

CLIENT:	Your Housing Group
PROJECT:	Ten Acres
SUBJECT:	Hydrogeological Conceptual Site Model Clarifications
JOB NO:	LD10587
DATE:	01 st March 2023
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INTRODUCTION AND BACKGROUND

This Technical Note (TN) has been prepared to summarise and clarify the Hydrogeological Conceptual Site Model (HCSM) that was outlined to the Environment Agency (EA) by Wardell Armstrong (WA) in the meeting dated 16th January 2023.

During this meeting, the EA suggested that further considerations would be required in relation to the hydrogeological model defined for the site. Subsequently, a more detailed summary of the hydrogeological conditions has been undertaken and outlined within this TN. This review includes a more focused and comprehensive summary of the perched groundwaters / leachates within the landfill and the groundwaters within secondary superficial aquifers beneath and surrounding the site.

The EA has highlighted a nearby Secondary A Aquifer which they believe may require further consideration. Upon further review, the presence of this specific aquifer (and associated controlled waters) was not supported by the site investigation (SI) data, available SI information from nearby sites or the most recent British Geological Survey (BGS) mapping.

Clarifications about the Secondary A Aquifer and ground model have been outlined below, however, much of the original detail can also be found within the *WA Phase I and Phase II Ground Investigation Report dated October 2022* (the “WA GI report”) and reference should be made to this report when reviewing this TN.

HYDROGEOLOGICAL CONCEPTUAL SITE MODEL CLARIFICATIONS

The HCSM for the site 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 a letter dated 16th February 2022 (EA ref: SO/2020/120757/05-L01).

Overall these works have generally included for but were not limited to; 55 No. cable percussion boreholes, 19 No. rotary boreholes, 220 No. trial pits, 57 No. windowless sample holes, 102 No. groundwater monitoring wells, 18 No. groundwater monitoring visits, 331 No.

laboratory tested soil samples, 46 No. laboratory tested groundwater samples and 19 No. laboratory tested leachate soil samples.

Secondary A Aquifer Clarifications

A superficial Secondary A Aquifer is recorded immediately adjacent to the north western section of the site, but the most recent BGS mapping (1:50,000 and 1:10,000 scale) indicates that the site and surrounding area are underlain by Glacial Till which is designated as a Secondary Undifferentiated Aquifer.

Superficial deposits that would typically be designated as a Secondary A Aquifer (e.g. Glaciofluvial Deposits, River Terrace or Alluvium) are absent where the Secondary A Aquifer is currently recorded.

Further investigation indicated that the designation of the Secondary A Aquifer adjacent to the north western section of the site is based on outdated BGS 1:63,360 Scale Geological Mapping Information as shown in the figures below.

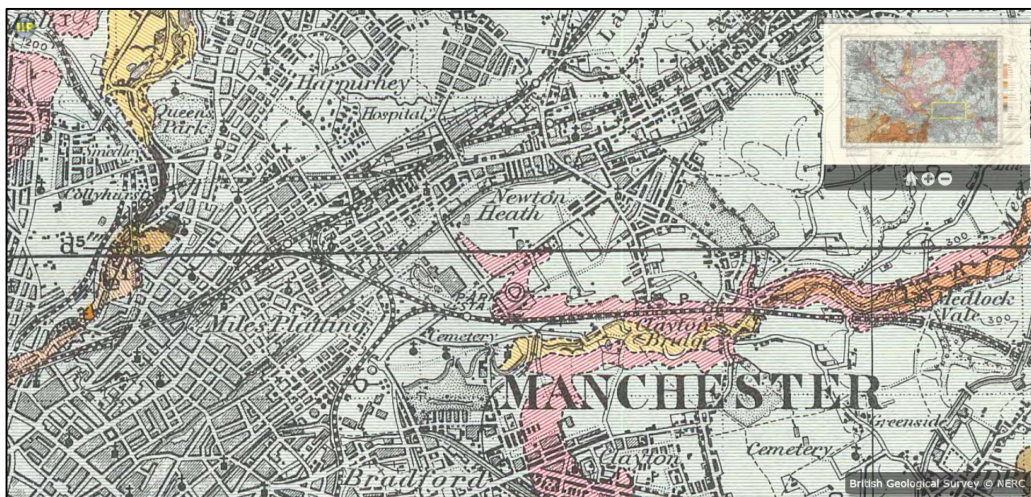


Figure 1: Extract of (now superseded) BGS 1:63,360 Scale Drift Geological Map Dated 1970.

The pink shading shown in Figure 1 (above) is recorded as 'Sand and Gravel' and it can be seen from Figure 2 (below) that the superficial Secondary A Aquifer has been mapped based on the coverage of this 'Sand and Gravel' and the extents of the Alluvium (Yellow) and Late Glacial Flood Gravels (Orange) to the south east.

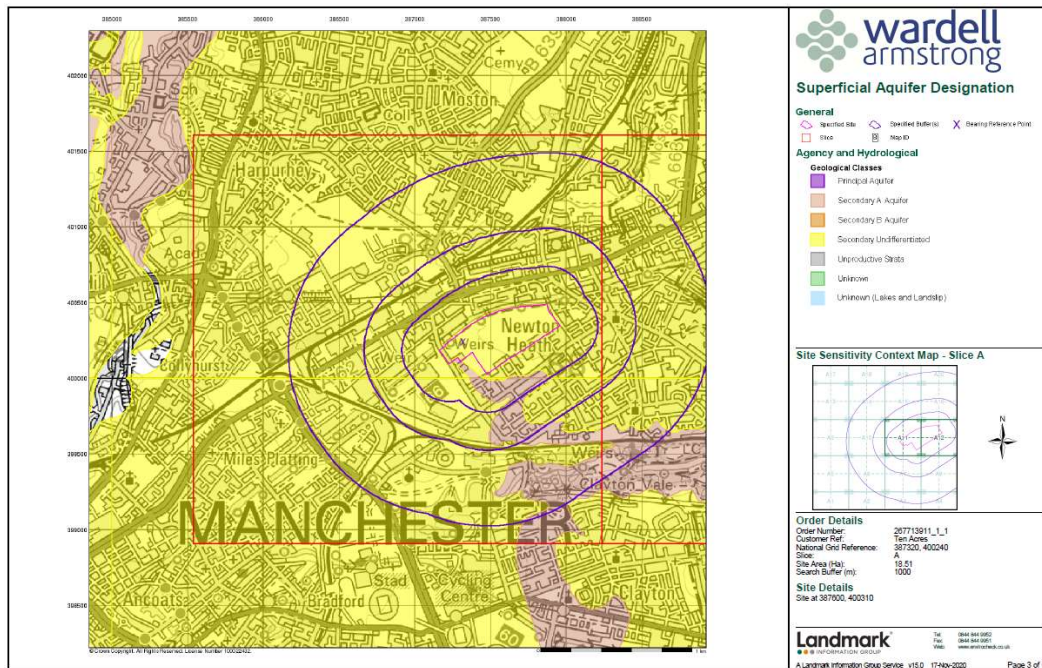


Figure 2: Extract of Envirocheck Superficial Aquifer Designation Map.

The most recent BGS Geological Mapping (1:50,000 and 1:10,000) shows that these 'Sand and Gravel' deposits are no longer recorded and instead the superficial geology is mapped as Glacial Till as shown in Figure 3 (below) and Figure 4 (following page).



Figure 3: Extract of BGS 1:50,000 Scale Bedrock and Superficial Geological Map Dated 2011.

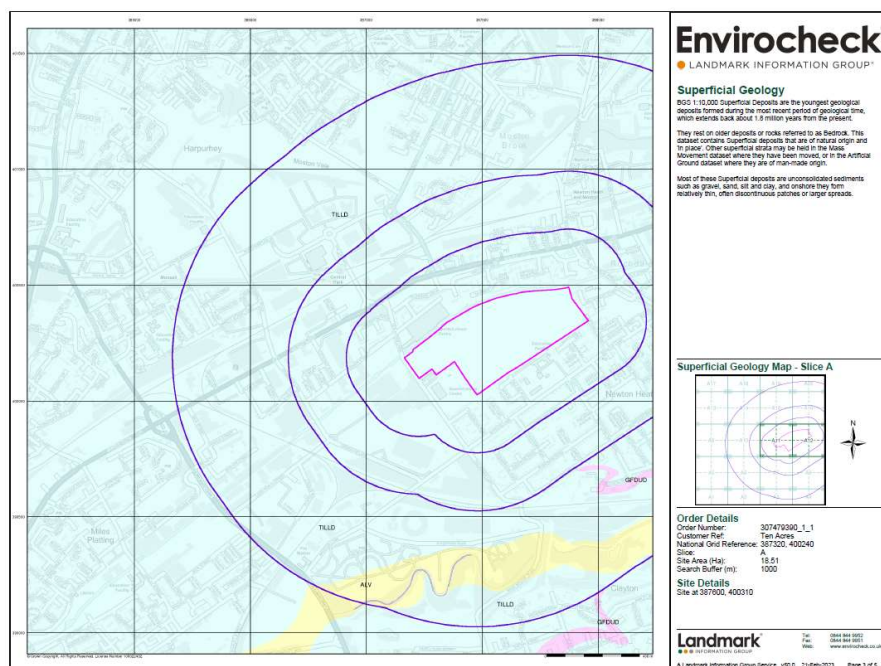


Figure 4: Extract of BGS Digital 1:10,000 Scale Superficial Geology.

As shown previously in Figure 2, the Glacial Till is recorded as a Secondary Undifferentiated Aquifer and subsequently, the Secondary A Aquifer designation is likely to be an unsubstantiated classification of the geology and should have been revised when the BGS Geological Mapping was updated, and the 'Sand and Gravel' deposits were remapped as Glacial Till.

This stance is also supported by the SI data and nearby BGS Borehole information, both of which demonstrate the absence of any near surface or significant 'Sand and Gravel' deposits that would justify a Secondary A Aquifer designation. In keeping with UK risk assessment protocol, wherever possible, site-specific evidence should take preference to mapped / desk study-based information. Further details can be found in the Ground Model Clarifications section of this TN.

Consequently, the natural superficial deposits at the site and the immediately surrounding area should be considered as a Secondary Undifferentiated Aquifer and the Secondary A Aquifer should instead be located c. 650-850m south east of the site where Alluvium is recorded alongside the River Medlock.

Due to various factors, such as the predominantly low permeability of the Glacial Till (i.e. a geological barrier), the fact that it contains relatively small and discontinuous quantities of perched groundwater and the lack of any potable groundwater abstractions within 2km of

the site; the Secondary Undifferentiated Aquifer assigned to the Glacial Till is not deemed to be sensitive.

Ground Model Clarifications

Proven ground conditions at the site include significant thicknesses of variable Made Ground to depths of between 0.3m and 14.8m below ground level (bgl). This layer of material is usually underlain by 35m to 45m of predominantly cohesive / low permeability Glacial Clay and to a lesser extent intermittent / discontinuous granular lenses. The above-mentioned layers are all in turn underlain by solid geology comprising weathered Sandstone of the Collyhurst Sandstone Formation and Chester Formation. The Manchester Marls Formation recorded on the BGS Geological Maps was not encountered.

The findings are consistent with the data ascertained from local BGS boreholes, nearby third-party SI works, and local geological memoir information which all indicate that the site is located within a buried glacial valley that predominantly comprises low permeability Glacial Clay.

The granular lenses beneath the site vary in thickness between 0.05m and 12m thick (on average 2.4m thick). Overall the SI information from the site and the immediately surrounding area demonstrate that these sand lenses are sporadic and not in continuity with other sensitive groundwaters or surface water bodies (further evidence for this is outlined below). While these lenses are indicated to be more abundant and shallower within the eastern section of the site compared to those within the western section of the site, this is due to changes in elevation, as shown in Figure 5 and Figure 6 below.

Celtic also concluded a lack of continuity with sensitive groundwater or surface water bodies based on the SI information that was available to them back in 2008 (much less information than what is now available). They concluded that the shallow groundwaters encountered at the site were perched and that they were unlikely to consist of a single interconnected groundwater body. Hence any active pathways from these perched groundwaters at the site to sensitive controlled waters receptors were discounted on the basis that the thick clay deposits created an effective natural barrier against contaminant migration.

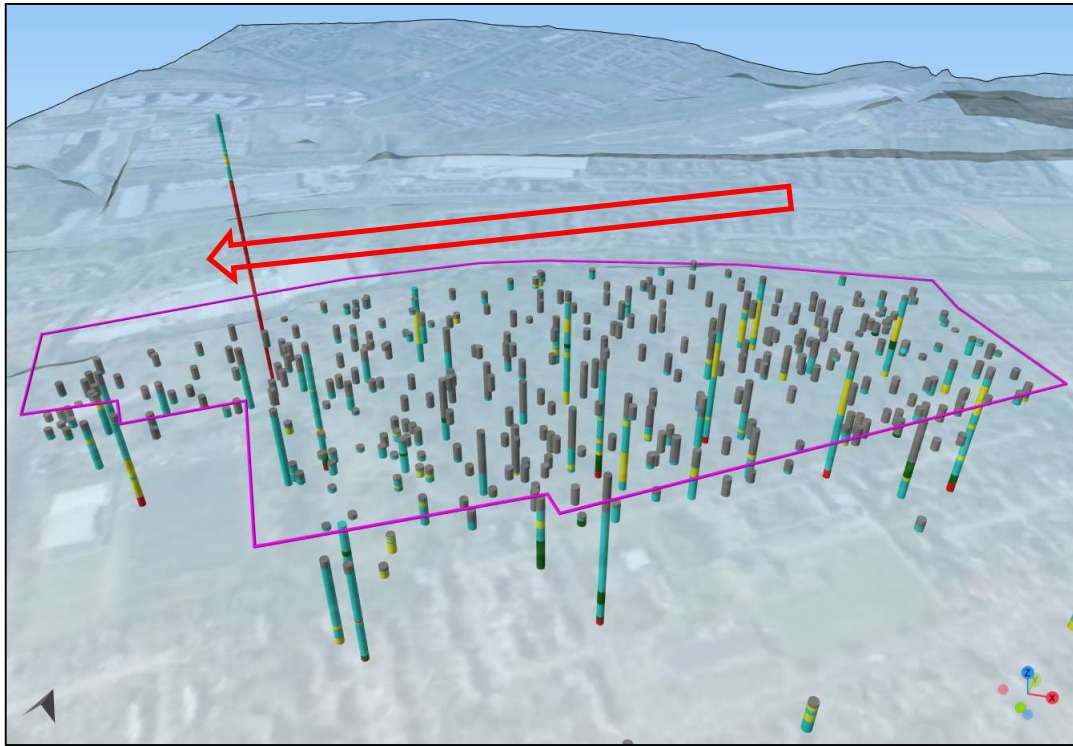


Figure 5: 3D Model screenshot showing the distribution of the granular lenses beneath the site. Grey = Made Ground, Turquoise = Glacial Clay, Yellow = Glacial Sand, Green = Glacial Gravel and Red = Rock. Arrow denotes decreasing topographic elevation which decreases by c. 10m from east to west.

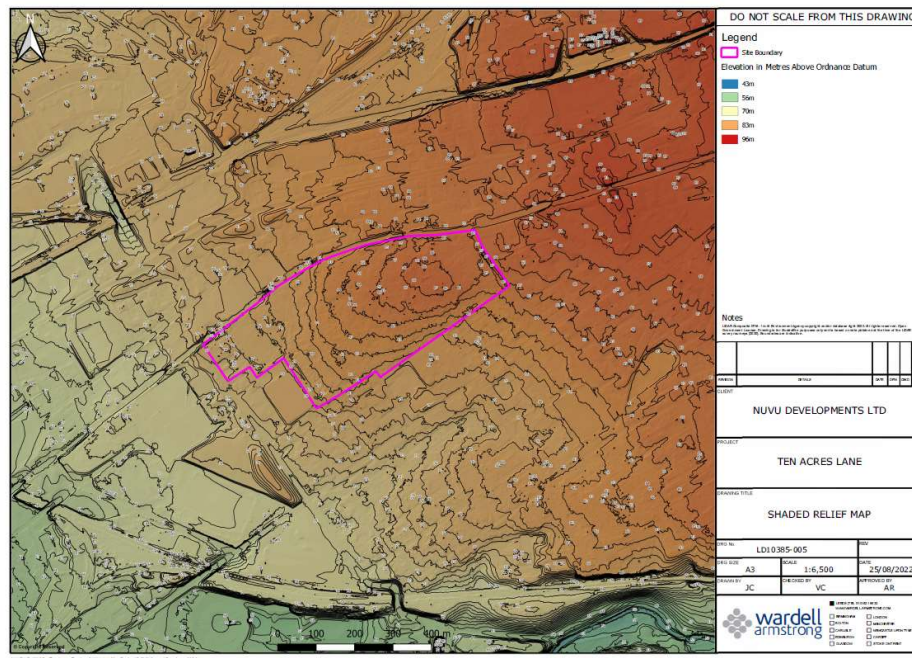


Figure 6: Shaded relief map for the site showing the change in topographical elevation across the site. Orange / red shading denotes higher elevations. Blues / green shading denotes lower elevations.

Continuity Between Shallower and Deeper Granular Lenses

Continuity between the shallower and deeper granular lenses has not been identified at the site or within the modelling and they are separated by significant thickness of low permeability Glacial Clay. This is illustrated by the 3D modelling in Figure 5 and supported by the multiple lines of evidence that have been summarised in further detail below (originally presented with the WA GI Report):

- The site lies within a BGS Buried Glacial Valley where the SI works have demonstrated that the landfill is underlain by between c. 35m and 45m of predominantly low permeability and overconsolidated glacial clay (i.e. a geological barrier) as shown in Drawing LD10385-007, the cross sections and the exploratory hole logs contained within the WA GI Report. The thickness of the superficial deposits and the depth to rockhead is also consistent with the findings from local BGS boreholes and third-party SI data as shown in WA GI Report Drawings LD10387-008 and LD10387-009.
- Exceedances of the controlled waters screening values and the highest concentrations of determinands were most widespread within shallow perched groundwater within the landfill. The absence of most of these determinands in deeper perched groundwaters within Glacial Till and groundwaters within bedrock, and the presence of elevated concentrations of contaminants not detected within the shallow perched groundwater within the landfill, supports the lack of continuity between the perched water within the Made Ground and the deeper groundwaters.
- Many of the elevated concentrations of determinands were from boreholes located outside of the recorded extents of the landfill and the highest and lowest concentrations were noted upgradient and downgradient, respectively. If the site were to be the source of the contamination within the deeper groundwaters, then the opposite trend should have been observed.
- Further evidence of the confined nature of the perched groundwater within the landfill and the lack of a vertical migration pathway to deeper groundwater is supported by the groundwater seepage that has been observed on-site during periods of heavy rainfall. If groundwater within the backfilled clay pits were infiltrating into the underlying natural strata at a significant rate, then this relationship is unlikely to have been observed.
- Sub artesian conditions within deeper groundwater are also indicated and this is also indicative of confined conditions within the deeper perched groundwaters within Glacial Till and bedrock.

- As noted previously the third-party DQRA undertaken by Celtic indicated that there was limited evidence to suggest that contaminants were leaching from Made Ground into the deeper groundwater at the site. This assessment was based on rockhead being encountered at c. 20m bgl and a reduced thickness of Glacial Till. However, given that rockhead has been proven to be significantly deeper at c. 45m bgl, this assessment is now known to have been highly conservative and this is also supportive of a lack of a source-pathway-receptor linkage.

Further details regarding the above can be found within Section 14 and Section 16 of the WA GI Report.

Vertical and Lateral Characteristics of Shallower Granular Lenses

The lateral and vertical characteristics of the shallower granular lenses are generally more variable, but they are also predominantly separated from each other by Glacial Clay. It should be noted that localised continuity is indicated for some of those shallow granular lenses within the eastern section of the site, but this is not considered to be significant for the reasons outlined below.

Several BGS boreholes and third-party boreholes within the area surrounding the site have also been reviewed. These 'off-site boreholes' predominantly identify Glacial Clays, and whilst some granular lenses are noted they are markedly reduced as shown below in Figure 7.

This is particularly evident for an area located downgradient and to the south west of the site (circled in red) where shallow granular lenses are indicated to be completely absent. This follows the characteristic trend observed for the westernmost section of the site and is partly due to changes in elevation. This is where only deep granular lenses isolated from the shallow perched groundwaters / leachates are indicated.

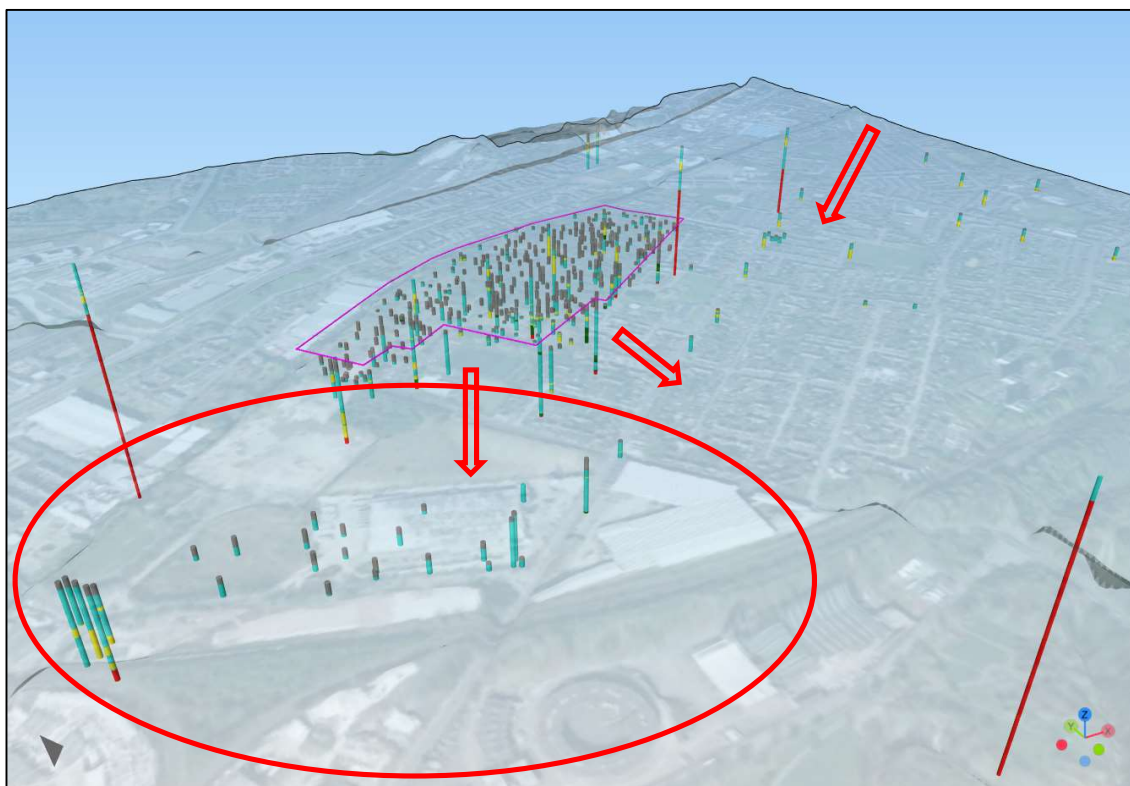


Figure 7: 3D Model screenshot showing all exploratory holes at the site and available third party and BGS boreholes within the surrounding area. Colour coding as identified within Figure 1. Arrows denotes downgradient topographical trends as shown in the shaded relief map in Figure 6.

Shallow granular lenses at a similar elevation to those encountered within the easternmost section of the site are indicated off-site to the east and south east. However, most are from upgradient areas, and even if pathways were to be present, the ground model suggests that continuity between the superficial Secondary A Aquifer and River Medlock (c. 650-850m to the south east) is highly unlikely for the following reasons:

- The shallow granular lenses at the site and off-site are significantly elevated (by c. 10-15m AOD) from the superficial deposits within which the Secondary A Aquifer are recorded.
- Due to the above, perched groundwaters / leachates would first have to migrate downwards into the deeper granular layers that are located at a similar elevation to those superficial deposits within the superficial Secondary A Aquifer / River Medlock.
- As outlined in the previous section, there are multiples lines of evidence to suggest that vertical migration pathways from the shallow perched groundwaters / leachates to the deeper granular layers are highly unlikely.

- Even if pathways were evident, then a lateral migration pathway through the ground would then have to be present extending over a significant distance towards the superficial Secondary A Aquifer / River Medlock in the south east. Laterally extensive, continuous, and uninterrupted granular layers over such a distance are not identified by the boreholes on-site or within the surrounding area and any migration would be retarded by the predominantly low permeability Glacial Clays.
- The above is also true for any shallower granular lenses that hypothetically could extend from the site towards the valley side of the River Medlock where seepage could occur. No such seepages have been observed and groundwater migration is restricted because of the discontinuous granular lenses noted above.
- Analysis of perched groundwater levels within the Made Ground / landfill are highly variable which is supportive of their perched nature but there are some areas where groundwater flow is indicated to be recorded towards the deeper parts of the clay pit excavations and towards the area where groundwater flooding / overspill is observed. This is another line of evidence that demonstrates the low permeability nature of the natural Glacial Clays and the lack of a pathway for groundwater to flow / travel off-site beyond the Made Ground that has been recorded at the site.
- Slightly confined (positive head) conditions are indicated for the groundwater within the shallow natural superficial deposits, and this suggests that these water bodies are isolated and that the granular lenses are not laterally or vertically continuous.

Further details can be found within the cross sections, drawings (LD10385-017 to LD10385-020) and text contained within the WA GI Report. The information can also be demonstrated more effectively via a live interaction with the information contained within the WA GIS database.

Post Development Improvement Considerations

The site has been derelict / vacant for the past c. 30 years and while it has had a history of residential planning applications, no redevelopment of the site has ever been undertaken as all previous applications were disbanded (despite approvals in the 1980's and 1990's). In part this is due to the many challenges that the site presents to a prospective developer.

The current proposals for the development of the site (if successful) would change the current status quo and result in a problematic site being brought back into positive use that would also result in an overall improvement from a contaminated land / controlled waters perspective.

Following development, infiltration / recharge to the Made Ground is likely to be significantly reduced from the baseline due to a c. 70% increase in hardstanding areas and the use of low permeability clean cover systems for private gardens and areas of Public Open Space (POS). Drainage designs would ensure that surface water is captured before soaking into the ground.

It has already been established that there is no identified linkage to off-site receptors, but it is also worth considering the post development drainage regime with regards to contaminant load that may enter perched water or surface water at the site, as this would reduce infiltration of rainwater into the near surface soils. Consequently, any associated leaching and downward migration of potential contaminants into the shallow perched groundwater or surface waters would be reduced.

There shall also be an improvement to the site following the completion of the remedial works as any contaminant loading within the sub-surface environment would be reduced via the removal and / or treatment of any gross contamination within both soils and shallow groundwaters. Ground improvement (e.g. compaction) undertaken for geotechnical purposes would also minimise air-voids in the soil and reduce permeability and perched groundwater recharge.

Per and Polyfluoroalkyl Substances (PFAS)

Following a consultation with the EA there were concerns that the site could contain PFAS; emerging contaminants that are the subject of accelerating environmental regulatory concern globally. These contaminants are mobile, persistent and bioaccumulate and hence are especially problematic for controlled waters receptors.

PFAS are most likely to be associated with sites where they were directly used in bulk quantities such as facilities for waterproofing textiles and furnishings; the site does not fit into this category. However, PFAS can be found in landfills and their leachates, but this is largely dependent on the types of materials deposited in the landfill.

The extensive ground investigations that have been undertaken at the site have shown that the main waste types identified comprises suspected ash, slag and clinker; suspected colliery spoil; suspected construction and demolition waste; and isolated pockets of more variable waste types.

It would not be considered likely that ash, slag, clinker and colliery spoil would be significant sources of PFAS. It is mainly the latter (more variable waste types) that could have the potential to contain sources of PFAS. As a result it is only a small proportion of the material at site which could be considered to represent any significant likelihood of representing a

source of PFAS. Investigation works to assess this have been undertaken and conclude the following.

- PFAS was detected in 4 out of 19 soil samples that were obtained from across the site and at depths of between 0.4m and 4.9m bgl. PFAS was only detected within Made Ground and was not encountered within natural superficial deposits.
- Total PFOS concentrations (the most extensively produced PFAS species) ranged from 1.4ug/kg to 4.35ug/kg and post oxidation Total PFOS concentrations ranged from <2ug/kg to 5.79ug/kg.
- The data indicated that the PFAS detections were localised and recorded mainly within the more variable waste types at depths of between 0.6m and 2.0m bgl.

Very low concentrations of PFAS have also been detected within those perched groundwaters that are present within the landfill and the findings can be summarised as follows:

- PFAS were detected in 10 out of 13 groundwater samples that were obtained from monitoring wells with shallow and deep response zones that intersected those various groundwater bodies that have been identified beneath the site.
- Total PFOS concentrations ranged from <0.65ng/l to 102ng/l and post oxidation Total PFOS concentrations ranged from <2ng/l to 129ng/l.
- The data indicated that the PFAS were mainly detected and at their highest concentrations within the perched groundwaters that were encountered within the landfill.
- A single reduced concentration was detected within perched groundwaters within an isolated / localised natural granular lense where continuity with the landfill is indicated (restricted to the location of CP203).
- PFAS were not detected in any of the deeper groundwater samples.
- PFOS concentrations in perched groundwaters beneath the site do not exceed up-gradient background concentrations recorded within the River Medlock (between 8ng/l and 209ng/l) which is located c. 650m south east of the site.

Given the incomplete Source-Pathway-Receptor linkages, it is reasonable to conclude that any further works for PFAS are unlikely to provide any further meaningful information from a controlled waters perspective.

CONCLUSIONS

Given the above clarifications regarding the absence of a superficial Secondary A Aquifer, that the extensive SI data (both on and off-site) demonstrates that the granular lenses are discontinuous and not in continuity over significant distances (both in a vertical and lateral sense) and that the perched groundwater / leachate (which contains low-level PFAS and other contaminants) at the site do not have a complete source, pathway, receptor linkages to those identified sensitive controlled waters receptors (e.g. Principal Aquifer and those receptors located c. 650-850m south east of the site); a controlled waters risk does not seem plausible.

The revised CSM on which this work is based is itself derived from detailed extensive site investigation work and a thorough ground model. Any further works characterising PFAS concentrations and distribution are unlikely to alter the current conclusions given there seems to be incomplete pollutant linkages between the receptor and the source for the reasons outlined above.

Regardless of the findings of those outstanding works or the above clarifications, it is considered that protection and improvement of the groundwater and surface waters would be best achieved through the pending remedial works and the construction of the proposed development. This would act to stabilise shallow hydrogeological conditions through reduced infiltration of rainwater, reduce contaminant loading within the shallow groundwater (potential leachate), which in turn would minimise the potential risk to the identified receptors. Based on this, we recommend any further consideration of the HCSM should be undertaken post-remediation.

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 the extensive GIS database that we have compiled for the site and a review of the 3D model and geological cross sections.