

CLIENT:	Your Housing Group (YHG)
PROJECT:	Ten Acres
SUBJECT:	Deeper Ground Conditions and Laboratory Testing Clarifications
JOB NO:	LD10587
DATE:	14 th April 2023
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1. INTRODUCTION

This Technical Note (TN) has been prepared to summarise and discuss the deeper ground conditions and laboratory testing that has been undertaken as part of the several phases of extensive site investigation (SI) works that have been undertaken at the Ten Acres Lane site.

The requirement for this TN follows a meeting held on the 27th March 2023 between the Environment Agency (EA) and representatives of YHG. During this meeting, the EA raised concerns that further detail was required about the Made Ground which extended below c. 3m below ground level (bgl).

This TN summarises the pertinent information that is recorded within the *WA Phase I and Phase II Ground Investigation Report dated October 2022* (the “WA GI report”), but with a particular focus on the deeper Made Ground. Reference should be made to the WA GI report for specific details when reviewing this TN.

2. BACKGROUND AND CONTEXT

The characterisation of the site and the Made Ground materials is robust and has been developed from several phases of extensive SI works that have been undertaken at the site between 2007 and 2022; the most recent of which had the scope agreed with the EA prior to commencement, as per the letter from the EA dated 16th February 2022 (EA ref: SO/2020/120757/05-L01). To date c. 350 No exploratory holes have been undertaken at the site.

Made Ground has been encountered across the entire site and was proven to a maximum depth of 13.85m bgl within the central south western section of the site, which corresponds with the deepest areas of excavation as indicated by Ordnance Survey (OS) historical mapping. 72 No. exploratory holes have proven the full thickness of the Made Ground at depths >3m bgl, 31 No. exploratory holes have proven the full thickness of the Made Ground at depths >5m bgl, 12 No. exploratory holes have proven the full thickness of the Made

Ground at depths >8m bgl and 5 No. boreholes have proven the full thickness of the Made Ground at depths >11m bgl.

Across c. 45% of the site area, Made Ground has been proven to be <3m in thickness, meaning that only c. 55% of the site area is underlain by Made Ground extending to depths >3m (as shown by Figure 1). Additionally only c. 35% of the site area is underlain by Made Ground extending to depths >5m (as shown by Figure 2), only c. 14% of the site area is underlain by Made Ground which extends to depths >8m (as shown by Figure 3) and that only c. 4% of the site area has Made Ground that extends to depths >11m (as shown by Figure 4).



Figure 1: Extract of Made Ground Thickness Contour showing areas where Made Ground exceeds c. 3m in thickness. This equates to c. 55% of the site area. Black dashed lines show the recorded extent of the former clay pit excavations.



Figure 2: Extract of Made Ground Thickness Contour showing areas where Made Ground exceeds c. 5m in thickness. This equates to c. 35% of the site area. Black dashed lines show the recorded extent of the former clay pit excavations.

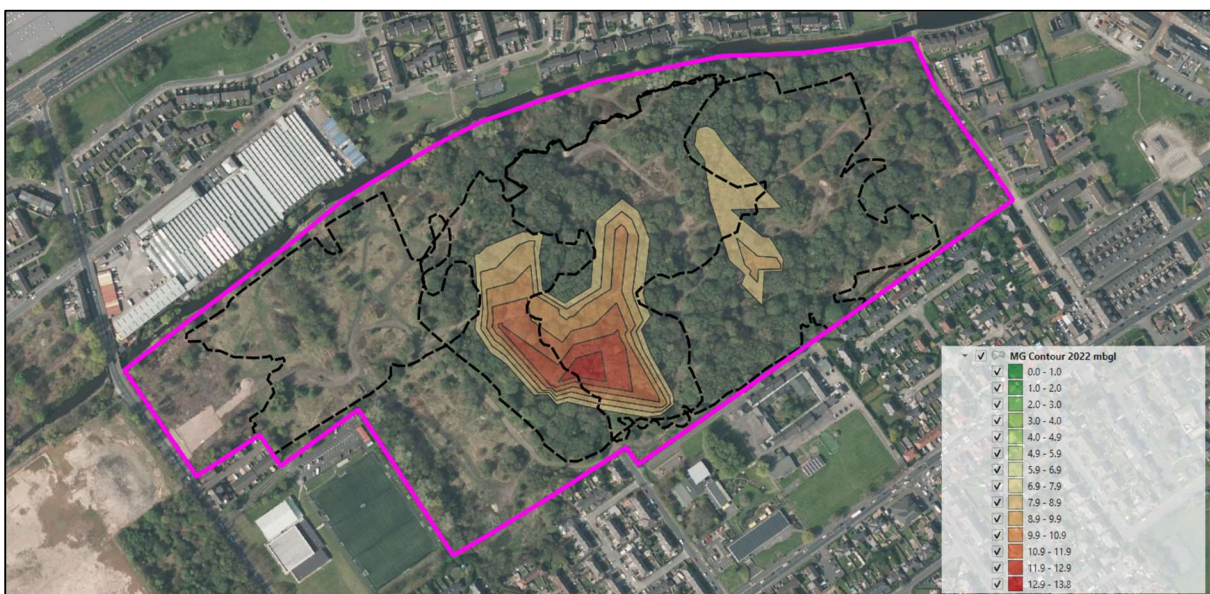


Figure 3: Extract of Made Ground Thickness Contour showing areas where Made Ground exceeds c. 8m in thickness. This equates to c. 14% of the site area. Black dashed lines show the recorded extent of the former clay pit excavations.

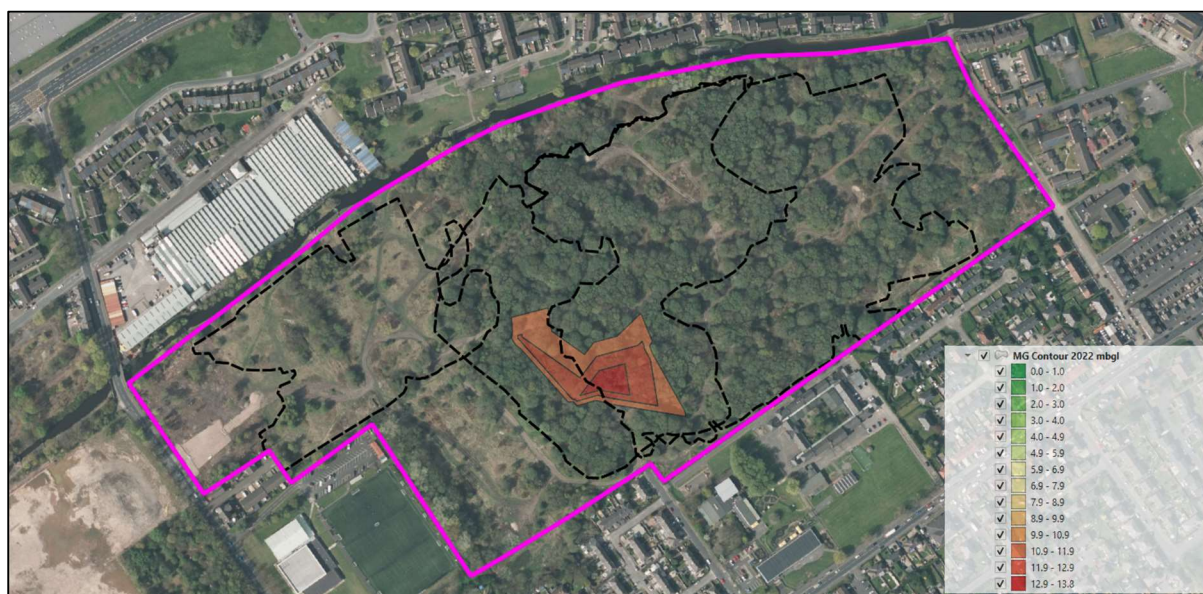


Figure 4: Extract of Made Ground Thickness Contour showing areas where Made Ground exceeds c. 11m in thickness. This equates to c. 4% of the site area. Black dashed lines show the recorded extent of the former clay pit excavations.

Preliminary volume calculations for the Made Ground have also been undertaken and are summarised in Table 1 below.

Table 1: Estimated Made Ground Volumes per Depth Range	
Made Ground Depth Range	Estimated Volumes
c. GL – 3.00m	c. 440,000m ³
c. 3.00 – 5.00m	c. 185,000m ³
c. 5.00 – 8.00m	c. 150,000m ³
c. 8.00 – 11.00	c. 55,000m ³
c. 11.00 – 13.85	c. 10,000m ³
Notes: GL = Ground Level Volumes estimates are preliminary and have been calculated using LSS v10.01.22 based on the LIDAR derived topographical profile and interpolated Made Ground Contour derived from site investigation data in QGIS.	

During the various phases of site investigation, c. 150 shallow perched groundwater strikes were encountered within Made Ground during the drilling / excavation of exploratory holes. This perched groundwater was typically encountered at depths of between 1.8m and 3.3m bgl (on average 2.4m bgl). Monitored perched / shallow groundwater from c. 40 monitoring wells with response zones within Made Ground was typically encountered at depths of between 1.2m and 2.8m bgl (on average 1.6m bgl).

3. SUMMARY OF LABORATORY TESTING

Soil and groundwater samples were mainly analysed for a comprehensive suite of potential determinands, and this included metals, polycyclic aromatic hydrocarbons (PAH), total petroleum hydrocarbons (TPH), cyanide, asbestos, general inorganics, polychlorinated biphenyls (PCB), methyl tertiary butyl ether (MTBE), benzene, toluene, ethylbenzene and xylene (BTEX), phenols, semi volatile and volatile organic compounds (SVOC and VOC) and perfluoroalkyl and polyfluoroalkyl substances (PFAS). Further details regarding overarching quantities are provided in Tables 10.1 to 10.4 in the WA GI report.

A summary of the laboratory testing undertaken from soils and perched groundwaters within the Made Ground across various depths is provided in Table 2 on the following page.

Table 2: Summary of Testing Quantities Over Depth Ranges				
Depth Range / Response Zone for Waters	Percentage of Site Area Occupied by Made Ground	WA Tests	Celtic Tests	TOTAL
Soils				
GL – 3.00m	<3m = 100%	116 (16)	99 (16)	215 (32)
3.00 – 5.00m	>3m – <5m = 56%	34 (4)	10 (8)	44 (12)
5.00 – 8.00m	>5m – <8m = 35%	4 (4)	4 (2)	8 (6)
8.00 – 11.00m	>8m – <11m = 14%	3 (3)	1 (3)	4 (6)
Perched Groundwaters				
<5m	-	12	0	12
>5m – <8m	-	4	2	6
>8m – <13.5m	-	4	2	6
Leachate				
GL – 1.50m	-	3	3	6
1.50 – 3.00m	-	3	4	7
3.00 – 5.00m	-	4	3	7
Notes:				
GL = Ground Level				
Numbers in brackets are additional samples undertaken from natural Glacial Till that was immediately beneath and / or at the interface of any Made Ground.				

The spatial distribution of the soils, shallow perched groundwater and leachate laboratory testing undertaken within the Made Ground is visually summarised in Figures 5-7 below and shows that testing has been undertaken within those areas where deeper Made Ground is indicated to be present. These figures do not include for all of the exploratory hole positions

(c. 350 positions) but c. 85% of all locations have had testing undertaken within the Made Ground.

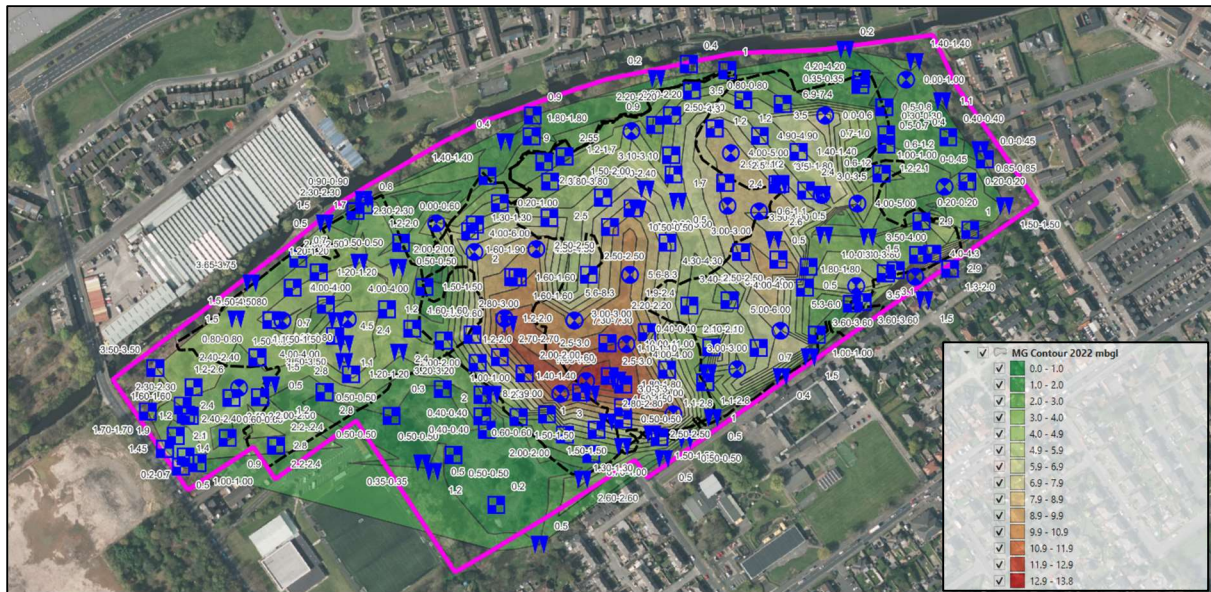


Figure 5: Spatial distribution of soil testing within Made Ground (depth labels and Made Ground thickness contours are also illustrated). Black dashed lines show the recorded extent of the former clay pit excavations.

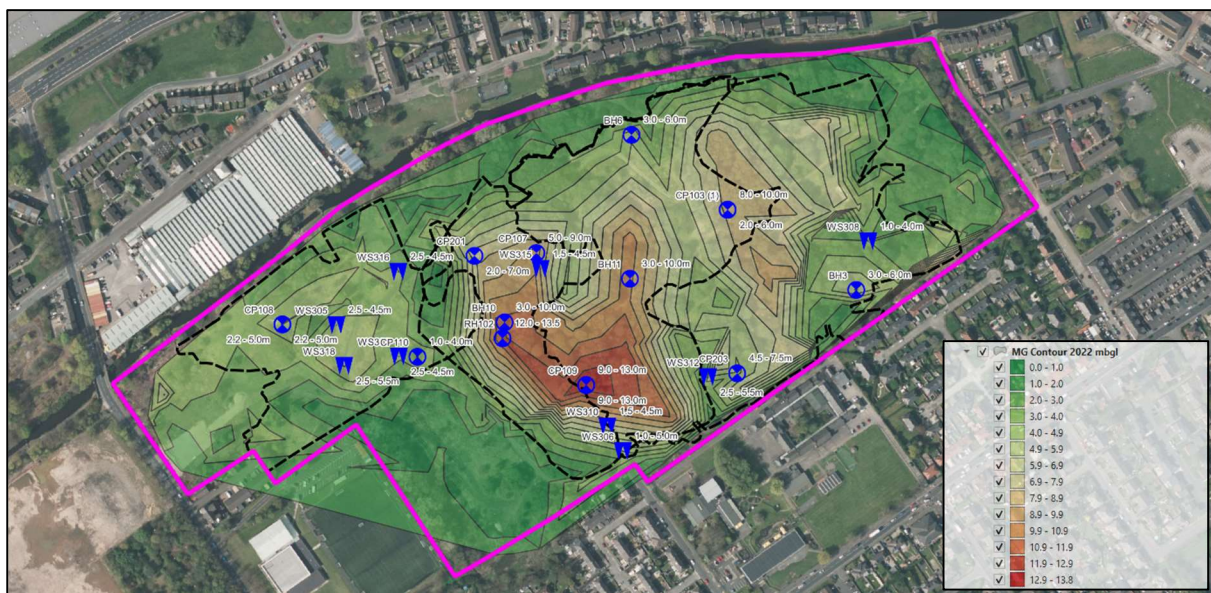


Figure 6: Spatial distribution of perched groundwaters testing within Made Ground (response zone labels and Made Ground thickness contours are also illustrated). Black dashed lines show the recorded extent of the former clay pit excavations.

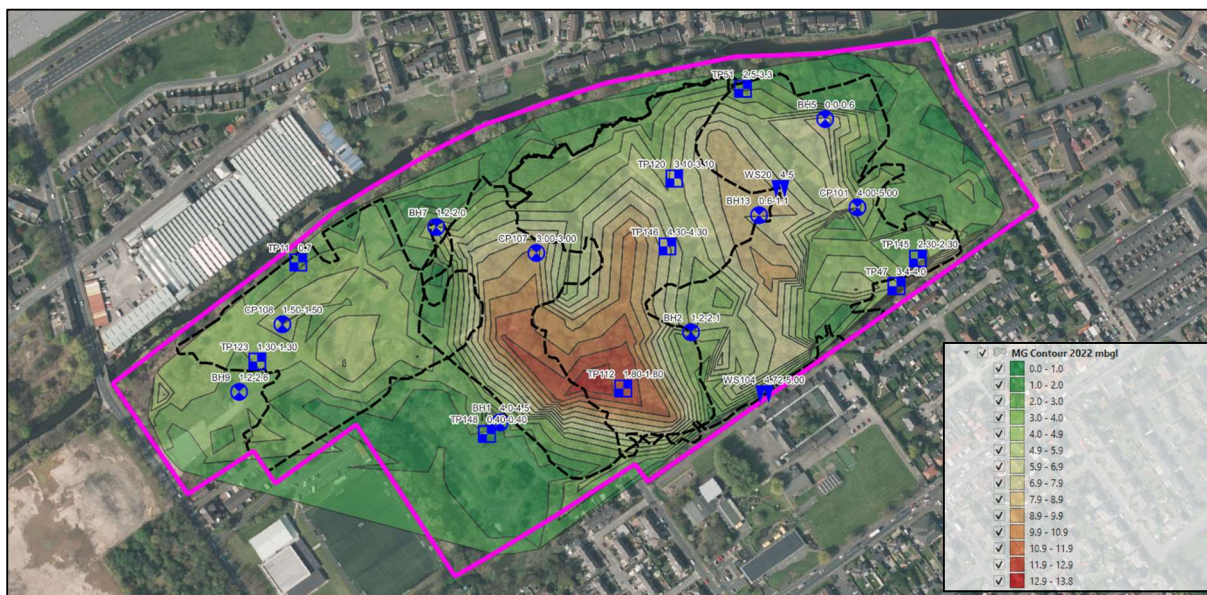


Figure 7: Spatial distribution of leachate testing within Made Ground (response zone labels and Made Ground thickness contours are also illustrated). Black dashed lines show the recorded extent of the former clay pit excavations.

To summarise, it has been demonstrated that testing has been undertaken for the deeper Made Ground materials (albeit of a reduced scope), but the deeper Made Ground materials are not present across the entire site and only accounts for a fraction of the total estimated volume of Made Ground as shown in Table 1 and only occupy a fraction of the total site areas as shown in Figures 1-4.

4. SUMMARY OF DEEPER GROUND CONDITIONS

For the deeper Made Ground, the WA GI report has concluded that these pose a very low risk to human health as they are unlikely to come into contact with these materials post development. Assessments have already been undertaken that quantify the risks posed by ground gas / vapours and further details are included within the WA GI report.

As such, any remaining deeper Made Ground is deemed to only potentially pose a risk to controlled waters receptors. The source-pathway-receptor (SPR) linkages have been discussed in the WA GI report, with further clarity and additional information being provided within a separate TN that has already been issued. However, it is still critical to further characterise the source in order to ultimately determine the importance of any further SPR linkages.

4.1 Physical Descriptions of Made Ground

Made Ground was encountered across the entire site and was proven to a maximum depth of 13.85m bgl within the central south western section of the site. Depth ranges, thicknesses, and percentages of the overall Made Ground types have been summarised in Table 3 below.

Table 3: Depth Ranges and Percentages of Various Made Ground Types				
Depth Range	Depth Range from Top m bgl	Depth Range to Base m bgl	Thickness Range m	Percentage of Total Thickness of Made Ground
General Granular Made Ground	GL – 9.00 (0.00 – 1.80)	0.10 – 12.70 (0.80 – 3.73)	0.10 – 12.70 (0.40 – 1.86)	26%
General Cohesive Made Ground	GL – 8.90 (0.20 – 2.15)	0.30 – 10.40 (1.20 – 4.00)	0.05 – 10.40 (0.40 – 2.10)	22%
Suspected Combustion Materials	GL – 6.00 (0.15 – 1.00)	0.40 – 8.00 (1.00 – 3.80)	0.10 – 4.80 (0.50 – 2.10)	17%
Suspected Construction and Demolition Materials	GL – 9.00 (0.20 – 1.63)	0.35 – 13.85 (1.20 – 4.05)	0.10 – 5.30 (0.60 – 2.55)	16%
Suspected Colliery Spoil	0.15 – 2.70 (0.40 – 1.09)	0.60 – 6.80 (2.28 – 5.70)	0.20 – 6.20 (1.71 – 4.88)	8%
Suspected Household Waste	GL – 8.00 (0.20 – 1.75)	0.20 – 9.00 (1.50 – 3.70)	0.10 – 3.80 (0.63 – 1.88)	6%
Topsoil Fill	GL – 3.50 (0.00 – 0.00)	0.05 – 4.20 (0.10 – 0.26)	0.05 – 1.10 (0.10 – 0.25)	4%
Reworked Natural Ground	0.40 – 3.10 (0.60 – 1.83)	0.80 – 4.30 (1.50 – 3.00)	0.20 – 2.55 (0.25 – 1.40)	1%
Notes: Interquartile range shown in brackets. Averages and percentage results rounded to two significant figures. Percentages have been calculated from the sum of the thicknesses for specific Made Ground types compared to the sum of the overall thickness of Made Ground.				

The Made Ground that was recovered from depths >8m bgl only accounted for c. 5% of the overall thickness of the Made Ground and comprised abundant *Granular Made Ground*, frequent *Cohesive Made Ground*, occasional *Suspected Construction and Demolition Materials* and rare *Suspected Household Waste*. This fits with the general trends noted above that demonstrate that only c. 8% of the total estimated volume of Made Ground was recorded at depths >8m bgl and that only c. 14% of the site area has Made Ground that extends beyond this depth.

Of the Made Ground that was recovered from depths between >5m and <8m bgl, this only accounted for c. 12% of the overall thickness of the Made Ground and comprised abundant *Granular* and *Cohesive Made Ground*, occasional *Suspected Construction and Demolition Material*, occasional *Suspected Colliery Spoil* and occasional *Suspected Combustion Materials*. This fits with the general trends noted above that demonstrate that only c. 18% of the total estimated volume of Made Ground was recorded at depths >5m and <8m bgl and that only c. 35% of the site area has Made Ground that extends beyond this depth.

Of the Made Ground that was recovered from shallower depths this accounted for c. 83% of the overall thickness of the Made Ground and predominantly comprised frequent *Granular Made Ground*, frequent *Suspected Combustion Materials*, occasional *Suspected Construction and Demolition Materials*, occasional *Cohesive Made Ground*, rare *Suspected Household Waste* and rare *Suspected Colliery Spoil*.

For the Suspected Colliery Spoil and Combustion Materials these were found to be largely ubiquitous and only encountered at shallow depth and within specific areas of the site as shown in Figure 8 below. The Suspected Construction and Demolition Materials were generally encountered within the central section of the site.

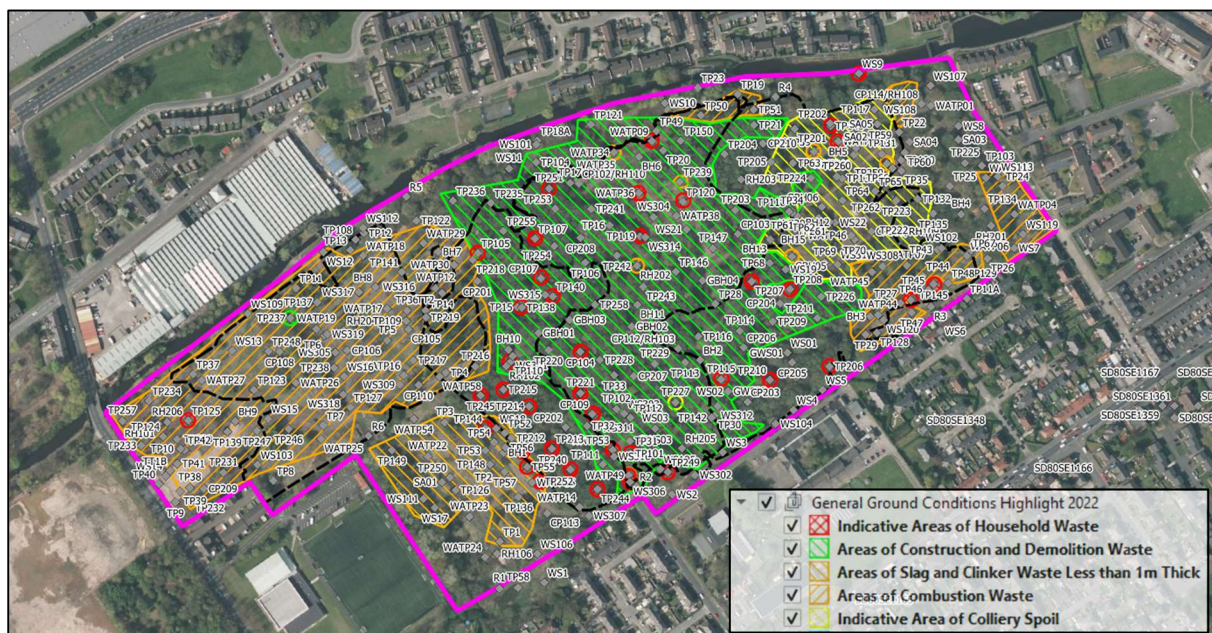


Figure 8: Spatial Distribution of the distinctive Made Ground types.

4.2 Visual and Olfactory Evidence of Contamination

Table 4 summarises the instances of visual and olfactory evidence of contamination within Made Ground across various depths noted during the WA and Celtic site investigations.

Table 4: Summary of Visual and Olfactory Evidence in Soil							
Depth Range m bgl	Hydrocarbon Staining / Odour	Organic Odour	Acrid Odour	Putrid Odour	Solvent / Chemical Odour	White Spirit Odour	Red / Yellow Dye
WA Data							
GL – 3.00	45	9	4	12	2	7	5
3.00 – 5.00	38	5	3	5	1	1	2
5.00 – 8.00	15	0	1	2	1	1	0
8.00 – 13.00	2	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0
Celtic Data							
GL – 3.00	22	2	0	1	1	0	0
3.00 – 5.00	6	2	0	0	0	0	0
5.00 – 8.00	1	0	0	1	0	0	0
8.00 – 13.00	1	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0
Notes:							
GL = Ground Level							
Observations at some isolated locations extend via multiple depths ranges. Where this has occurred, they have been noted across both depth ranges.							

During both the WA and Celtic site investigations, visual and olfactory evidence of contamination within soils was mainly noted within the top c. 3m of Made Ground materials and was typically associated with specific material types and specific areas of the site as outlined within the WA GI report (e.g. hydrocarbon odours and staining were frequently encountered within the Suspected Combustion Materials).

Visual and olfactory evidence of contamination at depth within the Made Ground was rare / isolated and this supports the observations about the more problematic material types not generally being encountered at depth.

Visual and olfactory evidence of contamination within perched groundwaters within the Made Ground included hydrocarbon odours and iridescent sheens, occasional solvent / chemical odours and occasional putrid odours. The hydrocarbon odours / iridescent sheens,

solvent / chemical odours were typically noted from response zones <5m with the putrid odours generally being noted from response zones >5m.

4.3 On-Site Screening

During the WA site investigation works, regular samples were screened on site for the presence of ionisable volatile organic compounds using a photo-ionisation detector (PID) with a 10.6 eV lamp. Only very low concentrations (between 0.0ppm and 13.8ppm) were recorded from soils and the results by depth ranges are summarised in Table 5 on the page below.

Table 5: Summary of PID Testing vs Depth				
Depth Range m bgl	Percentage of Site Area Occupied by Made Ground	No. of Tests	Range of Results ppm	Average
GL – 3.50	<3m = 100%	48	0.00 – 13.80	1.03
3.50 – 5.00	>3m – <5m = 56%	9	0.10 – 5.00	1.10
5.00 – 8.00	>5m – <8m = 35%	5	0.00 – 4.30	0.94
8.00 – 11.00	>8m – <11m = 14%	5	0.00 – 0.50	0.22
Notes: GL = Ground Level, PPM = Parts Per Million Results rounded to two significant figures				

A review of the data indicates that the higher PID concentrations were recorded within the top c. 3m bgl. This generally supports the trends observed from visual and olfactory evidence of contamination and the laboratory testing which has been summarised in Sections 4.2 and 4.4 respectively.

4.4 Laboratory Testing – Soils

Concentrations of all contaminants within soils from laboratory testing and above limits of detection (LOD) have been summarised, by depth ranges, in Table A1, that is enclosed at Appendix A.

The table shows that metals, inorganics (cyanide, sulphate, asbestos), TPH, PAH, VOC, SVOC, BTEX, PCB, phenols and PFAS have all been detected within the Made Ground, but that generally the highest concentrations, and highest average concentrations, are recorded within the top c. 3m of Made Ground.

This general trend was previously identified within the WA GI report, with specific contaminants being associated with particular material types and depth ranges (e.g. metal, cyanide, PAH, TPH, BTEX contamination were typically encountered within the *Suspected Combustion Materials* at shallow depths).

Slight exceptions to this general trend (although still showing reduction of concentrations with depth and in some cases up to three orders of magnitude lower) were observed as highlighted in Table A1 and this included boron, chromium, selenium, nickel, total cyanide, phenols, total TPH, PAH and some isolated SVOC / VOC's.

The highest concentrations and average concentration of lead, zinc, total sulphate, phenols, PCB's and isolated VOC / SVOC's were recorded at depths of between 3-5m bgl. However, further analysis of the data shows that the higher concentrations were clustered around the shallower depth ranges (i.e. closer to 3m than 5m bgl). For example, analysis of the lead results shows that the highest concentration of 28,700 mg/kg was recorded from a sample at 3.4m bgl and this was two orders of magnitude greater than the deeper results. Similar trends are observable for zinc, total sulphate, PCB's and many of the SVOC / VOC's.

Comparable trends were observed from the Celtic SI works with contamination generally being concentrated within the shallow Made Ground materials with some "hotspots" areas extending slightly deeper. Minimal evidence of contamination was found at depth or within the immediately underlying natural strata; the latter also reflected by the WA site investigations.

4.5 Laboratory Testing – Leachates

Leachate is defined as any contaminated liquid that is generated from water percolating through solid waste, accumulating contaminants, and moving into subsurface areas. Subsequently, leachate testing undertaken as part of the WA and Celtic SI's were generally undertaken within the unsaturated zone between GL and 5.00m bgl and hence do not provide any substantial information about the deeper ground conditions. If further details are required further reference should be made to the WA GI report.

4.6 Laboratory Testing – Groundwater

Concentrations of all contaminants within groundwaters identified from laboratory testing have been summarised, by depth ranges, in Table A2, that is enclosed at Appendix A.

The table shows that for cadmium, copper, manganese, nickel, zinc, calcium, iron, TPH and PAH, the highest concentrations were recorded from response zones within the top c. 3m of Made Ground. The opposite trend was observed for arsenic, boron, chromium, lead, selenium, cyanide, phenols, SVOC / VOC's (naphthalene, 2,4-dimethylphenol and 4-methylphenol), BTEX and total Perfluorooctane Sulfonate (PFOS) where the highest

concentrations were recorded from the response zones at depths >8m within Made Ground. PFAS has been further addressed at Section 5.3.

The Celtic data showed similar trends, although their dataset was restricted to 4 No. boreholes (two shallow and two deep) with the following notable exceptions:

- Arsenic and phenol was generally found at higher concentrations with the shallower response zones between 3-6m.
- Copper, chloride, total ammonia as NH₃, total ammonia as NH₄ and TPH were generally found at higher concentrations within the deeper response zones between 3-10m.

The groundwater data is generally more variable than it is for soils, but this is not unexpected due to the leaching of contaminants from the unsaturated zone, the Made Ground being predominantly granular (c. 75%) and c. 75% of the Made Ground materials being fully saturated / below the perched groundwater table. This is discussed further in Section 5.

5. DISCUSSIONS

Justification for the reduced number of soil samples obtained from the deeper Made Ground has been partly addressed in the context section 2 of this technical note. In short, deep Made Ground is only localised to specific areas of the site, accounts for a much smaller proportion of the total estimated volume of Made Ground and much of the Made Ground is located below the perched groundwater table. Further justification is provided in the following sections.

5.1 Proposed End Use and Assessments

Given the proposed sensitive end use (residential with plant uptake), the critical nature of the human health risk assessments was identified at an early stage, and this is partly why the focus of the soils testing has been related to the top c. 3m bgl. Deeper samples have also been tested, as it was identified that excavations could extend to c. 5m depth in places where “hotspots” are encountered. This approach ensured that the deeper soils were characterised / assessed for the full extent of the Made Ground across most of the site (i.e. for c. 65% of the site the soil testing has been for the full thickness of the Made Ground).

The risk to controlled waters is also a critical element of the works and prompted the extensive groundwater sampling and laboratory testing (along with leachate testing) to quantify the risk. Given that most of the site has a shallow perched groundwater table, data collected from this depth of the subsurface horizon was deemed to provide more representative data for controlled waters risk assessment. Nevertheless, it should be noted

that multiple stages of sampling and testing of groundwaters were also undertaken that related to Made Ground at depth.

As noted previously, c. 75% of the Made Ground materials are granular and are indicated to be highly permeable and c. 75% of the Made Ground is fully saturated / below the perched groundwater table. The Made Ground materials are also well over 50 years old (OS historical maps suggests that infilling started in the 1930s).

Given the above, it would not be unreasonable to assume that the dissolved contaminant concentrations measured in the perched groundwater either exist in equilibrium with the solid materials (worst case) or would be largely depleted from the solid materials (especially for those contaminants that are mobile in water). Furthermore, the dissolved contaminant concentrations are likely to be fairly well mixed throughout these saturated permeable Made Ground materials (mixing processes being predominantly diffusion-dominated given the likely absence of advective flow).

Consequently, the dissolved contaminant concentrations measured in perched groundwater carry greater a weight of evidence for assessing risk to Controlled Waters than the solid samples. This is in accordance with the EA Remedial Targets Methodology document that emphasises reliance on an assessment of groundwater (rather than solid samples) where the contaminants have already entered the groundwater, as demonstrated by the above.

5.2 Sample Quality / Methods of Sample Recovery

The reduced number of soil samples at depth (particularly those deeper than 5m bgl) has ultimately been a function of the exploratory methods that had to be used to retrieve soil samples from these depths (i.e., cable percussion borehole techniques) and that the nature of the Made Ground did not lend itself to any type of conventional or more advanced sampling or in-situ testing. This meant that obtaining sample of a sufficient quality for representative laboratory testing was not possible.

BS5930 and BS-EN1997-2 provide definitions for the types of sample quality that can be obtained from various intrusive techniques. This is mainly for geotechnical laboratory testing purposes but also has implications for chemical laboratory testing. Class 1 is the best type of sample quality that can be obtained, and Class 5 is the worst. Sampling by cable percussive drilling can result in significance disturbance due to mixing of soil samples and typically results in disturbed samples that are typically identified as Class 3 to 5.

As discussed previously, c. 75% of the Made Ground was also fully saturated / below the perched water table and, as such, the sample quality for the materials at depth via cable

percussive methods is reduced even further; for fine soils this is Class 4 and for granular soils this is Class 5 (i.e. the lowest sample quality). Given that the soils samples recovered from depth were unlikely to be representative, soil testing at depth has been undertaken in accordance with best practice guidance.

The focus of the SI approach has been on obtaining groundwater samples from monitoring well response zones that screen the deeper saturated strata to give an indication of the type and concentrations of contaminants that could still be present at the base of the landfill.

5.3 Perfluoroalkyl and Polyfluoroalkyl Substances

Reference has been made to the CLA:IRE Technical Note 19. in relation to PFAS being highly mobile, extremely persistent and able to bioaccumulate. PFAS have a low / moderate sorption to soils making them highly mobile in groundwater.

Long chain PFAS are hydrophilic and hydrophobic (amphiphilic), so tend to concentrate at the soil / water interface and is why soil testing has been concentrated between 0.4m and 4.9m bgl. This depth range covered the unsaturated zone and the zones at the soil / water interface (perched groundwater was typically encountered at c. 2.0m bgl) where PFAS within soils are most likely to be encountered.

Shorter chain PFAS are typically very soluble in water and are more mobile and given that the deeper Made Ground is saturated / below the perched groundwater table, it is unlikely that any shorter chain PFAS would remain adsorbed to soil at depth. Sorption of shorter chain PFAS to soils typically increases with decreasing pH and as shown by Table 6 below, pH of soils is generally increasing with depth suggesting that the soils conditions at depth are not conducive of sorption (i.e. significant sources of PFAS are unlikely to be adsorbed to soils).

Table 6: Summary of pH vs Depth				
Depth Range	Percentage of Site Area Occupied by Made Ground	No. of Tests	Range of Results ppm	Average
Soils				
GL – 3.00m	<3m = 100%	75	5.43 – 12.80	7.97
3.00 – 5.00m	>3m – <5m = 56%	17	6.19 – 11.40	8.30
5.00 – 8.00m	>5m – <8m = 35%	4	7.76 – 10.60	9.37
8.00 – 11.00m	>8m – <11m = 14%	3	8.03 – 8.99	8.57
Notes:				
Results rounded to two significant figures				

This is why groundwater samples from monitoring wells with response zones that screen shallow and deep Made Ground have been the main focus of the PFAS testing. PFAS located at the site is more than likely going to be encountered within the perched groundwaters. Only very low concentrations of PFAS have been detected in perched groundwaters (typically Total PFOS >55 ng/l). PFOS is one of the terminal breakdown products and is extremely mobile in groundwater and hence is a good indicator of the presence of any precursor PFAS compounds. These results do not indicate gross PFAS contamination within the soils at depth and is supportive of the above.

As noted in the descriptions of the Made Ground, the household type waste materials only make up c. 6% of the recorded Made Ground types and the presence of carpets, fabrics and other miscellaneous anthropogenic items that could contain PFAS are only a fraction of this material type. Based on the soils analysis data, Total PFOS has not been detected in these materials, but rather the *Granular Made Ground* and *Suspected Construction and Demolition Materials*.

During the site investigations it was also noted that numerous 'burnt-out' vehicles were present on-site and numerous fires are known to have occurred at the site. It is not known if firefighting foam (a primary source of PFAS) was used, but this should not be discounted, particularly in relation to the burnt-out vehicles.

Total Oxidisable Precursor (TOP) Assay tests provide indicative data regarding the PFAS chain length. The TOP Assay test results for the site suggest that shorter chain PFAS are present and that multiple sources are indicated such as aqueous film forming foams (i.e. firefighting foam), textile coatings, inks, paper and packaging etc. This is not unexpected for landfill given that the site contains various material types, and no single point source would be anticipated.

5.4 Limitations

It should be noted that the methods of intrusive investigation are a limiting factor for the classification of the deeper Made Ground materials, as they could only be recovered from cable percussion boreholes that were c. 8 inch in diameter and as such are unlikely to be representative of the strata as a whole. However, this is the only method by which these materials could be recovered from depth.

Intrusive investigations were also more frequent within the shallower Made Ground as trial pits could be undertaken at this depth and this enabled for more of the Made Ground materials to be observed resulting in more representative descriptions and sampling of these strata.

There is also the disparity between the number of laboratory testing undertaken for the shallow and deep Made Ground and how much of the material has been recovered for logging etc. This makes direct comparisons of the data between the shallow and deep Made Ground difficult but as noted already there is far less Made Ground material at depth compared to that at shallow depth and that the sampling and testing has been reflective of this, and the limitations associated with the only available methods of intrusive investigation (i.e. boreholes).

6. CONCLUSIONS

In relation to the aforementioned clarifications, it has been demonstrated that characterisation and testing of the deeper Made Ground materials has been undertaken. While this was to a lesser extent than that of the shallow Made Ground materials, this was due to the deeper Made Ground materials being less extensive (i.e. Made Ground >3m only accounts for c. 55% of the site area, Made Ground >8m only accounts for c. 14% of the site area and Made Ground >11m only accounts for 4% of the site area) and that the deeper Made Ground only accounts for a fraction of the total estimated volume of Made Ground as shown in Table 1.

Soil sampling within the deeper Made Ground has also had to be limited due to the limitations associated with obtaining representative samples within this type of material. For the top c. 3-5m of Made Ground material (i.e. within the reach of an excavator) characterisation and testing has been undertaken for the full depth of the Made Ground.

The deeper Made Ground materials are highly unlikely to pose a risk to human health (ground gas and vapours have been assessed separately and risks are minimal) and are therefore only a potential risk to controlled waters. As such and given that c. 75% of the Made Ground materials are granular and saturated / below the perched groundwater table, and that most of the Made Ground is well over 50 years, it would not be unreasonable to assume that the dissolved contaminant concentrations measured in the perched groundwater either exist in equilibrium with the solid materials (worst case) or would be largely depleted from the solid materials and that dissolved contaminant concentrations are likely to be fairly well mixed.

Consequently, the dissolved contaminant concentrations measured in perched groundwater carry a greater weight of evidence for assessing risk to Controlled Waters than the solid samples. This is in accordance with the EA Remedial Targets Methodology document that emphasises reliance on an assessment of groundwater (rather than solid samples) where the contaminants have already entered the groundwater. As such, additional soil sampling would not have been conducive to the assessment of controlled waters.

There are multiple supportive lines of strong evidence that demonstrates that the deeper Made Ground materials are unlikely to pose a significant risk to controlled waters, and these are outlined below:

- Physical descriptions of the Made Ground from the c. 350 exploratory hole positions indicate that the suspected household type waste was generally located at shallow depth (c. <3m bgl) and only accounted for c. 6% of the overall Made Ground materials. The suspected colliery spoil and combustion materials were also predominantly encountered at shallow depth and within specific areas of the site, although they were often intermixed with the deeper Made Ground also.
- Ground gas risk assessments undertaken as part of the WA GI report concluded that the current site is classified as Characteristic Situation 2 which is also supportive of an absence of a significant proportion of deleterious Made Ground / waste materials.
- Visual and olfactory evidence of contamination is also not indicative of widespread contamination within the deeper Made Ground materials and instead is concentrated within the shallower Made Ground.
- PID testing has only recorded very low concentrations (0 to 13.8ppm) from soils with the higher concentrations being recorded at shallow depth (<3m bgl) and concentrations decreasing by up to two orders of magnitude with depth.
- Review of the laboratory soil testing data indicates that metals, inorganics (cyanide, sulphate, asbestos), TPH, PAH, VOC, SVOC, BTEX, PCB, phenols and PFAS have all been detected within the Made Ground, but that generally the highest concentrations, and highest average concentrations, are recorded within the top c. 3m of Made Ground. Similar trends were also observed from the Celtic SI data. Please refer to Table A1 that is enclosed at Appendix A.
- Analysis of the groundwater laboratory testing indicates that distribution of contaminants within perched groundwaters within the Made Ground are more variable, but this is not unexpected as contaminants have been leaching from the unsaturated zone for well over 50 years and c. 75% of the Made Ground is predominantly granular and fully saturated / below the perched groundwater table. Please refer to Table A2 that is enclosed at Appendix A.
- Only very low concentrations of PFAS have been recorded at the site. The collated findings of the SI phase (i.e. most soils are below the perched water table), combined with the distinctive characteristics of PFAS (i.e. high mobility, high aqueous solubility

and low to moderate soil sorption properties), it is highly unlikely that a significant “source” of PFAS remains in soils at depth. It should also be noted that soil conditions recorded at the site are not conducive for sorption of shorter chain PFAS to soils.

- Subsequent to the above summary, PFAS is more than likely to be dissolved within the perched groundwaters (as reflected within the available analysis data) and would either exist in equilibrium with the solid materials (worst case) or would be largely depleted from the solid materials. Furthermore, only very low total PFOS concentrations have been recorded within perched groundwaters within Made Ground (both shallow and deeper), which is not indicative of gross PFAS contamination within the soils at depth.

Given that most of the site is recorded as a historical landfill there is the potential for extreme variability, but this also means is that there is unlikely to be a single “point source” of contamination due to the contamination resulting from the importation of already potentially contaminated Made ground.

It is not feasible to detect all of the possible wastes, contaminants etc, or classify all the materials, hence why contingencies for any unexpected contamination / ground conditions would be included within a robust remediation strategy and remediation implementation plan. Consequently, any unrecorded / unexpected contamination within the shallow Made Ground would naturally be dealt with as part of the remedial works. The available analysis data indicates that the greatest concentrations of contaminants are recorded at shallow depth.

It is also worth noting that the Made Ground materials are also well over 50 years old (OS historical maps suggests that infilling started in the 1930s). Therefore, those contaminants within soils below the perched groundwater table are likely to be dissolved within the perched groundwaters and would either exist in equilibrium with the solid materials (worst case) or would be largely depleted from the solid materials.

If required WA would be more than happy to liaise with the EA on the above, as much of the evidence can be communicated more easily via open dialogue etc.

Yours sincerely
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A handwritten signature in black ink, appearing to read "J Currie".

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Enclosed

Appendix A – Contamination Summary Tables

APPENDIX A

Table A1 : Summary of Contaminants with Depth (WA 2020 & 2022 Soils within Made Ground)													
Contaminant	LOD	0 – 3m			3 – 5m			5 – 8m			> 8m		
		Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average
Asbestos (%)													
Asbestos Quantification	<0.001	0.001	0.279	0.31	0.001	0.049	0.22	0.001	5.11	2.56	ND	ND	ND
Metals (mg/kg)													
Chromium, VI	<0.6	0.60	26	1.29	0.60	1.20	0.64	0.60	0.60	0.60	0.60	0.60	0.60
Boron	<1	1.00	8.54	1.56	1.00	7.46	2.33	2.15	15.3	8.76	7.17	40.80	18.57
Arsenic	<0.6	2.16	1930	58.36	8.20	309.00	40.60	6.61	32.00	19.93	4.85	14.10	8.65
Beryllium	<0.01	0.21	4.87	1.43	0.37	1.77	0.99	0.57	1.25	0.91	0.31	1.06	0.65
Cadmium	<0.02	0.02	37.40	1.39	0.02	7.17	0.84	0.12	1.19	0.41	0.28	4.59	1.76
Chromium	<0.9	0.90	497	40.95	7.72	884	80.09	12.10	585.00	178.18	6.55	23.00	13.12
Copper	<1.4	7.56	9990	382.92	24.50	3600	300.64	18.50	510.00	256.35	22.40	61.00	38.47
Lead	<0.7	6.38	10400	504.30	20.60	28700	2021.79	30.10	245.00	135.53	119	601	432
Mercury	<0.1	0.10	13.10	0.75	0.10	1.43	0.34	0.10	1.40	0.81	0.10	0.10	0.10
Nickel	<0.2	2.00	309	48.49	5.68	180.00	46.03	16.40	535.00	181.9	12.80	26.70	19.23
Selenium	<1	1.00	31.10	2.47	1.00	16.90	2.05	1.00	10.00	5.50	1.00	1.05	1.02
Vanadium	<0.2	2.04	332	42.11	18.30	45.20	27.00	27.10	34.90	31.00	10.90	24.40	18.87
Zinc	<1.9	15.70	7290	509.74	62.40	5610.00	533.05	108.00	316.00	240.25	60.90	438.00	195.20
Inorganics (mg/kg)													
pH	<1	5.43	12.8	7.97	6.19	11.4	8.30	7.76	10.60	9.37	8.03	8.99	8.57
Total Sulphate	<48	48	28000	2668.36	158.00	19800.00	4933.00	599	6110	2607.25	1030	3850	2490
Total Cyanide	<1	1.00	499.00	12.04	1.00	79.50	10.13	1.00	1.00	1.00	1.00	11.50	4.50
Phenols (mg/kg)													
Phenol	<0.01	0.01	0.43	0.02	0.01	1.37	0.08	0.01	0.02	0.013	0.01	0.01	N/A
Cresols	<0.01	0.01	0.71	0.03	0.01	6.16	0.34	0.01	0.04	0.02	0.01	0.01	0.01

Table A1 : Summary of Contaminants with Depth (WA 2020 & 2022 Soils within Made Ground)													
Contaminant	LOD	0 – 3m			3 – 5m			5 – 8m			> 8m		
		Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average
Xylenols	<0.015	0.015	1.37	0.05	0.015	3.22	0.20	0.015	0.015	N/A	0.15	0.06	0.03
Phenols, Total Detected monohydric	<0.035	0.035	2.08	0.09	0.035	10.80	0.61	0.035	0.059	0.041	0.035	0.07	0.05
TPH (µg/kg)													
Total Aliphatics & Aromatics >C5-C44	<10000	10000	17400000	10866010	10000	32300000	3017330	29800	322000	153950	216000	899000	518333
BTEX (µg/kg)													
Sum of BTEX	<40	40	374000	10954.78	40	8000	1315.22	40	800	N/A	40	800	N/A
PAH (µg/kg)													
PAH, Total Detected USEPA 16	<118	118	17800000	576969.13	388	7770000	447507	901	136000	36520.25	12100	76900	38133.33
SVOC and VOC (µg/kg)													
Pentachlorophenol	<100	100	2000	N/A	100	5000	692.85	100	500	N/A	100	500	N/A
n-Dioctyl phthalate	<100	100	2000	385.10	100	5000	N/A	100	500	N/A	100	500	N/A
Dimethyl phthalate	<100	100	2000	368.91	100	5000	N/A	100	500	N/A	100	500	N/A
n-Dibutyl phthalate	<100	100	2000	370.55	100	5000	N/A	100	500	N/A	100	500	N/A
Dibenzofuran	<100	100	5830	674.45	100	114000	6585.57	100	560	215	228	1200	801.33
Carbazole	<100	100	3170	516.13	100	64800	5883.00	100	500	N/A	100	1000	533.33
Butylbenzyl phthalate	<100	100	2000	N/A	100	10200	5404.76	100	500	N/A	100	500	N/A
bis(2-Ethylhexyl) phthalate	<100	100	13700	665.51	100	37300	2325.14	100	500	N/A	100	1560	720
bis(2-Chloroethoxy)methane	<100	100	2000	382.45	100	5000	N/A	100	500	N/A	100	500	N/A

Table A1 : Summary of Contaminants with Depth (WA 2020 & 2022 Soils within Made Ground)

[illegible]

Table A1 : Summary of Contaminants with Depth (WA 2020 & 2022 Soils within Made Ground)

Contaminant	LOD	0 – 3m			3 – 5m			5 – 8m			> 8m		
		Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average

Notes:

Green cells = lowest concentrations.

Yellow cells = second lowest concentrations.

Orange cells = second highest concentrations.

Red cells = highest concentrations.

Results rounded to 2 significant figures.

N/A in the average column means that all results were below the LOD.

Italics = recoded below LOD. Some determinands had a range of LOD's. Further details can be found in the WA GI Report.

All other determinands were recorded below the LOD and have not been included within this table. Please refer to the WA GI Report

Table A2 : Summary of Contaminants with Depth (WA 2020 & 2022 Perched Groundwater within Made Ground)

Contaminant	LOD	Response Zone 0 – 5m			Response Zone 5 – 8m			Response Zone > 8m		
		Min	Max	Average	Min	Max	Average	Min	Max	Average
Metals (µg/l)										
Arsenic (diss.filt)	<0.5	2.02	14.4	4.34	1.43	15.6	7.59	4.08	33.3	16.90
Boron (diss.filt)	<10	176	3110	1031.92	742	2260	1405.50	768	11300	8567.00
Cadmium (diss.filt)	<0.08	0.08	11	0.99	0.08	0.08	N/A	0.08	0.08	N/A
Chromium (diss.filt)	<1	1	1	N/A	1	6.98	3.59	4.28	10.7	8.06
Copper (diss.filt)	<0.3	0.3	140	12.10	0.3	1.07	0.55	0.3	0.448	0.37
Lead (diss.filt)	<0.2	0.2	3.73	0.87	0.2	2.71	1.05	0.274	5.53	2.57
Manganese (diss.filt)	<3.0	132	3450	756.58	230	1060	507.25	73	277	166.58
Nickel (diss.filt)	<0.4	0.4	130	15.98	0.997	10.9	3.95	0.771	11.7	8.34
Selenium (diss.filt)	<1.0	1	1.09	1.01	1	1.39	1.10	1	1.88	1.43
Zinc (diss.filt)	<1.0	1.46	54.5	17.66	1	11.3	6.15	5.36	5.36	5.36
Calcium (Dis.Filt)	<0.2	187000	511000	265670	107000	388000	221750	24400	210000	115630
Iron (Dis.Filt)	<19	245	11000	5620	116	783	450	240	2220	1140
Inorganics (mg/l)										
Sulphate	<2	8.4	654	192.88	2	497	211.25	2	135	42.65
Cyanide, Total	<0.05	0.05	0.05	N/A	0.05	0.13	0.08	0.05	0.18	0.11
Cyanide, Complex	<0.05	0.05	0.05	N/A	0.05	0.13	0.09	0.05	0.18	0.09
Thiocyanate	<0.05	0.05	0.05	N/A	0.05	0.05	N/A	0.05	0.12	0.08
Phenols (mg/l)										
Cresols	<0.006	0.006	0.006	N/A	0.006	0.01	0.01	0.006	0.006	N/A
Xylenols	<0.008	0.008	0.37	0.04	0.008	0.008	N/A	0.11	0.11	0.11
Phenols, Total Detected monohydric	<0.016	0.016	0.37	0.05	0.016	0.016	N/A	0.11	0.11	0.11
TPH (µg/l)										

Table A2 : Summary of Contaminants with Depth (WA 2020 & 2022 Perched Groundwater within Made Ground)

[illegible]

Table A2 : Summary of Contaminants with Depth (WA 2020 & 2022 Perched Groundwater within Made Ground)

Contaminant	LOD	Response Zone 0 – 5m			Response Zone 5 – 8m			Response Zone > 8m		
		Min	Max	Average	Min	Max	Average	Min	Max	Average

Italics = recoded below LOD. Some determinands had a range of LOD's. Further details can be found in the WA GI Report.

All other determinands were recorded below the LOD and have not been included within this table.

Only those PAH tests undertaken as part of the SVOC testing suite with either DWS or EQS have been included. SVOC and VOC's without DWS or EQS values have also been excluded. Please refer to the WA GI Report for further details.