

- UK Drinking Water Quality Standards (DWS) from *The Water Supply (Water Quality) Regulations* 2016 (England).
- Environment Agency 2017 *Hazardous substances to groundwater: minimum reporting values*
- World Health Organisation *Guidelines for Drinking Water Quality*, Fourth Edition, Volume 1, (2011).

Surface Water

- Environmental Quality Standards (EQS) from The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.

In the case of petroleum hydrocarbons the CL:AIRE guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies³⁰, itself based on WHO guidelines, will be used where applicable for considering petroleum hydrocarbon fractions and derivatives in more detail.

29.3 Land Gas Assessment Criteria

An initial assessment has been made using the method outlined in BS8485:2015. Gas concentrations and borehole flow rates are combined to provide gas screening values (GSV) for both carbon dioxide and methane. In this assessment the highest concentrations per

³⁰ Petroleum Hydrocarbons in Groundwater - Guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies – CL:AIRE, March 2017

monitoring well have been combined with the highest flow rates to provide a conservative Tier 1 assessment.

A gas screening value is assigned to the site / zone in conjunction with the conceptual site model and typical gassing levels associated with the identified source to characterise the gassing regime. Appropriate design protection measures are recommended in line with BS8485:2015.

30 Analytical Test Results – Soils

30.1 Metals and Non Metals

A screening table including all of the laboratory testing is included within Appendix H and a summary of results is provided below. At the initial screening stage the sample results have not been sub-divided into separate populations based on depth profile / stratum.

Table 21: Summary of soil contamination test results

Determinant	Minimum (mg/kg)	Maximum (mg/kg)	Number of samples tested	Tier 1 Generic Assessment Criteria (mg/kg)		Samples which exceed residential GAC
				Residential with homegrown produce	Commercial	
Arsenic	5.3	63.2	63	37	640	TP112 0.35m 63.2mg/kg <i>TP146 0.20m 44.3mg/kg</i>
Cadmium	0.5	3.5	63	22	410	None
Chromium	13.3	87.5	63	910	8600	None
Hexavalent Chromium	<0.8	<0.8	63	21	49	None
Copper	7.8	1550	63	2,400	68000	None
Lead	20	1050	63	200	2300	TP112 0.35 m 1050mg/kg <i>TP127 0.20m 222mg/kg</i> <i>TP128 0.10m 547mg/kg</i>

						<i>TP140 0.1m</i> <i>352mg/kg</i> <i>TP141 0.1m</i> <i>613mg/kg</i> WS105 0.25m 214mg/kg <i>WS113 0.7m</i> <i>320mg/kg</i>
Mercury ¹	0.6	0.8	63	40 ¹	1100	None
Nickel	9.8	153	63	130	980	TP112 0.35m - 153mg/kg
Selenium	<1.0	<1.0	63	250	12000	None
Zinc	66.1	2850	63	3,700	730000	None

Notes to table

1. *Assessment criterion based on inorganic mercury*
2. *Values in italics relate to samples located in the proposed commercial use area.*
3. *Values in bold relate to samples located in the proposed residential use area*

Of the 63 samples tested for heavy metals, arsenic, lead and nickel were recorded at concentrations above residential land use GACs. Of samples collected from the proposed residential land use area (Western Area) only soil samples collected from TP112 and WS105 reported metal contaminants at concentrations above screening criteria.

The sample from TP112 at 0.35m recorded arsenic, lead and nickel at concentrations above residential GAC, the trial pit log records black stained sand and gravel fill beneath a reinforced concrete slab. WS105 at 0.25 m recorded lead at concentrations marginally above the GAC. Made ground was recorded to 0.40 m in this location and included brick and 'blacktop'/clinker fragments.

Five soil samples collected from the Eastern Area reported lead at concentrations above the residential GAC, but at concentrations less than the commercial land use GAC.

Samples collected from 'natural' soils did not record metal contaminants at concentrations above the soil screening criteria.

30.2 Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are widespread within made ground and the urban environment generally. They are one of the most common contaminants in made ground and the one that most commonly drives remediation. Benzo(a)pyrene is a particular problem, being very commonly found in

association with tarmac, clinker and any burnt products and also being highly toxic to human health.

The mean Soil Organic Matter of the population has been used to determine an appropriate Tier 1 GAC and results are summarised as follows:

Table 22: Summary of BaP and Naphthalene

Determinant	Minimum (mg/kg)	Maximum (mg/kg)	Number of samples tested	Tier1 Generic Assessment Criteria ¹ (mg/kg)		Samples that exceed GAC
				Residential with home grown produce 2.5% SOM	Commercial	
Benzo(a)pyrene ¹	0.2	87.3	63	5.0	77	<i>BH104 at 0.5m- 6.3mg/kg</i> WS105 at 0.25m- 87.3mg/kg <i>TP141</i> at <i>0.10m- 14mg/kg</i>
Naphthalene ²	0.2	1.2	63	5.6	190	None

Notes to table

1. As a surrogate marker for genotoxic PAH
2. As a marker compound for threshold PAH
3. Values in italics relate to samples located in the proposed commercial use area.
4. Values in bold relate to samples located in the proposed residential use area.

Three samples recorded benzo(a)pyrene above the 5mg/kg GAC for a residential setting with plant uptake. It is noted that the highest concentration, 87.3mg/kg recorded at WS105 at 0.20m was sampled from the former car park area to the northwest of the retained building.

Two soil samples collected from the Eastern Area (TP141 at 0.10 m and BH104 at 0.50 m) exceeded the residential GAC concentration for benzo(a)pyrene, but were less than the commercial GAC.

Naphthalene in the samples tested was not detected at concentrations above GAC for either residential or commercial land use.

No elevated PAH concentrations were recorded within the eight natural soils tested.

30.3 Petroleum Hydrocarbons (PHC)

Speciated PHC testing split by aromatic and aliphatic fractions and by carbon chain length, was carried out on 15 samples taken from made ground, reworked soils and natural deposits. The rationale for the analysis was based on olfactory or visual signs of hydrocarbons, noting that non-aqueous phase liquids, tars, heavy oil or strong hydrocarbon odours were not observed in any of the trial holes excavated during this phase of investigation.

A summary of total petroleum hydrocarbon concentrations detected is summarised below:

Table 23: Summary of Petroleum Hydrocarbon Results

Matrix	Exploratory location and depth	Total >C5-C40 Aliphatic/Aromatic concentration (mg/kg)
Made ground	TP112 – 0.1m	1050
	TP112 – 0.35m	14.3
	<i>TP124 – 0.9m</i>	<i>1.5</i>
	<i>TP131 – 0.3m</i>	<i>210</i>
	<i>TP150 – 0.3m</i>	<i>24</i>
	<i>TP151 – 0.7m</i>	<i>47.1</i>
	<i>WS102 – 0.2m</i>	<i>1170</i>
	<i>WS105 – 0.25m</i>	<i>2140</i>
Reworked Clay	<i>TP117 – 0.6m</i>	<i>387</i>
Silt	<i>TP126A – 1.0m</i>	<i>1.1</i>
	TP111 – 0.4m	5.1

Notes to table

1. Values in italics relate to samples located in the proposed commercial use area.

In all samples tested none of the PHC fractions exceeded the residential or commercial GAC.

Sample TP112 at 0.1m comprised blacktop hardstanding and samples TP112 0.35m, TP131 0.3m, WS102 0.2m and WS105 0.25m contained blacktop fragments or were closely overlain by blacktop hardstanding. No BTEX compounds were recorded at concentrations above the analytical limits of detection in any of the samples tested.

It should also be noted that the current works comprised non targeted testing across the site to provide information on post demolition ground conditions and did not specifically target areas where hydrocarbons had previously been encountered or where remediation of grossly

impacted soils was known to occurred. However, where trial holes coincided with these areas evidence of PHC was not recorded.

30.4 Volatile and Semi Volatile Organic Compounds (VOCs and SVOCs)

Two samples were tested for the presence of VOCs and SVOCs. No VOCs above the 10 µg/kg detection limit were recorded in either sample. Several SVOCs were detected above analytical limits of detection, most of related to PAH compounds and were not at concentrations above relative assessment criteria for their marker compounds for a residential end use. Low concentrations, at or slightly above, the detection limit of the following SVOC were recorded in TP115 at 1.4m: 3 and 4 methylphenol, 2-methylnaphthalene, 1-methylnaphthalene and carbazole. Given that carbazole (recorded at 0.04mg/kg) is a PAH, the risk posed from this compound is considered against benzo(a)pyrene (residential GAC 5mg/kg). It is therefore not considered to be significantly elevated. The methyl naphthalene compounds (0.01mg/kg) are also not considered a risk compared with the naphthalene GAC of 5.6m/kg.

It is noted that previous post demolition investigations also recorded low levels of carbazole and limited other SVOCs and their risk was assessed using benzo(a)pyrene as a marker compound. The concentrations were recorded at below the benzo(a)pyrene GAC and determined not a significant risk.

30.5 Asbestos

Sixty-six samples from the current investigations were screened for the presence of asbestos containing materials and/or loose asbestos fibres.

Asbestos was detected in one sample, namely chrysotile bitumen in TP133 at 0.1m. In a previous investigation by LEAP (August 2020), no asbestos was found and investigations carried out previously by others post-commencement of demolition recorded 11 positive asbestos identifications.

No visual signs of ACM were noted at surface during this phase of the investigation. On the basis of the visual inspections and laboratory testing the risk of ACM contamination of surface ground by the security breaches and removal of valuable metals from the retained building noted by WSCC in Section 8 is not considered to be significant.

30.6 Poly Chlorinated Biphenyls (PCBs)

Eight samples were tested for total PCB content as for waste classification purposes. One sample of made ground from TP108 at 2.0m recorded a total PCB concentration of 0.03mg/kg, which is at the analytical detection limit.

TP108 is located in the Western Area north of the footprint of Building 18. Historical and anecdotal records and previous reports have not identified potential PCB sources at this location.

31 Analytical Test Results – Water

Three rounds of groundwater monitoring of the deep groundwater wells installed within BH101-BH106 were undertaken between 8th February and 9th March 2021. A single shallow groundwater sample was collected from BH101S on 6th April 2021, to ascertain if the phenol and xylene recorded in BH101D was from a shallow source. A summary of the recorded contaminant concentrations and the Tier 1 assessment criteria are summarised below.

Table 24: Summary of Groundwater Test Results Above Tier 1 Assessment Criteria

Determinant (Total, unless otherwise specified)	Measured Range (µg/l)	Tier 1 Assessment Criteria (µg/l)		Samples that exceed Tier 1 Criteria
		UK Drinking Water Standard ² or other relevant standard as indicated	Annual Average Environmental Quality Standard	
METALS				
Copper	<5-13	2,000	1(bio)	BH101D 1 st round only BH101S BH105 All rounds
Mercury	<0.1-0.3	1	0.07	BH101D 1 st round BH101S
Nickel	<5-46	20	4 (bio)	BH101D All rounds BH102 2 nd and 3 rd round BH104 1 st and 2 nd round BH104 3 rd round BH105 2 nd and 3 rd round BH106 1 st and 2 nd round BH106 3 rd round BH101S
Zinc	<5-21	5000	10.9	BH102 3 rd round BH104 All rounds

				<i>BH106 3rd monitoring round</i>
Cyanide	<5-18	50	1	<i>BH105 3rd monitoring round</i> <i>BH101S</i>
PHC				
Total Petroleum Hydrocarbons (TPH)	<5 – 357	10 ⁴		BH101D 2nd and 3rd Monitoring round BH101S
Phenols	<1 – 392	-	7.7	<i>BH101 All rounds</i> <i>BH105 3rd monitoring round</i>
PAHs				
Benzo(a)pyrene	<0.1 – 0.01	0.01	0.00017	BH101D 2nd monitoring round BH101S
BTEX				
Xylenes ⁶	<1 – 72.4	3	30	BH101D 2nd and 3rd rounds BH101S
Others				
pH	6.3-12.4	6.5-9.5	6-9	BH101D All rounds BH101S BH104 2nd and 3rd round BH105 1st and 2nd monitoring round

Notes to Table

1. Range in Assessment criterion representing variation in dissolved CaCO₃ within waters
2. UK Drinking Water Standards, unless otherwise stated
3. WHO drinking water objective 2017 (2008 for petroleum hydrocarbons)
4. Assessment Criterion based on former target concentration for dissolved or emulsified hydrocarbons – now withdrawn.
5. Values in italics exceed UK EQS, values in **bold** exceed UKDWS
6. EA 2017 Hazardous substances to groundwater: minimum reporting values

Nickel was marginally above UK DWS in BH104 in the first two monitoring rounds and in BH101 (shallow) and BH106 on one occasion.

Total TPH was recorded above a withdrawn screening criterion of 10 µg/l in BH101 (deep) during the second and third monitoring rounds (values ranging from 76.3 µg/l to 357 µg/l) and in BH101 (shallow) in the single sampling round (126 µg/l), but below published WHO TPH guidance values for speciated petroleum hydrocarbons in all samples tested.

Xylene was reported above an indicative minimum reporting value of 3 µg/l in BH101 (deep) in the second and third monitoring rounds (72.4 to 75.3 µg/l) and BH101 (shallow) (28 µg/l) only.

Benzo(a)pyrene was reported at analytical detection limit (0.01 µg/l) in BH101 (deep) on the second monitoring round and BH101 (shallow) during the additional monitoring round.

Potential contaminants that exceeded the published UK Environmental Quality Standards are copper (BH101D/BH101S), mercury (BH101D/BH101S), nickel (BH101D/ BH101S, BH102, BH104, BH105, BH106), and zinc (BH102, BH104, BH106). Cyanide was recorded above the EQS value in BH105 in the final monitoring round, but below the UK DWS.

Phenol was detected above UK EQS in BH101D during all monitoring rounds, but not in the single shallow ground water sample collected from BH101S. Phenol was also marginally above the UK EQS in BH105 during the last monitoring round.

pH values fall outside of the published UKDWS or UKEQS ranges for groundwater sampled in BH101D/S, BH104 and BH105.

32 Land Gas Monitoring Results

As described above six gas monitoring rounds have been completed at the site and the results are provided in Appendix I and summarised in Table 25, below:

Table 25: Summary of land gas monitoring results

Monitoring Visit Date / Location Ref.	Maximum Recorded Concentration*							
	CO ₂ (%)	CH ₄ (%)	CO (%)	O ₂ (%)	VOC peak (ppm)	Peak Flow rate (l/hr)	Atmospheric Pressure (mB)	Was response zone flooded?
WS102								
08/02/21	0.9	0.1	0	16.0	1.2	-1.7	996	Yes
22/02/21	0.1	0.1	0	20.5	0.7	0	1013	Yes
08/03/21	1.1	0.1	2	19.7	0.4	0	1025	Partially
15/03/21	0.2	0.2	0	20.8	n.m.	0.03	1017	Partially
22/03/21	0.7	0.2	0	20.2	n.m.	0	1024	Partially
06/04/21	2.0	0	0	20.2	0.1	0	1017	No
WS103								
08/02/21	0.1	0	21	20.3	0	0.1	1008	Yes
22/02/21	0.1	0.1	9	20.8	1.1	-2.3	1013	Yes
08/03/21	0	0	1	21.0	0.8	-3.0	1022	Yes
15/03/21	0	0.1	1	20.9	n.m.	0.1	1017	Yes
22/03/21	0.1	0.1	7	20.0	n.m.	13.7	1024	Yes
06/04/21	0	0.1	15	19.8	5.3	0.0	1017	Partially
16/04/21	0.8	0.0	-10	20.1	n.m.	0.60	1025	No
WS105								
08/02/21	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.
22/02/21	8.6	0.1	4	18.3	3.9	-2.7	1013	Yes
08/03/21	0.6	0.1	0	21.1	1.0	0	1020	Yes
15/03/21	0.1	0.1	0	21.2	n.m.	0	1017	Yes
22/03/21	0.1	0.2	0	21.2	n.m.	0	1022	Yes
06/04/21	4.8	0.2	0	19.0	1.1	0	1017	Yes
WS106								
08/02/21	0.9	0.1	0	16.0	0	0	1009	Yes
22/02/21	0.6	0.5	0	16.2	1.2	-5.7	1013	Yes
08/03/21	1.7	0.4	0	15.3	0	0.1	1022	Partially
15/03/21	0.7	0.4	0	15.3	n.m.	3.8	1017	Partially

Monitoring Visit Date / Location Ref.	Maximum Recorded Concentration*							
	CO ₂ (%)	CH ₄ (%)	CO (%)	O ₂ (%)	VOC peak (ppm)	Peak Flow rate (l/hr)	Atmospheric Pressure (mB)	Was response zone flooded?
22/03/21	0.8	0.3	0	14.5	n.m.	0	1017	Partially
06/04/21	0.7	0.1	0	13.6	0.8	0	1017	Partially
16/04/21	0.7	0.0	0	16.5	n.m.	0	1025	Partially
WS108								
08/02/21	0.9	0.1	11	20.0	1.8	-5.1 (0.0)	997	Yes
22/02/21	1.5	0.1	1	19.7	1.5	0	1014	Yes
08/03/21	2.4	0.1	0	20.5	1.2	-0.2	1021	Yes
15/03/21	0.2	0.2	0	20.9	n.m.	0	1017	Yes
22/03/21	3.0	0.1	0	20.8	n.m.	4.1 (0.0)	1022	Yes
06/04/21	1.6	0.1	0	19.5	0.8	2.0 (0.0)	1017	Partially
WS109								
08/02/21	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.
22/02/21	0.2	0.3	0	20.4	4.5	0	1013	Yes
08/03/21	0.5	0.1	0	21.1	0.1	0	1021	Yes
15/03/21	0.5	0.2	0	20.5	n.m.	0	1017	Yes
22/03/21	0.1	0.2	0	20.6	n.m.	0	1022	Partially
06/04/21	0.3	0.1	0	21.0	0.3	0	1017	Yes
WS111								
08/02/21	0	0	0	14.8	0.8	0.4	1001	Yes
22/02/21	0.1	0.1	0	20.3	0.6	-0.1	1013	Partially
08/03/21	0.1	0.1	0	20.7	0.3	0	1021	No
15/03/21	0	0.1	1	20.8	n.m.	0	1016	No
22/03/21	0	0.2	0	20.8	n.m.	0	1022	No
06/04/21	0	0.1	0	21.1	0.6	0	1017	No
WS113								
08/02/21	0.1	0.1	3	20.5	3.1	0.8	1000	Yes
22/02/21	0.1	0.2	0	20.8	4.8	0	1013	Yes
08/03/21	0	0.1	0	20.7	2.5	0	1021	Partially

Monitoring Visit Date / Location Ref.	Maximum Recorded Concentration*							
	CO ₂ (%)	CH ₄ (%)	CO (%)	O ₂ (%)	VOC peak (ppm)	Peak Flow rate (l/hr)	Atmospheric Pressure (mB)	Was response zone flooded?
15/03/21	0	0.2	0	20.4	n.m.	0	1016	Partially
22/03/21	0	0.2	0	20.4	n.m.	0	1022	Partially
06/04/21	0.1	0.1	0	20.5	2.4	0	1022	No
WS115								
08/02/21	0	0	0	16.2	0.8	17.7 (0.0)	1001	Yes
22/02/21	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	1013	Yes
08/03/21	0.1	0	0	21.3	0.2	-0.1	1020	Partially
15/03/21	0	0.2	0	21.3	n.m.	-0.1	1016	Yes
22/03/21	0	0.2	0	16.5	n.m.	10.1 (0.0)	1022	Yes
06/04/21	0	0.1	3	17.9	1.2	0	1017	Yes
WS116								
08/02/21	0.7	0	0	16.1	0.1	-1.1	995	Yes
22/02/21	0	0.2	0	21.1	0.6	-0.1	1013	Yes
08/03/21	0.1	0	0	21.1	1.1	-0.1	1021	Yes
15/03/21	0	0.1	0	21.1	n.m.	0	1016	Yes
22/03/21	0	0.2	1	20.8	n.m.	0	1023	Yes
06/04/21	0	0.1	1	21.2	3.2	0	1016	Yes
WS118								
08/02/21	0.1	0	0	2.6	0.8	66.6 (1.5)	996	Yes
22/02/21	1.7	0.1	0	20.8	1.2	0	1012	Yes
08/03/21	1.6	0	0	19.3	0.2	0	1022	Yes
15/03/21	0.4	0.2	1	21.0	n.m.	0.5 (0.0)	1016	Yes
22/03/21	1.4	0	0	19.3	n.m.	0	1024	Yes
06/04/21	3.6	0.1	0	13.2	0.4	0	1016	Yes
BH101S								
08/02/21	0	0	0	16.2	3.1	0.3 (0.1)	1000	Yes
22/02/21	0.1	0.2	0	21.0	0.4	0	1013	Partially
08/03/21	0.1	0.1	0	21.2	1.4	0	1021	Partially

Monitoring Visit Date / Location Ref.	Maximum Recorded Concentration*							
	CO ₂ (%)	CH ₄ (%)	CO (%)	O ₂ (%)	VOC peak (ppm)	Peak Flow rate (l/hr)	Atmospheric Pressure (mB)	Was response zone flooded?
15/03/21	0	0.2	1	20.8	n.m.	0	1016	Partially
22/03/21	0	0.2	0	20.8	n.m.	0	1022	Partially
06/04/21	0	0.1	0	19.7	5.4	0	1022	Partially
BH103S								
08/02/21	0.1	0.1	0	16.0	1.2	-0.1	996	Yes
22/02/21	0.1	0.1	0	21.1	1.7	-0.1	1013	Yes
08/03/21	1.2	0.1	0	15.6	0.6	0	1020	No
15/03/21	0.2	0.2	0	20.3	n.m.	0	1016	Partially
22/03/21	1.0	0.2	0	14.9	n.m.	0	1023	Partially
06/04/21	0.9	0.2	0	17.6	3.2	0	1016	Partially
BH106								
19/01/21	13.6	0.0	0	1.0	n.r.	104	984	n.r.
08/02/21	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.
22/02/21	0.1	0.1	0	21.2	0.3	5.7	1014	Partially
08/03/21	7.9	0	9	10.4	0.4	3.8	1022	Partially
15/03/21	0	0.1	0	21.2	n.m.	3.4	1022	Partially
22/03/21	0	0.1	0	20.8	n.m.	3.6	1024	Partially
06/04/21	8.1	0.1	32	10.1	0.5	2.8	1016	Partially
16/04/21	0.0	0.0	-10	20.5	n.m.	52 (7.2)	1025	Partially

Notes to table

* With the exception of Oxygen which is recorded as minimum

n.m. – not measured

Values in bracket steady state readings

Seven land gas monitoring rounds have been carried out at the site during this investigation. Carbon dioxide concentrations ranged from 0.1% to 13.6% and methane concentrations ranged from 0.1% to 0.5%. A maximum flow rate of 104 l/hr was reported in BH106, noting that this was outside of the programmed monitoring visits. The first monitoring round was undertaken during low <1000 mB atmospheric pressure conditions.

Detected carbon monoxide concentrations ranged from 1 up to 32 ppm measured in BH106.

We note that the response zones in all wells were flooded or partially flooded during one or more of the monitoring rounds, as such the gas concentrations and flow rates in monitoring wells affected by fully flooded wells are not representative of land gases for the stratum that they are screened within.

Outside of the planned gas monitoring rounds, and as described in Section 13.5 on 19th January 2021 land gases were observed venting from ground around the headworks to BH106. A flow rate of 104 l/hr was recorded from the gas valve, with 13.6% carbon dioxide, 0% methane, 1.0% oxygen recorded. The high flows were noted for several days following the initial event. The response zone from BH106 was screened across the Tunbridge Wells Sand Formation from 11-20 m. Significantly high flow rates were not recorded in BH106 in subsequent monitoring rounds, with the exception of an additional visit on 16/04/21 where a peak flow of 52 l/hr was recorded reducing to a steady state reading of 7.2 l/hr.

33 Risk Assessment

33.1 Human Health

This investigation found that the made ground and reworked soils beneath the site are locally impacted with arsenic, lead, nickel, and benzo(a)pyrene for a residential land use. Figure 13 highlights sample locations with contaminants above a residential GAC. Asbestos was identified in one location. Previous investigations by KDC Contractors Ltd in 2015/16 also identified elevated concentrations of arsenic, beryllium, lead, copper and benzo(a)pyrene for a residential land use and asbestos in onsite soils.

These determinands pose a risk to residential land users in uncapped areas i.e. gardens or soft landscaping. Contamination may impact human health through the direct ingestion, inhalation, skin contact and/or plant uptake pathways that would be present in a residential setting.

For a commercial land use, potential contaminants of concern were not recorded at concentrations above generic assessment criteria and as such the existing soils are not considered to pose an unacceptable risk for this land use. The exception is asbestos in soils, which could also pose a potential risk to commercial land users in soft landscaped areas, as well as for the construction workers on site present during the construction works phase.

PAHs and PHC contamination may pose a risk to incoming water via permeation into the supply lines. LEAP has not been made aware of the proposed locations of services. The use of protective water supply infrastructure may be required by the water supplier if water services are to be placed within the made ground soils on site.

Some remediation to eliminate human health risk from potential asbestos fibres, heavy metals and benzo(a)pyrene would be required within all soft landscaped areas (private gardens, public open space and commercial landscaped areas) – See Section 36. A remediation strategy addressing these areas will also be required.

There remains the possibility that as yet unidentified contamination may be present, particularly north and south of the retained building where below ground services limited investigations in these areas, including possible below ground interceptors and historically decommissioned fuel storage tanks.

33.2 Controlled Waters

33.2.1 Groundwater

Previous investigations recorded some potential contaminants of concern at elevated concentrations above screening criteria in the shallow perched aquifer. Although discounted as a risk to groundwater the previous investigations did not investigate the groundwater quality of the deeper aquifer. This investigation has found that there is a shallow perched groundwater towards the base of the made ground layer, but also groundwater seepages in the upper layers of the Upper Tunbridge Wells Sand Formation (generally between 1-2m bgl). However, there are differences between recorded groundwater elevations in the deep and shallow monitoring wells, which imply that there is limited connectivity between the shallow and deeper groundwater bodies and the weathered clays and silts at the top of the bedrock may limit vertical migration of potential contaminants of concern.

With respect to risks to the deep aquifer BH105 and BH106 located in the western half of the site within the Secondary A Aquifer of the Tunbridge Wells Sand - sandstone and mudstone. BH101-BH104 are in the eastern half of the site within the unproductive aquifer of the Tunbridge Wells Sand – mudstone.

The groundwater laboratory tests recorded nickel at concentrations above UK Drinking Water Standards in three location namely BH104, BH106 and BH101S. Nickel was reported at concentrations between 21 and 28 µg/l in BH104 and BH106 and 46 µg/l in BH101S compared with the screening value of 20 µg/l. Nickel was not detected above UK DWS in BH101D. Soil testing of shallow made ground or reworked soils at these locations did not report nickel concentrations in soils above normal background concentrations (42 mg/kg) suggesting that a significant soil source is not present at these locations.

BH104, BH106 and BH101S are located in an area where the bedrock is mapped as unproductive strata. On the basis of marginal exceedances, low sensitivity of the aquifer (mapped as an unproductive aquifer) and absence of potable water abstractions proximal to the site, identified nickel is not considered to pose a significant risk to groundwater receptors.

Total TPH was detected marginally above the withdrawn screening criteria of 10 µg/l in BH101 shallow and deep (ranging between 79.3 to 357 µg/l). The TPH fractions were at concentrations below published WHO TPH guidance values. Given that the groundwater in the eastern half of the site is mapped as an unproductive aquifer, a non-aqueous phase liquid (NAPL) was not identified and exceedances of WHO TPH guidance values were not reported. Petroleum hydrocarbons reported in BH101S/D are not considered to pose a significant risk to groundwater receptors.

Xylene was detected at concentrations above the published UK Minimum Reporting Value (MRV) of 3µg/l in BH101D and BH101S, higher concentrations were reported in the deeper monitoring well (BH101D) with concentrations ranging from 72.4 to 75.3 µg/l compared to 28 µg/l in BH101S.

BH101 is located beneath a former firewater runoff storage reservoir and to the north of a diesel storage area that has been remediated by others. The exploratory holes excavated by LEAP at BH101 and to the north, west and south of the location (TP145-TP146) did not describe the presence of NAPL, malodours or significantly discoloured soils that may be a source of the xylene present in groundwater at BH101D/S. MRV are used for the protection of groundwater as a long term drinking water resource, the eastern half of the site is highly unlikely to be used for potable water supply.

On the basis of the above, the xylene concentrations reported in BH101D/S are not considered to pose a significant risk to groundwater receptors on the basis that an ongoing source is unlikely to be present, the aquifer is of low sensitivity (mapped as an unproductive aquifer), and the absence of potable water abstractions / source protection zones in the vicinity of the site and the other deep monitoring wells did not detect xylene.

Benzo(a)pyrene was detected at analytical detection limit (0.01 µg/l) in BH101D/S. The low concentration of this polycyclic aromatic hydrocarbon is not considered to pose a risk to groundwater receptors.

In summary, a soil source of nickel, PHC, xylene or benzo(a)pyrene was not identified in the locations where exceedances of groundwater Tier 1 screening criteria were identified. Although present in groundwater the risk is not considered significant to offsite groundwater receptors and groundwater remediation is not proposed.

We note that there are no published UKDWS for phenol, however phenol was reported at elevated concentrations in BH101D in all three monitoring rounds. It was not detected in shallow groundwater at BH101S. An onsite source of the phenol was not identified during this investigation and the risk to groundwater is not considered significant.

33.2.2 Surface Water

The CSM did not identify plausible groundwater contaminant source pathway linkage to offsite surface water receptors, with the exception of a possible preferential pathway via surface water drains that extend through the eastern half of the site and connect to the Horsham Pond ~800m to the southwest of the site.

An assessment of the connectivity between shallow groundwater and the surface water drains is beyond the scope of this assessment. The presence of significant surface water drainage and historic drainage channels taking upstream waters across site and towards the pond should be the subject of further investigation, firstly to ensure the continued integrity of the system and also to assess whether leakages are contributing to the groundwater issues noted in the east of the site.

33.3 Land Gases

Adopting the methods described in 29.3, Gas Screening Values (GSV) per monitoring well location have been derived, using the highest gas concentration and flow readings. Negative flow readings have not been considered, as they are judged unrepresentative of a worst case, on the basis that the highest inflows were short duration and recorded in flooded wells during periodic monitoring events and as such are considered likely to be an artifact of pressure change when the gas valve was opened rather than of land gas generation.

Where negative flows or no flow have been measured the instrument detection limit (0.1 l/hr) has been used, where no methane is detected a concentration of 0.1% is assumed (the detection limit of the equipment used by LEAP).

Table 26: Preliminary Gas Screening Values

Location	Maximum reported values			Gas Screening Value L/hr	
	Carbon dioxide %	Methane %	Peak Flow L/hr	Carbon dioxide	Methane
WS102	1.1	0.1	0.3	0.0033	0.0003
WS103	0.8	0.1	13.7^^	0.1096	0.0137
WS105	8.6	0.1	0.1	0.0086	0.0001
WS106	1.7	0.5	3.8	0.0646	0.019
WS108	3	0.1	4.1^^	0.123	0.0041
WS109	0.5	0.3	0.1	0.0005	0.0003
WS111	0.1	0.2	0.4	0.0004	0.0008
WS113	0.1	0.2	0.8	0.0008	0.0016
WS115	0.1	0.2	17.1^^	0.0171	0.0342
WS116	0.7	0.2	0.1	0.0007	0.0002
WS118	3.6	0.2	66.6^^	2.3976	0.1332
BH101S	0.1	0.2	0.3	0.0003	0.0006
BH103S	1.2	0.2	0.1	0.0012	0.0002
BH106	13.6	0.1	104	14.144	0.104

^^ from a flooded well; green shading is GSV <0.07 (CS1 very low risk or green NHBC); orange shading GSV >0.07 to <0.7 (CS2 low risk or Amber 1 NHBC); dark orange shading >0.7 to <3.5 (CS3 moderate risk or Amber 2); red shading >3.5 to <15 (CS4 moderate to high risk or red NHBC)

The land gas readings from the majority of the monitoring locations are classified as CS1 very low risk or green under NHBC. WS103, WS108 and WS118 have been classified as CS2 or CS3 on the basis of the high flow rates recorded in the monitoring wells, these high flows were measured from flooded wells.

BH106 is classified as CS4 moderate to high risk or red under NHBC based on the high flow rates and elevated carbon dioxide initially reported in January 2021, prior to the planned gas monitoring rounds.

Section 6.3.6 of BS8485:2015 +A1:2019 states that where water is above the top of the response zone any peak flow is likely to be due to a build-up of pressure caused by rising water trapping the gas within the solid section of the pipe and the initial peak is not representative of the rate of gas generation within the ground. On this basis, we have re-assessed the GSV using steady-state flows or peak flows recorded when the response zone was not flooded for WS103, WS108, WS118.

The revised GSVs WS103, WS108 and WS118 are provided in Table 27, below:

Table 27: Revised Gas Screening Values for WS103, WS108 and WS118 only

Location	Maximum reported values			Gas Screening Value L/hr	
	Carbon dioxide %	Methane %	Peak Flow L/hr	Carbon dioxide	Methane
WS103	0.8	0.1	0.6^	0.0048	0.0006
WS108	3.0	0.1	0.1\$\$	0.003	0.001
WS118	3.6	0.2	0.1\$\$	0.0036	0.002

^ from an unflooded monitoring round;\$\$ steady state; green shading is GSV <0.07 (CS1 very low risk or green NHBC); orange shading GSV >0.07 to <0.7 (CS2 low risk or Amber 1 NHBC); dark orange shading >0.7 to <3.5 (CS3 moderate risk or Amber 2); red shading >3.5 to <15 (CS4 moderate to high risk or red NHBC).

With the exception of BH106 the land gas classification for the site is CS1 very low risk or green following NHBC. This classification is consistent with the findings of the ground investigation in that no significant on site land gas generating sources were identified such as deleterious material, paper etc. Some areas of made ground deeper than 2.0 m were identified across the site, but these locations largely comprised demolition rubble, which is not typically associated with having a high land gas generation potential. Carbon dioxide peaks shown in WS105, WS108 and WS118 are likely related to microbial respiration of organic matter in soil, which typically have low to zero methane concentrations and flow.

BH101S is the closest onsite monitoring well to historical infilled clay pits, which are within 60 m of the well. BH101S is also located in an area of deep made ground. Carbon dioxide and methane were not detected at concentrations that would indicate a significant land gas risk

from the deep made ground at the location or from the backfilled historical clay pits to the south.

With respect to the offsite sources (railway lines / commercial land to the east) BH101S, BH103S and WS116 did not identify elevated concentrations of land gases that would pose a risk to the proposed development.

With respect to BH106, high gas flow rates (104 l/hr) and 13.6% carbon dioxide were recorded in January 2021 soon after the well was installed. At the time of this initial reading gases were visible around the annulus of the standpipe i.e. gas bubbling through standing water within the headworks. Subsequent gas monitoring rounds at BH106 recorded steady state flow rates between 2.8 to 7.2 l/hr with a peak flow rate of 52l/hr noted on the last monitoring round. During planned monitoring events carbon dioxide has periodically been detected at concentrations between 0.1% to 8.1%. Methane has not been detected above threshold concentrations in BH106. Carbon monoxide of 32 ppm was detected on one occasion.

The response zone for BH106 is installed from ~11 m to ~20 m below ground level in the Tunbridge Well Sand Formation. No land gas sources for the BH106 have been identified on site that would account for the flow rates reported in January 2021. LEAP has discounted the shallow made ground in the vicinity of BH106 as being a significant land gas generation source on the basis that shallow monitoring wells installed at WS106, WS103 and WS105, within, 2 m, 35 m and 30 m respectively did not record flow rates or carbon dioxide concentrations in the same range as BH106. Made ground thicknesses at these locations ranged from 0.40 m (WS105) to 1.70 m (WS103) and was described largely as demolition rubble with brick, concrete and clinker fragments i.e. typically low land gas generation potential. No visual signs of large amounts of deleterious organic material are reported in or around these locations. From ~2.0 m below ground level the bedrock of the Tunbridge Well Sand Formation is present.

Offsite, approximately 28 m north of BH106 a 225 mm diameter foul sewer is present aligned east to west along Parsonage Road. LEAP consider it unlikely that accidental leakages from the sewer could have percolated through the bedrock to 11-20 m depths, and degraded to cause a trapped pocket of land gases resulting in flows of 104 l/hr. Further, during monitoring rounds hydrogen sulphide and methane (which are typical components of sewer gases) were not detected. No odours, sheens or significantly discoloured water was observed during water sampling at this position.

During drilling no voids or below ground service strikes were recorded that may account for the flow rates and carbon dioxide, although we cannot discount that a ruptured compressed air line is present at depth, noting that these were used at part of the pharmaceutical works infrastructure. The initial very high flow rates were noted following a period of heavy rainfall and it was initially supposed that the flows may be generated as an artifact of water flow through the permeable made ground layer creating flows. However, significantly reduced, but

still elevated flow rates have been recorded in the subsequent monitoring visits during periods of dry weather.

It is possible that BH106 has punctured a localised pocket of gas generated from degradation of organic material at depth in the sandstone layer (lignite noted on log at ~10 m bgl), although the flow rates would also be considered unusual for this type of source. The peak flows noted in January may have been the trapped source degassing with force and as pressures equalised the flows have reduced. Once the initial source has been depleted it is not expected to pose an ongoing risk, as microbial degradation of this material will not generate high flows or gas concentrations in the timeframe that properties will be present.

Notwithstanding the above, further investigation and land gas assessment is recommended at BH106 to determine the risk to the proposed development.

34 Geo-Environmental Conclusions

On the basis of the non-targeted ground investigate, made ground was found to generally extend up to 1-2 m in thickness, with deeper areas up to 4m in the east, and is locally impacted with asbestos, arsenic, lead, nickel and benzo(a)pyrene. This is similar to the findings of the previous ground investigations that targeted potential sources of contamination. Made ground soils pose a potential risk to future land users from direct contact and ingestion pathways i.e. in soft landscaped areas.

Access to areas to the north and south of the retained building were limited due to below ground services. The desk study highlighted the potential for a groundwater interceptor to be present to the immediate south of Building 3/36 and fuel tanks to the southwest (anecdotally reported to have been decommissioned).

Xylene was recorded in deep groundwater and shallow groundwater in BH101 at concentrations above published MRVs for groundwater. In the areas investigated by LEAP a potential hydrocarbon source was not identified. Xylene was not considered to pose a significant risk to groundwater receptors, that warrants remediation. Phenol was detected in the deep monitoring well at BH101 during all monitoring rounds and in BH105 in the last round. Phenol does not pose a risk to offsite groundwater receptors for the reasons highlighted for xylene in section 33.2.1.

However, a preferential pathway may exist via the existing surface water drains and historical ditches that extend through the site. A 2018 CCTV found sections of the surface water drains potentially damaged.

An assessment of the potential risk to the Horsham Pond from the surface water drains that extend through the site was beyond the scope of our appointment but should be the subject

of further investigation, including inspection of the integrity of the drains as well as laboratory testing of the water quality within the drains as they enter and exit the site.

Based on gas monitoring undertaken to this date, the site gas regime is currently assessed as CS1 for the majority of the site, with the exception of elevated gas flows and carbon dioxide emanating from BH106. Areas identified as potential land gas sources (deep made ground / infilled clay pits) a land gas risk was not identified.

It is recommended to extend the gas monitoring within locations which detected the elevated concentrations of carbon dioxide and carbon monoxide (BH106, WS103, WS105 and WS106) via the means of continuous monitoring and chemical gas bulk sample analysis. This would provide more information on the true nature and the potential source of the released gases at BH106 and hence the residual risks, if any, to the proposed properties in this part of the site.

35 Waste Disposal

It is anticipated that the proposed development will generate waste soils and materials will need to be removed from site as part of the construction process.

Where soils are to be disposed off-site, it is the duty of the waste producer, in this case the developer, to ensure that all waste is disposed of appropriately and that any that is sent to landfill is sent to an appropriately licensed one. All waste sent to landfill must be classified and must be pre-treated. There are various forms of pre-treatment that are acceptable. In this case it could include “reduction in volume”, which could be achieved by segregating the Made Ground and re-using part of it on site.

Where made ground soil is to be re-used on site then it is recommended that this is carried out under the CL:AIRE Definition of Waste Industry Code of Practice (DoWCoP) for re-use of soils³¹.

Sixty-six soil samples were preliminarily assessed for waste classification purposes using HazWasteOnline® screening tool and the results are presented in Appendix J. It is considered that the made ground soils would be classified mainly as non-hazardous for waste disposal purposes, but localised areas hazardous material due to heavy metals, TPH and benzo(a)pyrene cannot be discounted. The non-hazardous threshold for TPH (1000mg/kg) was exceeded in the made ground sample at WS102 0.2m and TP112 at 0.1 m. We note that benzo(a)pyrene:TPH ratio is <1000:1 in WS102 at 0.2 m. Hazardous waste concentrations for

³¹ The Definition of Waste: Development Industry Code of Practice. Version 2 2011. CL:AIRE

TPH and benzo(a)pyrene levels were also encountered in the made ground at WS105 0.25m. The heavy metal threshold was exceeded in made ground fill sample encountered below the blacktop and concrete hardstanding at TP112 0.35m. Where asbestos fragments are identified they would be classed as hazardous waste. Twelve soil samples were recorded as hazardous waste due to pH concentrations reported above 11.5 pH units. This may be due to concrete in the sample producing an alkaline test result and not a true reflection of the soil pH.

Eight samples were tested for waste acceptance criteria to indicate whether it will be accepted at landfill. This indicates the waste would be accepted mainly as non-hazardous with potential inert acceptance of segregated natural and reworked natural soils. However, it is recommended that this is confirmed with the haulier and the receiving waste management site.

Further testing and inspection of soils will be required to confirm waste classification of material leaving the site. A watching brief ensuring previously unencountered asbestos is not removed as non-hazardous waste is recommended.

It is strongly advised that detailed discussions be held with remediation/groundworks contractors and that receiving landfill sites are identified in advance of commencing any waste removal.

36 Recommendations for Remediation

The risk driver for remediation is exposure of future site users to heavy metals, benzo(a)pyrene as well as remaining potential for asbestos to be encountered within the made ground. The pathway for impact to future users is direct exposure to the outlined contaminants.

Where soft landscaping is proposed in areas of made ground then remedial works will be required to prevent potential risks to future land users. Where hardstanding is proposed this will break contaminant linkages and remedial measures will not be required.

In private garden areas, where made ground is present a capping solution comprising 600mm of verified clean cover material, including a minimum of 150mm topsoil, and clean corridors for service runs would act to break the pathway of exposure and render the material suitable to be reused on the site. Depending on the final development levels, this may require material to be removed and disposed off-site. Given the potential presence of asbestos, it is recommended that the formation level is inspected to confirm ground conditions prior to placement of capping layer. A visible marker layer (geotextile membrane) should be considered where made ground remains at formation level. Where asbestos containing materials are suspected at formation level further excavation may be required and/or the placement of a 150 mm hard to dig barrier in addition to the geotextile membrane. In public open space / commercial soft landscaped areas the thickness of capping material may be

reduced to 300 mm thick. Clean cover thicknesses should be extended to 900 mm depths if new trees are proposed or to 450 mm where shrub planting is proposed. Clean cover systems should be made with reference to CIRIA Special Publication 124:1996 *Barriers, liners and cover systems for containment and control of land contamination*.

Remedial measures for proposed soft landscaping use are not required where natural soils are present.

Surveying and sampling of the surface water drains along the north-eastern boundary (where they enter the site) and along the southern boundary (where they exit the site) should be undertaken to confirm the integrity of the drainage system and the quality of water discharging through the site drains.

Access into the areas north and south of the retained building and along of the southern boundary from the centre towards the south east corner was restricted due to present limited space, proximity to the railway lines, hardstanding and services. It is recommended that once hardstanding has been removed and it is safe to dig without risk of damage to services, formation inspections by a competent environmental engineer with possible further intrusive investigations are undertaken within these locations.

The presence of asbestos within the made ground has been detected in this and previous investigations. Groundworks should be carried out following suitable health and safety protocols, for example, dust suppression measures and reassurance monitoring, as required.

The works should be planned with reference to the Joint Industry Working Group Asbestos in Soil and Construction & Demolition (C&D) Materials guidance titled “Control of Asbestos Regulations 2012: Interpretation for Managing and Working with Asbestos in Soil and Construction & Demolition materials: Industry Guidance (CAR-SOILtm)”.

37 Validation of Remediation

A final remediation method statement will be required to be prepared once the final site designs are complete. This method statement should be submitted to the appropriate regulatory authorities. It is advised that the local authority are advised of the intended build programme in order that they can phase the sign off of planning conditions as required.

The remediation strategy will require the importation of clean topsoil, and possibly subsoil. Imported soils should be tested at source by the supplier. The validation engineers should then make spot checks as and when necessary once material has been imported.

Provision should also be made for dealing with further localised hotspots of contamination which may come to light during construction. Any such soils should be inspected by the validation engineers and appropriate remedial action taken as necessary.