

sample recorded a plasticity index of 26 %, suggesting medium volume change potential. Moisture contents were also determined and ranged from 12 to 26 %.

- 5.2.5.3 Sieve analysis carried out on two samples of granular soil described the material as greyish brown very clayey sandy gravel with cobbles.
- 5.2.5.4 Triaxial tests were performed on two undisturbed samples of clay obtained from depths of 2.3 and 3.0 m bgl in boreholes MBH01 and MBH02. The tests revealed average undrained shear strengths of 33 and 26 kN/m², respectively. These results are indicative of soft low strength ground conditions.
- 5.2.5.5 Four SPT N values were obtained wholly within the clay stratum – at 1 m depth, values of 3, 5 and 9 were obtained indicating very soft, soft and firm conditions. An N value of 14 was obtained in clay at 4 m depth, indicating firm approaching stiff clay.
- 5.2.5.6 A clayey sand was locally observed below clays and above sandstone units which may be glacial in origin or completely weathered bedrock. An N value of 37 was obtained from this stratum indicating dense conditions.
- 5.2.6 South Wales Lower Coal Measures
 - 5.2.6.1 Strata consistent with the published geological descriptions of the South Wales Lower Coal measures were encountered as sandstone in MBH01-MBH03 at depths of 4.0 to 8.1 m bgl. This was observed as a grey, argillaceous fine-grained sandstone. Mudstone was encountered in MWS05 at 3.50 m bgl.
 - 5.2.6.2 Coal was encountered in MBH03 between 7.20 and 8.0 m bgl.

SECTION 6 PRELIMINARY GEOTECHNICAL RECOMMENDATIONS

6.1 FOUNDATIONS

- 6.1.1 The proposed development comprises low-rise residential housing with private gardens, parking, soft landscaping and associated infrastructure. It is understood that housing will occupy the lower level, which covers the majority of the site, and also the middle level, whilst the upper level will be a biodiversity reserve.
- 6.1.2 The recent ground investigation revealed ground conditions consisting of variable thicknesses of made ground (0.2 to 2.5 m thick) underlain by superficial deposits of Till (Diamicton) (1.2 to 7.7 m thick). These soils were underlain by a pale grey fine grained sandstone of the South Wales Lower Coal Measures Formation, which was revealed at depths of between 4.0 and 8.1 m bgl.
- 6.1.3 SPTs performed in the upper superficial clays revealed very soft / soft low strength ground conditions, whilst firm medium strength conditions were present below. Natural clay encountered in all trial pits and windowless sample holes was consistently described as soft in nature. Deposits of sand encountered in MBH01

were found to be dense in nature. SPTs undertaken in the underlying sandstone and limestone were met with refusal, indicating typically competent rock.

- 6.1.4 Based on the variable thickness of made ground and consistently weak nature of the upper natural soils across the site, traditional shallow strip / trench footings are not considered to be feasible for the new development at current site levels. Alternative solutions, including rafts, ground improvement and piles, will need to be adopted. These options are discussed below.
- 6.1.5 Raft foundations could be adopted within the weak natural clay soils where existing made ground is relatively shallow. These would allow structural loads to be distributed over a larger area, thereby limiting total settlements. Allowable bearing pressures of 30 kN/m² will be achievable in the shallow natural clay for two-storey structures.
- 6.1.6 Alternatively, ground improvement could be carried out, utilising vibro stone columns. Stone columns could be installed along the lines of all load bearing walls and keyed into the underlying dense sand or rock to depths of around 5 - 6 m in order to provide a more uniform founding medium. This would enable strip footings to be constructed on the improved ground at depths of around 1 m. Allowable bearing pressures of around 100 kN/m² are likely to be achievable for footings up to 1 m wide. Light mesh reinforcement will need to be incorporated into all footings constructed on vibro treated ground. In order to assess the suitability of using ground improvement a specialist contractor should ideally be invited to attend site to view the ground conditions for themselves.
- 6.1.7 If ground treatment is not deemed economically or technically suitable for the development or does not yield the required allowable bearing pressures for the imposed building loads, then a piled foundation solution should be adopted.
- 6.1.8 It is envisaged that either driven or bored / Continuous Flight Auger (CFA) piles could be adopted at the site. Driven piles could possibly be utilised as they have the advantage that no arisings are generated, however, the effects of noise / vibrations are likely to be an issue given the proximity of the existing residential development.
- 6.1.9 The advantage of using bored / CFA piles is the low noise / vibration of the system, however, arisings are generated by bored / CFA piles. Piles would need to be taken through the made ground and weak superficial deposits to found within the underlying competent rock. Pile lengths will vary depending on the depth of the bedrock however, it is likely that minimum lengths of around 5 m will be required in the northern part of the site.
- 6.1.10 It is recommended that the advice of a specialist contractor be sought in order to determine the most appropriate / cost effective system and to advise on pile diameters, depths and safe working capacity. A preliminary guide to safe working loads for individual bored / CFA piles of varying length and diameter is presented in the table below. Pile calculations have been based on assessing skin friction and

end bearing resistance in the undisturbed natural strata. No allowance has been made at this stage for any potential drag down (negative skin friction). This should be assessed and allowed for by the designer.

- 6.1.11 The calculations assume a pile penetrating into the competent bedrock, whilst no contribution from existing fill materials has been allowed for. A factor of safety of 3.0 has been applied to the calculated ultimate capacities. As discussed, these values are for guidance purposes only and should be verified by a specialist contractor. In addition, the safe working loads given are for individual isolated piles. The group effect should be assessed during the design stage.

Table 9: Safe Working Capacities for bored / CFA Piles

Pile Diameter (mm)	Length (m)	Safe Working Capacity (kN)
300	5	100
	10	175
450	5	195
	10	300
600	5	315
	10	455

6.2 EXCAVATIONS AND GROUNDWATER

- 6.2.1 Based on the ground conditions observed at the site, any shallow excavations have the potential to become unstable in the short term, therefore, if man-entry is required, excavations should be supported by shoring or otherwise battered back to a safe angle in order to protect the workforce from possible collapse.

- 6.2.2 Old foundations and any buried structures associated with previous buildings should be removed and the resulting excavations backfilled with suitable granular fill.

- 6.2.3 Groundwater was encountered during the intrusive investigation in various locations at depths ranging from 1.0 to 3.6 m bgl. In view of this, it is considered possible that groundwater ingress will occur in shallow excavations, therefore, provision for dewatering during the construction period should be considered.

6.3 FLOOR SLABS

- 6.3.1 In view of the presence of made ground and cohesive natural soils at shallow depth across the site, it is recommended that suspended floor slabs are adopted for the proposed development.

6.4 BURIED CONCRETE

- 6.4.1 Recommendations given in BRE Special Digest 1:2005 "*Concrete in aggressive ground*" have been followed in order to give recommendations with respect to buried concrete.
- 6.4.2 Water soluble sulphate analysis was carried out on twenty-five soil samples obtained from depths of between 0.0 and 6.0 m bgl with soil pH determination also carried out on these samples. Water soluble sulphate contents ranged between < 0.01 and 0.4 g/l. In accordance with BRE guidelines the characteristic value is calculated by determining the mean of the highest 20 % of results. In this case the characteristic value is 0.21 g/l. On this basis the Design Sulphate Class is DS-1.
- 6.4.3 The pH values in the soil samples varied between 6.7 and 11.2. The mean of the lowest 20 % of values is 7.1 which represents the characteristic value. Mobile groundwater conditions have been assumed and on this basis the Aggressive Chemical Environment for Concrete (ACEC) class for the site is AC-1.

6.5 ROADS AND PAVED AREAS

- 6.5.1 *In situ* Plate Load tests were performed in ten locations in order to determine California Bearing Ratio (CBR) values. The tests were carried out within shallow test pits excavated within predominantly granular made ground to depths of between 0.4 and 0.8 m bgl. The tests revealed CBR values ranging from 9.3 to 22.5 %.
- 6.5.2 Based on the test results obtained to date, it is recommended that a California Bearing Ratio (CBR) value of 9 % is adopted for the shallow made ground.

6.6 SOAKAWAYS

- 6.6.1 A total of fourteen soakage tests were carried out in nine trial pits. Soakage data is included in Appendix 8 and the data sheets show that the water level fell by a maximum of 1150 mm over a period of 30 minutes in MSP03 (Test 3), whilst in MSP09 the water level fell by only 60 mm over approximately 2 hours.
- 6.6.2 The BRE methodology for calculation of soil infiltration rate requires measurement of the volume out flowing from between 75 % and 25 % of the effective depth of the trial pit (height of water in the pit), i.e. three-quarters of the water should soak away. If, due to low levels of infiltration the water level does not fall from between 75 % and 25 % of the total water height, it may be possible to extrapolate from a curve derived from the plots of actual depth to water against time elapsed. A summary of calculated infiltration rates is provided in the table below.

Table 10: Summary of Infiltration Rates

Soakage Test Location	Test Depth (m bgl)	Ground Conditions	Infiltration Rate (m/s)
MSP01 – Test 1	2.30	Sandy / gravelly CLAY	2.4×10^{-5}
MSP01 – Test 2	2.30	As above	9.7×10^{-6}
MSP01 – Test 3	2.10	As above	2.0×10^{-5}
MSP02	2.30	Very sandy gravelly CLAY	10^{-7}
MSP03 – Test 1	2.10	Granular made ground over very sandy gravelly CLAY	1.0×10^{-4}
MSP03 – Test 2	2.10	As above	1.7×10^{-4}
MSP03 – Test 3	2.10	As above	1.4×10^{-4}
MSP04 – Test 1	2.30	Made ground over very sandy gravelly CLAY	$10^{-7} - 10^{-8}$
MSP04 – Test 2	2.30	As above	$10^{-7} - 10^{-8}$
MSP05	2.60	Made ground over sandy slightly gravelly CLAY	10^{-7}
MSP06	2.00	Made ground over clayey GRAVEL over sandy CLAY	$10^{-7} - 10^{-8}$
MSP07	1.60	Made ground over sandy CLAY	$10^{-7} - 10^{-8}$
MSP08	2.60	Made ground over silty CLAY	$10^{-7} - 10^{-8}$
MSP09	2.60	Made ground over sandy / gravelly CLAY	$10^{-7} - 10^{-8}$

- 6.6.3 The test results obtained to date indicate that the shallow predominantly cohesive natural soils are unsuitable for the use of soakaways. However, despite the cohesive nature of the soils, more favourable infiltration rates were recorded in two locations (MSP01 and MSP03) situated in the southern part of the site. A possible reason for the better infiltration rates in these locations could be the presence of gravel and cobbles observed within the clay, which may have allowed the water to drain away.

SECTION 7 ENVIRONMENTAL ASSESSMENT

7.1 SOIL QUALITY

- 7.1.1 A total of 16 soil samples (excluding samples taken from stockpiles) were taken and submitted for chemical laboratory analysis, including six samples from natural ground and 10 samples from made ground. The laboratory chemical analysis certificates are contained in Appendix 4. The results of the analysis are summarised in Table 8.
- 7.1.2 An initial screening exercise has been undertaken whereby contaminant concentrations recorded in soils have been assessed against *Suitable for Use Levels* (S4ULs) published in 2015 by LQM/CIEH¹. These precautionary screening levels are designed to be representative of minimal risk to human health in a number of land use scenarios. In this report S4ULs have been selected for a residential land use where the possibility of consumption of homegrown produce exists and assuming a soil organic matter of 1 %. For lead the DEFRA Category 4 Screening Level² has been used as this is based on updated toxicological data and a low risk to human health.
- 7.1.3 An additional set of phytotoxin screening levels have been adopted from 'The Code of Agricultural Practice for the Protection of Soil' Ministry of Agriculture, Fisheries and Food (MAFF), 1993, which are protective of healthy plant growth.

Table 8: Summary of Soils Chemical Analysis Results

CONTAMINANT	UNITS	MAX	MEAN	No of Tests	SCREENING LEVEL (SL)	No > SL*
HUMAN HEALTH RISK ASSESSMENT						
Asbestos in soil	-	0.001	0.001	16	Detected	4
pH	-	11.2	9.2	16	5 – 9	5
Arsenic	mg.kg ⁻¹	43.0	18.6	16	37	1
Cadmium	mg.kg ⁻¹	0.8	0.3	16	11	0
Chromium (total)	mg.kg ⁻¹	22.0	14.7	16	910	0
Hexavalent Chromium	mg.kg ⁻¹	0.5	0.5	16	6	0
Lead	mg.kg ⁻¹	710.0	135.3	16	200	5
Mercury	mg.kg ⁻¹	0.7	0.2	16	40	0
Nickel	mg.kg ⁻¹	72.0	26.1	16	130	0
Selenium	mg.kg ⁻¹	1.4	0.4	16	250	0
TPH Aliphatic >EC ₅ - EC ₆	mg.kg ⁻¹	<1.000	<1.000	16	160	0
TPH Aliphatic >EC ₆ - EC ₈	mg.kg ⁻¹	<1.000	<1.000	16	530	0

¹ Nathanail, C. P., McCaffrey, C., Gillett, A. G., Ogden, R. C. and Nathanail, J. F. 2015. *The LQM/CIEH S4ULs for Human Health Risk Assessment*. Land Quality Press, Nottingham. Copyright Land Quality Management Limited reproduced with permission; Publication Number S4UL3100. All rights reserved. Including August 2015 nickel update.

² SP1010 *Development of Category 4 Screening Levels Main Report* (Dec 2013) and *SP1010 Policy Companion Document* (Mar 2014).

CONTAMINANT	UNITS	MAX	MEAN	No of Tests	SCREENING LEVEL (SL)	No > SL*
HUMAN HEALTH RISK ASSESSMENT						
TPH Aliphatic >EC ₈ - EC ₁₀	mg.kg ⁻¹	<1.000	<1.000	16	150	0
TPH Aliphatic >EC ₁₀ - EC ₁₂	mg.kg ⁻¹	<1.000	<1.000	16	760	0
TPH Aliphatic >EC ₁₂ - EC ₁₆	mg.kg ⁻¹	29.00	2.75	16	4300	0
TPH Aliphatic >EC ₁₆ - EC ₂₁	mg.kg ⁻¹	34.00	3.57	16	110000	0
TPH Aliphatic >EC ₂₁ - EC ₃₅	mg.kg ⁻¹	37.00	4.31	16	110000	0
TPH Aromatic >EC ₅ - EC ₇	mg.kg ⁻¹	<1.000	<1.000	16	300	0
TPH Aromatic >EC ₇ - EC ₈	mg.kg ⁻¹	<1.000	<1.000	16	660	0
TPH Aromatic >EC ₈ - EC ₁₀	mg.kg ⁻¹	<1.000	<1.000	16	190	0
TPH Aromatic >EC ₁₀ - EC ₁₂	mg.kg ⁻¹	<1.000	<1.000	16	380	0
TPH Aromatic >EC ₁₂ - EC ₁₆	mg.kg ⁻¹	35.00	3.13	16	660	0
TPH Aromatic >EC ₁₆ - EC ₂₁	mg.kg ⁻¹	100.00	21.06	16	930	0
TPH Aromatic >EC ₂₁ - EC ₃₅	mg.kg ⁻¹	970.00	149.94	16	1700	0
Benzene	mg.kg ⁻¹	<0.001	<0.001	16	0.37	0
Toluene	mg.kg ⁻¹	<0.001	<0.001	16	660	0
Ethylbenzene	mg.kg ⁻¹	<0.001	<0.001	16	260	0
Xylene	mg.kg ⁻¹	<0.001	<0.001	16	310	0
Naphthalene	mg.kg ⁻¹	6.20	0.72	16	13	0
Acenaphthylene	mg.kg ⁻¹	4.30	0.42	16	920	0
Acenaphthene	mg.kg ⁻¹	4.50	0.71	16	1100	0
Fluorene	mg.kg ⁻¹	5.50	0.88	16	860	0
Phenanthrene	mg.kg ⁻¹	57.00	8.09	16	440	0
Anthracene	mg.kg ⁻¹	17.00	2.60	16	11000	0
Fluoranthene	mg.kg ⁻¹	130.00	20.34	16	890	0
Pyrene	mg.kg ⁻¹	130.00	17.39	16	2000	0
Benzo(a)anthracene	mg.kg ⁻¹	96.00	11.45	16	13	2
Chrysene	mg.kg ⁻¹	93.00	11.94	16	27	2
Benzo(b)fluoranthene	mg.kg ⁻¹	140.00	15.39	16	3.7	7
Benzo(k)fluoranthene	mg.kg ⁻¹	49.00	5.42	16	100	0
Benzo(a)pyrene	mg.kg ⁻¹	92.00	10.02	16	3	5
Indeno(1,2,3-c,d)pyrene	mg.kg ⁻¹	63.00	6.84	16	41	1
Dibenzo(a,h)anthracene	mg.kg ⁻¹	21.00	2.36	16	0.3	7
Benzo(g,h,i)perylene	mg.kg ⁻¹	53.00	5.81	16	350	0
Phenol	mg.kg ⁻¹	0.3	0.3	16	380	0
PHYTOTOXICITY RISK ASSESSMENT						
	Units	Max	Mean	No of Test	Screening Level (SL)	No > SL
Copper	mg.kg ⁻¹	180.0	43.1	16	200	0
Nickel	mg.kg ⁻¹	72.0	26.1	16	110	0
Zinc	mg.kg ⁻¹	190.0	89.8	16	300	0

Notes: * Number of samples exceeding screening level

nd = not detected

7.1.4 Zootoxic Metals (harmful to human health)

7.1.4.1 An elevated levels of arsenic was encountered in one location, within made ground from MBH01 at 0.0 – 0.4 m bgl. Arsenic was reported at 43 mg.kg⁻¹ which is slightly elevated compared to the screening level of 37 mg.kg⁻¹. The remaining 15 samples reported arsenic levels well below the screening level.

7.1.4.2 Five locations returned elevated levels of lead. The screening level for lead is 200 mg.kg⁻¹. Four of these exceedances were made ground samples with three samples being reported between 220 – 250 mg.kg⁻¹. One location, MWS02 at 0.0-0.9 m bgl, was reported as 710 mg.kg⁻¹, which is significantly elevated compared to the screening level. One exceedance was from natural ground, MWS02 at 1.4 – 1.6 m bgl, which was reported as 260 mg.kg⁻¹.

7.1.5 Phytotoxic Metals (harmful to plant health)

7.1.5.1 No exceedances were noted for heavy metals which pose a risk to plants.

7.1.6 Organic Contaminants

7.1.6.1 There were multiple exceedances of Polyaromatic Hydrocarbon (PAH) compounds reported:

- i. Two locations within made ground reported elevated Benzo(a)anthracene and Chrysene. These locations were MWS02 at 0.0-0.9 m bgl and MSP01 at 0.4 m bgl. Compared to the screening levels of Benzo(a)anthracene (13 mg.kg⁻¹) exceedances were 54 mg.kg⁻¹ and 63 mg.kg⁻¹ respectively.
- ii. Seven locations reported elevated concentrations of Benzo(b)fluoranthene, with six within the made ground and one in natural clay. The screening level of Benzo(b)fluoranthene was 3.7 mg.kg⁻¹. Of the made ground samples, four were reported as 13 mg.kg⁻¹ or less. Two samples, MWS02 at 0.0-0.9 m bgl and MSP01 at 0.4 m bgl, reported exceedances of 65 mg.kg⁻¹ and 140 mg.kg⁻¹ respectively. The natural clay sample was located at MWS02 at 1.4-1.6 m bgl, reported 9.1 mg.kg⁻¹.
- iii. Five locations reported elevated levels of Benzo(a)pyrene with four within the made ground and one in the natural clay. The screening level of Benzo(a)pyrene is 3 mg.kg⁻¹. Of the made ground samples, two were between 7.5-7.6 mg.kg⁻¹. Two locations, MWS02 at 0.0-0.9 m bgl and MSP01 at 0.4 m bgl, reported exceedances of 42 mg.kg⁻¹ and 92 mg.kg⁻¹ respectively. The natural clay sample was located at MWS02 at 1.4-1.6 m bgl, reported 5.5 mg.kg⁻¹.
- iv. One location reported an elevated level of Indeno(1,2,3-c,d)pyrene. MSP01 at 0.4 m bgl had an exceedance of 63 mg.kg⁻¹ compared to the screening level of 41 mg.kg⁻¹.

- v. Seven locations reported elevated levels of Dibenzo(a,h)anthracene with six within the made ground and one in the natural clay. The screening level of Dibenzo(a,h)anthracene was 0.3 mg.kg⁻¹. Of the made ground samples, two were 0.77 mg.kg⁻¹ or lower and an additional two were between 0.77 mg.kg⁻¹ to 2.1 mg.kg⁻¹. Two locations, MWS02 at 0.0-0.9 m bgl and MSP01 at 0.4 m bgl, reported exceedances of 9.9 mg.kg⁻¹ and 21 mg.kg⁻¹ respectively.

7.1.7 Inorganic Contaminants

- 7.1.7.1 Five locations reported moderately to highly alkaline pH, two within the made ground and three within the natural strata. Made ground samples were located at MWS02 at 0.0-0.9 m bgl and MWS05 at 0.4 m and had exceedances of 11.2 and 10.4 respectively. Both samples were taken from the black-grey clayey gravel containing fragments of brick and concrete. The three natural strata samples were taken from MWS02 at 1.4-1.6 m bgl, MWS03 at 0.6-0.9 m bgl and MWS05 at 1.6 m and were all within the pH range of 10.3 to 10.7. All made ground samples were taken from brown clay or gravelly clay to clayey gravel containing gravels of mudstone and sandstone.

- 7.1.7.2 Asbestos was identified in four samples. The maximum concentration at 0.001% w/w was as free fibres/clumps of Chrysotile. All asbestos was identified within the made ground.

- i. MBH03 at 0.0-0.1 m bgl.
- ii. MWS02 at 0.0-0.9 m bgl.
- iii. MWS05 at 0.4 m bgl.
- iv. MTP12 at 0.6-0.8 m bgl.

- 7.1.7.3 Bulk materials analysis of 11 samples collected from the 2019 walkover found chrysotile asbestos in two samples: a black floor tile and bitumen material attached to concrete slab. From the current investigation a bulk fragments of asbestos cement were identified along with a green asbestos floor tile.

7.1.8 Summary

- 7.1.8.1 The majority of exceedances within the made ground were identified within samples MWS02 at 0.0-0.9 m bgl, and MSP01 at 0.4 m. These two samples showed exceedances of multiple PAH compounds, Benzene and elevated pH. Additional exceedances were noted of PAHs were reported in four samples. All of these samples were within 0.0 to 0.4 m of the surface and were taken from a similar layer of brown clayey gravel made ground containing brick, concrete, roadstone and tile.
- 7.1.8.2 The lead exceedances are notable, as out of five locations that exceeded the screening level of 200 mg.kg⁻¹, four were 260 mg.kg⁻¹ or less. However, MWS02 at

0.0-0.9 m bgl had an exceedance of 710 mg.kg⁻¹, which is significantly above the screening level.

- 7.1.8.3 The noted exceedances of PAH compounds are often linked to incomplete combustion of hydrocarbons or by-products of coal processing. The blackish-grey-brown made ground fill present onsite was often ashy and given the site's location on a coal measure and within heavily mined Welsh hills it is likely that some coal ash has been incorporated into the made ground.
- 7.1.8.4 The exceedances noted in the natural ground are limited to three exceedances due to elevated pH and one sample, MWS02 at 1.4-1.6 m bgl. The elevated pH corresponds to natural clay containing gravel of sandstone and mudstone, which may be slightly calcic causing the more alkaline pH reading.
- 7.1.8.5 Sample MWS02 at 1.4-1.6 m bgl, reported slightly elevated levels compared to the corresponding screening level of lead, Benzo(b)fluoranthene, Benzo(a)pyrene and Dibenzo(a,h)anthracene. Overlying this natural clay is black-grey made ground which also showed exceedances of the same contaminants, plus additional compounds. It is therefore possible that the contamination noted in this sample has migrated from the above made ground. The lack of similar contamination in other natural ground samples suggests a limited migration potential for contaminants to be present within the clay.
- 7.1.8.6 All asbestos detects within the laboratory results can be classified as low level. However, the visible fragments found on the surface are notable and can be assumed to be present across the site.

7.2 GROUNDWATER

- 7.2.1 Groundwater level monitoring was undertaken on six occasions with sampling undertaken on two occasions. Resting waters levels were recorded at 1.05 – 3.58 m bgl on the lower level of site and 3.06 – 4.90 m bgl on the higher ground. The groundwater appears to include discontinuous bodies perched within the made ground, within lower portion of the superficial deposits of clays and sands and natural sandstone strata beneath.
- 7.2.2 Chemical analysis of six groundwater samples collected from boreholes MBH01-MBH03, MWS02, MWS03 and MWS06 has been undertaken for comparison against screening levels sourced primarily to be protective of groundwater resources.
- 7.2.3 Metals, metalloids, polyaromatic hydrocarbons.
 - i. UK Technical Advisory Group on the Water Framework Directive, 2016. (UKTAG) *Technical Report on groundwater Hazardous Substances*. Table 1. Hazardous substances Concentrations in groundwater below which the danger of deterioration in the quality of the receiving groundwater is avoided (an annual mean µg/l). These are derived from 75% of the WFD threshold,

where that threshold is used for the protection of groundwater as a long-term drinking water resource.

ii. The Water Supply (Water Quality) Regulations 2016 (UKDWS)

7.2.4 Petroleum Hydrocarbons (TPH CWG Fractions)

- i. CL:AIRE, 2017. *Petroleum Hydrocarbons in Groundwater: Guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies*. Tables 5.3 & 5.4.

7.2.5 The laboratory chemical analysis certificate is contained in Appendix 6 and groundwater level data is contained in Appendix 5. A summary of groundwater contaminant concentrations is contained in Table 9.

Table 9: Summary of Groundwater Chemical Analysis Results

CONTAMINANT	UNITS	MAX	MEAN	UKTAG	UKDWS	CL:AIRE	No > SL
MTBE	µg.l ⁻¹	<1	<1	-	-	15	0
TPH Aliphatic >EC ₅ - EC ₆	µg.l ⁻¹	<1	<1	-	-	15000	0
TPH Aliphatic >EC ₆ - EC ₈	µg.l ⁻¹	<1	<1	-	-	15000	0
TPH Aliphatic >EC ₈ - EC ₁₀	µg.l ⁻¹	<1	<1	-	-	300	0
TPH Aliphatic >EC ₁₀ - EC ₁₂	µg.l ⁻¹	<10	<10	-	-	300	0
TPH Aliphatic >EC ₁₂ - EC ₁₆	µg.l ⁻¹	<10	<10	-	-	300	0
TPH Aliphatic >EC ₁₆ - EC ₂₁	µg.l ⁻¹	<10	<10	-	-	300	0
TPH Aliphatic >EC ₂₁ - EC ₃₅	µg.l ⁻¹	<10	<10	-	-	300	0
TPH Aromatic >EC ₅ - EC ₇	µg.l ⁻¹	<1	<1	-	-	10 [†]	0
TPH Aromatic >EC ₇ - EC ₈	µg.l ⁻¹	<1	<1	-	-	700 [†]	0
TPH Aromatic >EC ₈ - EC ₁₀	µg.l ⁻¹	<1	<1	-	-	300 [†]	0
TPH Aromatic >EC ₁₀ - EC ₁₂	µg.l ⁻¹	<10	<10	-	-	90	0
TPH Aromatic >EC ₁₂ - EC ₁₆	µg.l ⁻¹	<10	<10	-	-	90	0
TPH Aromatic >EC ₁₆ - EC ₂₁	µg.l ⁻¹	85	22.5	-	-	90	0
TPH Aromatic >EC ₂₁ - EC ₃₅	µg.l ⁻¹	1000	175	-	-	90	1
Benzene	µg.l ⁻¹	<1	<1	0.5*	1	10	1*
Toluene	µg.l ⁻¹	<1	<1	350	-	700	0
Ethylbenzene	µg.l ⁻¹	<1	<1	-	-	300	0
Xylenes	µg.l ⁻¹	<1	<1	-	-	500	0
Anthracene	µg.l ⁻¹	2.89	0.49	0.05	-	-	1
Benzo(a)pyrene	µg.l ⁻¹	12.9	2.16	0.005	0.01	0.01	1
Benzo(b)fluoranthene	µg.l ⁻¹	18.6	3.11	0.05	0.1	-	1
Benzo(k)fluoranthene	µg.l ⁻¹	7.17	1.20	0.05	0.1	-	1
Benzo(ghi)perylene	µg.l ⁻¹	8.06	1.35	0.05	0.1	-	1
Arsenic	µg.l ⁻¹	3.94	1.15	5	10	-	0
Cadmium	µg.l ⁻¹	0.17	0.06	-	5	-	0
Chromium (dissolved)	µg.l ⁻¹	2.5	1.88	-	50	-	0

CONTAMINANT	UNITS	MAX	MEAN	UKTAG	UKDWS	CL:AIRE	No > SL
Copper	µg.l ⁻¹	2.9	1.48	-	2000	-	0
Lead	µg.l ⁻¹	2.3	0.6	5	10	-	0
Mercury and its compounds	µg.l ⁻¹	<0.05	<0.05	0.5	1	-	0
Nickel	µg.l ⁻¹	6.1	3.0	-	20	-	0
Cyanide	µg.l ⁻¹	<10	<10	-	50	-	0
Sulphate	µg.l ⁻¹	219000			250000		

† Screening levels for these aromatic fractions use those for benzene, toluene and ethylbenzene as marker substances. * Limit of detection does not resolve down to the screening level.

- 7.2.6 Generally, metals were detected but all found to be below their respective screening levels. Mercury was undetected in all samples.
- 7.2.7 The inorganic contaminant, cyanide, was undetected.
- 7.2.8 Sulphate concentrations varied between 30300 and 219000 µg.l⁻¹ but were all below the drinking water based screening level
- 7.2.9 The monoaromatics and oxygenates - BTEX and MTBE – were undetected.
- 7.2.10 Petroleum hydrocarbons were detected as above the CL:AIRE screening level for C₁₆-C₂₁ and C₂₁-C₃₅ aromatics in one sample – MWS02. None of the petroleum hydrocarbon fractions were detected in any of the remaining five samples. MWS02 was also found to contain PAH compounds in excess of screening levels. This location was also found to contain relatively elevated PAH in soils.
- 7.3 **HAZARDOUS GAS**
- 7.3.1 Gas monitoring has been undertaken on six occasions from 16th February 2021 to 21st April 2021. Levels of methane, carbon dioxide and oxygen were recorded in each standpipe, together with associated parameters including borehole flow and ambient air pressure. The results of these gas monitoring rounds are contained in Appendix 7.
- 7.3.2 The monitoring rounds were undertaken at barometric pressures ranging from 977 to 1010 mb, with falling pressure measured over the duration of the third monitoring round. Positive flow was recorded as 0.4 to 49.9 l hr⁻¹ as initial peaks which, typically, quickly dissipated. The maximum sustained flow was 3.3 l.hr⁻¹ in MBH2 on the first monitoring visit. Sustained flows were mainly zero or slightly negative and it is considered borehole gas flows are largely influenced by groundwater levels.
- 7.3.3 Over the six monitoring rounds methane (CH₄) was undetected at 0.0 % by volume (% v/v), carbon dioxide (CO₂) was detected to a maximum of 5.1 % v/v and depleted oxygen concentrations (down to a low of 3.2 % v/v) were measured inconsistently in the deeper boreholes. No carbon monoxide was detected.

7.4 WASTE CLASSIFICATION, OFF-SITE DISPOSAL OR RE-USE

7.4.1 Waste Considerations of Stockpiles

7.4.1.1 Nine samples from four stockpiles underwent testing of a broad suite of potential chemical contaminants to inform waste classification. Between one to three sample locations from each stockpile were analysed and solid contaminant levels subject to waste classification in accordance with the technical guidance on waste classification in document WM3. Where more than one location was tested, an average was taken across each contaminant to provide a representative classification for the stockpile. These are based on the chemical contamination levels.

- i. Stockpile 6: Petroleum hydrocarbons in Sample 6C exceeds the hazardous waste threshold for HP7 carcinogenic properties. The average petroleum hydrocarbon content of the three samples also exceeds the HP7 hazardous waste threshold. However, the sample which contained the only exceedance of the threshold appears related to stained and malodorous material, segregation of which could be considered.
- ii. Stockpile 7: Non-hazardous
- iii. Stockpile 9: Non-hazardous
- iv. Stockpile 10: Hazardous. One sample analysed which contained pH of 12.1 which may render the material hazardous due to corrosive properties. However, based on the overall pH levels of similar materials, this maximum may be an unusual value.

7.4.1.2 *Visible* asbestos containing materials are considered hazardous and where present within the stockpile may render the whole pile as mixed waste and potentially hazardous.

7.4.1.3 Due to the asbestos fibre content and mixed debris components, it is unlikely that the piles would be considered as suitable for disposal at facilities licensed to accept only inert wastes.

7.4.2 General soil arisings

7.4.2.1 Generally, in situ soil chemical contamination levels are indicative of non-hazardous materials, if arisings are disposed of as waste. It is unlikely that the made ground would be considered as suitable for disposal at facilities licensed to accept only inert wastes.

7.4.2.2 Materials, including waste soils which are not to be retained on site, should be removed and disposed of in accordance with all relevant statutes including the *Environmental Protection Act 1990* (as amended), *The Controlled Waste Regulations 2012* (as amended), *The Waste (England and Wales) Regulations 2011*

(as amended) , *The Hazardous Waste (England and Wales), Regulations 2005* as amended, *The Waste Management (England and Wales) Regulations 2006*, and *The Environmental Permitting (England and Wales) Regulations 2016* (as amended).

7.4.2.3 It is a requirement of these regulations that waste sent to landfill should have been subject to measures to reduce the amount of waste, reduce harmful or hazardous properties and facilitate recycling. These requirements may be satisfied by measures such as segregation and screening of wastes to recover suitable fill and material for crushing, segregation of inert materials and putrescible wastes.

7.4.3 Re-use Considerations

7.4.3.1 As a sustainable alternative to off-site disposal, it may be possible to re-use site-won soils provided the following criteria are met:

- i. Use of the material will not create an unacceptable risk of pollution to the environment or harm to human health;
- ii. The material must be chemically and geotechnically suitable without further treatment;
- iii. There must be certainty of use within the scheme;
- iv. Material should only be used in the quantity necessary for that use.

7.4.3.2 Provided these criteria are met, the re-use of site-won materials is unlikely to be deemed a waste activity. Production of a *Materials Management Plan* under the industry *CL:AIRE Code of Practice on the Definition of Waste* represents a robust method of demonstrating that the proposed re-use of material meets the criteria and is not liable for landfill tax.

7.4.3.3 For stockpiled materials to be safely re-used on site poorly sorted rubble would likely need to be processed to a grade where it would be geotechnically suitable and if hydrocarbon impacted pockets are removed (Stockpile sample 6C). The presence of asbestos materials and potential for their deterioration from crushing and screening activities could result in significant hazard to health and hamper re-use efforts where segregation is difficult, time consuming or expensive. It is recommended a remediation contractor is consulted to advise on practicality of segregating ACMs to allow processing. The very low levels of asbestos fibres indicate that airborne levels could be minimised during processing and placement. However, use of fibre impacted brick and concrete crush is recommended only under sufficient depth of clean cover and with robust safeguards. Placement as running surfaces/haul routes is not recommended due to potential for drying out and dust generation.

SECTION 8 RISK ASSESSMENT

- 8.1 The potential sources of contamination at the site and the implications with respect to development have been interpreted in accordance with the current government guidance on source-pathway-receptor risk assessment.
- 8.2 The investigations demonstrate that the former uses of the site have resulted in made ground containing rubble debris and ashy materials, numerous stockpiles of demolition materials impacted by asbestos and in situ soils sporadically affected by lead contamination, asbestos fibres and PAHs. In addition, scattered fragments of bulk asbestos materials (ACM) are present at and near surface and there is the potential for further ACM in ducts (e.g. as pipe lagging) and within buried structures. Groundwater has also been locally affected by hydrocarbons. These materials are considered for their potential to act as sources for a number of pollutant linkages.
- 8.3 The potential impacts of contamination sources have been considered with respect to the following receptors:
- i. The general public
 - ii. Residents of future development,
 - iii. Groundwater,
 - iv. Surface water,
 - v. Construction workers,
 - vi. Adjacent land, and
 - vii. Infrastructure.
- 8.4 In each case the existence of a pollutant linkage requires a pathway by which the receptor could be exposed to the source. A qualitative assessment of risk is thus considered in the first instance with respect to the site in its current condition and is summarised in the sections below.
- 8.5 The General Public
- 8.5.1 Unauthorised access to the site is possible by members of the public. A risk from hazardous structures and buildings materials, drug paraphernalia is considered to be more immediate. The risk from soil contamination is considered to be low as soil exposure from casual access is likely to be limited.
- 8.6 Residents of Future Development
- 8.6.1 Soil contamination (chemical)
- 8.6.1.1 The development will introduce human receptors who can be exposed to soil contamination via dermal contact, inadvertent ingestion, consumption of home-

grown produce and dust inhalation. The presence of lead and PAH contamination in made ground (and locally impacted natural ground) would indicate a moderate risk to residents from soils in gardens and landscaped areas.

8.6.2 Asbestos

8.6.2.1 The quantities of chrysotile fibres measured in in-situ made ground soils would indicate a low risk from disease resulting from fibre inhalation. However, the potential for deterioration of bulk ACMs present either in or on the soil and attached to underground services and buried building materials, indicate an increased risk could occur over the longer term.

8.6.3 Hazardous Soil Gas/Vapours

8.6.3.1 British Standard BS8485(2015+A1:2019) and NHBC guidance has been followed to assess the recorded soil gas and flow conditions. Calculations are presented in Appendix 7 which indicate that:

- i. for low-rise residential housing with a minimum 150 mm ventilated subfloor void, an NHBC GREEN gas risk regime would apply *i.e.* a negligible gas regime. It is acknowledged that the maximum carbon dioxide concentration (5.1 %) is above the typical value (5 %) for this category, however given the marginal nature of the exceedance and the isolated occurrence, it is not deemed necessary to raise the risk classification on this occasion, particularly given the presence of ventilation.
- ii. For alternative construction types which do not align with the NHBC assumptions (*i.e.* apartments or houses without a ventilated sub-floor void), BS8485 suggests that Characteristic Situation 2 is appropriate *i.e.* low risk but requiring basic gas protection measures.

8.6.3.2 Hydrocarbon contamination within the ground identified to date does not indicate a significant risk from vapour ingress into new dwellings.

8.6.3.3 The site is not in a radon affected area.

8.7 Controlled Waters

8.7.1.1 Low level impact by hydrocarbons has been identified in one groundwater sample. Whilst this occurrence exceeds the screening level by approximately 11 times, the fairly low sensitivity hydrogeological setting and low permeability strata would indicate a risk to wider controlled waters resources is unlikely.

8.8 Construction workers

8.8.1 Potentially, construction workers are initially at the greatest risk from exposure to hazardous contamination due to excavation works and during the handling of materials including imported soils. The main risk to workers are considered to arise from dust inhalation and predominantly asbestos fibres in air.

8.9 Adjacent land

8.9.1 Chemical contamination has not been found at levels likely to migrate from site via leaching or groundwater mobilisation.

8.9.2 Ground gas levels and borehole gas flows do not indicate a significant risk of hazardous gas migration from the site to adjacent land.

8.9.3 A risk from fugitive dusts containing asbestos is considered to exist. The risk is expected to be active during remediation, groundworks and construction phases which could disturb soils containing fibres and disturb or cause deterioration of bulk ACMs. An asbestos management plan should be put in place by the remediation / groundworks contractor prior to commencing the works. The asbestos management plan should set out in line with the Control of Asbestos Regulations (CAR) 2012. Material should be processed using control measures to minimise the risk of fibre release.

8.10 Infrastructure

8.10.1 Phytotoxic contamination which may inhibit healthy plant growth, has not been found at significant concentrations. However, made ground materials which cover the site and subsoils are likely to provide poor growth media.

8.10.2 Contamination with the potential to permeate polymeric services has been identified by this investigation, as hydrocarbons and PAH. It is recommended that the utility provider is consulted with respect to their requirements for water supply pipes.

8.10.3 Utility companies apply strict guideline levels on use of polymeric pipes and may consider all made ground unsuitable for typical plastic pipe materials to be used.

SECTION 9 UPDATED CONCEPTUAL MODEL

9.1 Following completion of phases 1 and 2 of the investigation and a qualitative risk assessment, the conceptual model for the site, with relation to pollutant linkages, has been updated. The revised model is presented in Table 10 below.

Table 10: Revised Conceptual Model

POSSIBLE POLLUTANT LINKAGE			
POTENTIAL SOURCES	PATHWAYS	RECEPTORS	RISK CHARACTERISATION
Heavy metals and hydrocarbons (made ground)	Contact with contaminated soil	Human health (general public)	Low risk identified Site is disused but may be accessed by unauthorised members of public. Exposure potential to soils from such access is anticipated to be low
	Ingestion and inhalation of contaminated soil and dust	Human health (general public)	
Heavy metals and hydrocarbons (made ground)	Contact with contaminated soil	Human health (future residents and construction workers)	Moderate risk identified Risk from metals and PAH contamination via soils handling

POSSIBLE POLLUTANT LINKAGE			RISK CHARACTERISATION
POTENTIAL SOURCES	PATHWAYS	RECEPTORS	
	Ingestion and inhalation of contaminated soil and dust	Human health (future residents and construction workers)	during construction and in gardens and landscaped areas during occupation
Asbestos (made ground)	Ingestion and inhalation of contaminated soil and dust	Human health (future residents and construction workers)	Moderate risk Sporadic ACMs on surface and near surface made ground and impacting stockpiles. Very low levels of dispersed fibres in soil matrices. Potential for deterioration and dust generation
Contamination (all forms)	Vertical migration to aquifer	Controlled waters	Low risk Identified Localised contamination by hydrocarbons in shallow groundwater. Mobility limited by low permeability clay.
Contamination (all forms)	Horizontal migration to surface water	Controlled waters	Low risk Identified Low potential for wider groundwater migration to affect nearest watercourse.
Hydrocarbons	Direct contact	Plastic water pipes	Moderate risk Identified Locally elevated PAH and hydrocarbons in made ground
Hazardous Gas/Vapours in soil	Ingress into buildings and voids	Human health (future residents and construction workers)	Low risk Identified Potential for made ground which could act as source of hazardous gas. Monitoring data indicates slightly elevated CO ₂ but low levels of sustained borehole gas flow. Basic gas protection required for certain structures.
Adjacent Land	Fugitive dusts	Adjacent land users, the public.	Moderate risk Sporadic ACMs on surface and near surface made ground and impacting stockpiles. Very low levels of dispersed fibres in soil matrices. Potential for deterioration and dust generation

SECTION 10 PRELIMINARY REMEDIATION STRATEGY

- 10.1 The identified risks at the site can be mitigated by removal of either the source, pathway or receptor. With reference to the conceptual model for the site a remediation strategy, based on source or pathway removal, has been designed.
- 10.2 It is understood that finished site levels will remain similar to existing and the accommodation of stockpiled materials as fill is unlikely. Due to the presence of asbestos in piles, care will need to be taken to ensure that asbestos impact upon underlying surface soils is addressed.
- 10.3 On the basis that piled materials are to be removed from site, recommendations are provided to address contamination risks from currently in situ ground. It is also pointed out that ground engineering works to remove buried ground obstructions, remnant structures, to excavate, grade and compact loose rubble fill, remove service ducts and any works to slopes, may well result in significant alteration to the soil profile. As a result, following stockpile removal and ground remedial works, a post-

remedial assessment of remnant ground conditions may be appropriate to review ongoing contamination risks.

- 10.4 To protect future residents from soil-borne contamination, clean soil should make up the upper 600 mm of materials within gardens and landscaped areas. This is likely to require removal of contaminated made ground to accommodate clean soils if levels are to remain at or near existing. Therefore, soil removal to 600 mm or to clean natural soil is expected. If site levels can be raised to accommodate clean soil placement, then excavation can be minimised. Where made ground remains at the base of clean cover layers a marker and separator layer should be placed which may include a geotextile membrane and/or clean granular dig barrier. Such measures should be designed to allow drainage and infiltration in gardens.
- 10.5 Material imported for the formation of domestic gardens and landscaped areas should be obtained from a validated source. The validation should incorporate an assessment of the provenance of the material and chemical analysis.
- 10.6 For structures which align with the assumptions in NHBC guidance (i.e. low rise housing with a beam and block floor and ventilated underfloor void), no additional gas protection measures are required. For other structures (i.e. apartments or dwellings without a ventilated sub-floor void) then basic gas protection measures commensurate with Characteristic Situation 2 are required and should achieve 3.5 gas protection points using the BS8485 system. Further guidance on achieving the required points using the BS8485 system is provided in Appendix 7.
- 10.7 Stockpiles and asbestos materials. It is likely that movement (including loading and unloading) of asbestos contaminated stockpiles, removal of buried obstructions containing asbestos (such as lagged pipes in ducts) and works with made ground would be classed as working with asbestos. An asbestos plan of works and management should be produced to set out the working procedures, assess risks and propose monitoring and mitigation measures in accordance with the Control of Asbestos Regulations 2012 and its Approved Code of Practice.
- 10.8 Asbestos containing materials have been identified across the site within the stockpiled materials and unsorted demolition materials. Investigation methods have been undertaken to observe and identify as much contamination as possible. However, the potential for further underground structures and buried materials containing asbestos remains. Should any materials or ground conditions be identified atypical to those identified in this investigation then works should stop and they should be reported to IDOM so that an assessment of appropriate action can be made.
- 10.9 Japanese knotweed. Eradication of stands encroaching on to the site should be undertaken by a suitable specialist. Options include bulk excavation of infested soils and repeated herbicide treatment. The chosen methods typically depend on available treatment timescales, ability to eradicate off-site sources and ongoing liability issues.

- 10.10 *General contamination* - potential risks to construction workers have been identified and the adoption of appropriate Health and Safety procedures will ensure that risks to operatives from hazardous materials at the site are minimised. Operatives should not be allowed to eat, drink or smoke on site except in designated areas and should be required to wash all exposed skin at the end of each shift. Operatives should be informed of the potential hazards at the site and should be required to report any observations of suspect material.
- 10.11 It is recommended that this report is submitted to the regulators (Local Authority EHO and Planners, NRW Planning Liaison and NHBC) for approval prior to commencement of the works.
- 10.12 Any observations of ground conditions atypical of those already described should be reported to IDOM immediately so that an assessment of appropriate action can be made.

APPENDIX 1 ▪ Drawings

Legend



Merebrook borehole with location reference



Merebrook window sample with location reference



Merebrook trial pit location with reference



Merebrook soakage test location with reference



Merebrook CBR test location with reference



Merebrook stockpile audit location with reference



First issue

19/02/2021

Issue Details

TPC

Client/Project

LB

Drawn

Chd

Approved

TPC

Coronado
Former St Tydfil Hospital
Merthyr Tydfil

Dwg Title

Approximate Undertaken
Investigation Locations

Job No.

21988

Dwg No.

304-001

Revision

-

Scale

N.T.S

Date

February 2021

Frame Dimensions mm

(A3) 400 x 280

Drawn

TPC

Checked

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Approved

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APPENDIX 2 ▪ Photographic record of exploratory holes



Plate 1: Overview of Stockpile 1 in the north of site.



Plate 2: Stockpile 1A of black-grey made ground containing fine gravel to boulder-sized fragments of concrete, brick, wood, pipes, and linoleum.