



e3p

Phase II Geoenvironmental Site Assessment
Land at Greenbooth Road and Edenfield Road, Norden

Reference: 16-465-R2-2
Date: June 2023



PHASE II GEOENVIRONMENTAL SITE ASSESSMENT

Land at Greenbooth Road and Edenfield Road
Norden
Rochdale
OL12 7TD

Prepared for:

Stonebond.

**Report Ref: 16-465-R2
Date Issued: June 2023**

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QUALITY ASSURANCE

PROJECT NUMBER	16-465		
VERSION	Version 1	Version 2	
REMARKS	Final	Updated following revised development plan	
DATE	January 2023	June 2023	
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QUALIFICATIONS	BSc (Hons), FGS	BSc (Hons), FGS	
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EXECUTIVE SUMMARY

Site Address	Land at Greenbooth Road and Edenfield Road, Norden, Rochdale, OL12 7TD.
Grid Reference	E 385812, N 414724.
Site Area	2.62 Ha.
Proposed Development	Stonebond Properties Ltd intends to construct a low-rise residential development comprising 49 residential dwellings with associated gardens, estate roads, infrastructure, and a connecting bridge.
Current Site Use	The subject site is an irregularly shaped disused parcel of land located to the north of Greenbooth Road and Edenfield Road, Norden Rochdale. Hardstanding comprises over half the land cover, but the site can be split into two distinct areas: the former Tack Lea Works (Woodhouse Mills) area occupying the northern and central portions of the site and the former Sheppard Mill area in the east and south-eastern part of the site. The site is predominantly old industrial land with five structures present in the centre of the Tack Lea Works area. The structures comprised an old boiler house, a coal hopper, a vehicle spray workshop, a coal bunker, and a gas substation. Concrete and brick-lined structures, believed to be historical filter tanks and reservoirs, are also present within an area of semi-mature woodland in the eastern section of the Tack Lea Works area. No structures were identified within the Sheppard Mill area. An earthen bund approximately 1 m in width and height is located to the immediate west of the old boiler house and bisects the Tack Lea Works area from northeast to southwest. Naden Brook enters from the northwest and generally flows in a south/southeast direction, adjacent to the site's western and southern boundary along Greenbooth Road. Woodhouse Lane Brook enters the site from the north and flows south, separating the Tack Lea Works area and Sheppard Mill area before entering Naden Brook. The south of the site has been artificially raised and levelled where previous industrial mills were located.
Site History	Earliest mapping (circa 1851) shows the site comprised industrial land with numerous buildings (Woodhouse Mill and Sheppard Mill) associated with bleaching, fulling, dyeing and finishing mills. Several reservoirs are present in the centre and east of the site, and a sandstone quarry is present in the northwest. Wooded areas are present in the centre and southeast of the site. From 1890, additional structures and reservoirs have been erected in the centre of the site along Naden Brook. The sandstone quarry is no longer present (replaced by woodland), and a pond is located in the northwest. Additional structures are also present to the northwest of Sheppard Mill. Wooded areas have also expanded to include the central and northern parts of the site. From 1910, additional structures and tanks are present in the northwest of the site (in the location of the former sandstone quarry). Filter tanks have also been developed in the northeast within an area of woodland in the centre along Naden Brook.



Site History <i>Continued...</i>	From 1929, unnamed structures in the northwest and filter tanks in the northeast have expanded. The unnamed structure to the northwest of Sheppard Mill has been demolished and replaced with a larger structure. From 1961, unnamed structures in the northwest and south along Naden Brook have been expanded further. The pond in the northwest and a number of reservoirs in the centre are no longer present, with new structures erected over the presumed infilled reservoirs. Since 1974, structures in the northwest have been expanded and several filter tanks are located in the centre within the wooded area. Filter tanks in the wooded area in the northeast and reservoirs in the east have been removed, with part of Sheppard Mill demolished. A tank is located to the southeast of Sheppard Mill. Since 1990, structures in the northwest and Sheppard Mill in the southeast have been expanded. Rochdale MBC hold records of a licensed historical landfill located in the eastern section of the Tack Lea Works area and west of Woodhouse Lane Brook within an area of semi-mature woodland. The landfill site was licensed to accept inert and industrial wastes (i.e., 'building wastes') to be used for 'land reclamation, tipping and landscaping' between 1987 and 1991. From 2003, Woodhouse Mill, Sheppard Mill, unnamed structures in the centre bordering Naden Brook and the tank southeast of Sheppard Mill are no longer present. From 2012 to the present, only five structures remain in the Tack Lea Works area. Extensive hardstanding is present across the north-western and south-eastern sections of the site and extensive vegetation/tree cover is present across the central and northern sections of the site.	
Environmental Setting	Drift Geology	Till – Devensian (Diamicton)
	Bedrock Geology	Rough Rock -SANDSTONE
	Faults	There are no faults close enough to the site to influence ground stability.
	Hydrogeology	Secondary undifferentiated superficial aquifer with a Secondary A bedrock aquifer recorded. The site is not located within a groundwater source protection zone. No active groundwater abstraction points identified within a 1 km radius . The nearest active surface water abstraction point is located 498 m northwest of site (United Utilities) – located upstream of site.
	Hydrology	Woodhouse Lane Brook bisects the site in the centre and runs from north to south before entering Naden Brook. Naden Brook is located along the western and southern boundaries of the site. Naden Brook is classified by the EA as a Statutory Main River.



Environmental Setting <i>Continued...</i>	Hydrology <i>Continued...</i>	Anecdotal evidence indicates the presence of a culverted watercourse beneath the former mill building in the Tack Lea Works area, which arises from a spring beneath the former mill building and discharges into Naden Brook. A second spring and stone-lined well is anticipated to be present in the basement area of the former dye house in the Tack Lea Works area. A second culverted watercourse is also anticipated to be present beneath the former mill building in the Sheppard Mill area, which discharges into Woodhouse Lane Brook. During the site walkover, a spring was identified in the far northwest part of the Tack Lea works area within an area of outcropping bedrock. Due to the local topography, any shallow groundwater will likely flow in a south-easterly direction, following the topographical gradient towards Naden Brook and Woodhouse Lane Brook.
	Flood Risk	Predominantly located within a currently defined "Flood Risk Zone 1". However, sections of the western and southern boundaries of the site are located within "Flood Risk Zones 2 and 3" and as such are considered to be affected by river flooding. There is a high potential for surface water flooding to occur at the site, with the highest risk areas being located in the southern sections of the site. The site is at risk of flooding from reservoirs in the area (i.e., from Greenbooth Reservoir located approximately 430 m to the north). There is a low to negligible potential for groundwater flooding to occur at the site.
Natural Landform and Geomorphology	Naden Brook flows in a southerly direction along the western and southern boundaries of the site. The subject site is situated within a plateau in a small valley with a steep, wooded embankment to the north and east boundaries. It would appear that the current site-level plateau will have been formed by the placement and upfilling of material before the construction of the historical development. Historical level raising has resulted in greater thicknesses of Made Ground overlying the natural glacial till and alluvial soils associated with Naden Brook.	
Previous Reports	The following previous reports have been provided for review: ✳ Encia Consulting Limited – Geoenvironmental Appraisal – Land at Greenbooth Road, Norden (Report Ref: 7112/1, June 2006); and, ✳ LK Consult – Geoenvironmental Risk Assessment – Land at Greenbooth Road, Norden (Report Ref: CL602-LKC 20 1618-01, September 2020). Details are set out in Section 2.1.	



Utility Locations	A number of service covers have been identified in the north-western and central sections of the Tack Lea Works area. An above-ground water pipe was also identified in the eastern section of the Tack Lea Works area running north to south over Naden Brook. A review of online records identified the following utilities on-site: ✳ Low and medium pressure gas mains entering Tack Lea Works area from Greenbooth Road, runs northwest to a gas substation and vehicle spray workshop. ✳ 6Kv electricity cable entering the Tack Lea Works area from Greenbooth Road, runs northwest connecting the vehicle spray workshop and old boiler house before terminating at former electricity substation. Low voltage electricity cable splits off from 6Kv cable and runs east towards former filter tanks before turning north/northwest up wooded slopes towards the northern access track and Woodhouse Lane. Low voltage cables are entering the Sheppard Mill area from Edenfield Road, runs northwest before terminating at former Sheppard Mill building. ✳ 6-inch distribution water main entering the Tack Lea Works area from Greenbooth Road, runs northwest before terminating south of the vehicle spray workshop. A private pipe splits off from the water main, runs underneath the old boiler house to the northwest before terminating in the northwest section of the Tack Lea Works area. Another private pipe runs along the northern access track to the east before terminating at the coal hopper. ✳ Overhead telecoms cable entering the Sheppard Mill area from the east, runs to the west before terminating on the northern slope. A full utility survey, formal drainage survey and a review of online records is recommended to determine the presence of underground services
Landfill Sites and Ground Gases	There is one licenced historical landfill located on-site in the eastern section of the Tack Lea Works area and west of Woodhouse Lane Brook within an area of semi-mature woodland. The landfill site was licensed to accept inert and industrial wastes between 1987 and 1991. Several infilled ponds/reservoirs are located in the Tack Lea Works area in the northwestern section and beneath the old boiler house and coal bunker. Two infilled reservoirs are located in the southern section of the Sheppard Mill Area. A historical sandstone quarry (presumed infilled) is located in the northwestern section of the Tack Lea Works area. The site has also undergone extensive historical development and ground working. The Made Ground associated with these historical land uses together with recorded landfill may produce hazardous ground gases such as methane and carbon dioxide.
Radon	A BGS Radon Report was purchased for the site, which indicated that the northeast and northwest of the site is situated in an area where 1–3% of homes are above the "Action Level" and the rest of the site is situated in an area where 0–1% of homes are above the "Action Level". Therefore, full radon protective measures are not necessary for the construction of new dwellings or extensions.



Coal Mining/Land Stability	A coal mining assessment has indicated that the site is located within a CA reporting area but not within a high-risk development zone. Coal Authority mining report for the site concluded that no mine entries are located within 100 m of the site, no outcrops are recorded within close proximity of the site, and the site is not in a surface coal resource area. Therefore, no risk from coal mining is present and no further measures are required.
Brine Workings	The site is not located within an area deemed to be at risk from ground instability due to historical brine pumping activities and/or salt extraction.
Hazardous Installations	No hazardous installations that could potentially prejudice the proposed construction of highly sensitive residential dwellings have been identified within influencing distance of the subject site.
Environmental Permit Requirements	As parts of the proposed development works (i.e., demolition and construction) will be completed within 8 m of a main river, a Flood Risk Activity Permit (FRAP) will be required. Any material within the historical landfill located in the eastern section of the Tack Lea Works area is likely to be classified as waste and would therefore require an environmental permit to excavate and treat it before it could be re-used. A Material Management Plan (MMP) may not be a route for this material. It is noted that current proposals are to not develop in the area of the landfill, except for the proposed estate road and connecting bridge.
Initial Conceptual Site Model	Due to the developed nature of the site, a number of potential sources of contamination have been identified. Made Ground deposits are likely to be present across the site to significant depths in the footprints of current and historical buildings, filter tanks, ponds, reservoirs, infilled sandstone quarry, tanks and the historical landfill, which potentially may be impacted by heavy metals, non-volatile PAHs, petroleum hydrocarbons and asbestos. PCBs may also be present in the centre of the Tack Lea Works area where the former electricity substation was located. A number of potential sources of mobile contamination have been identified. Impacted Made Ground, current and historical buildings (bleaching, fulling dyeing and finishing mills, and vehicle spray workshop) and historical tanks represent potential sources of mobile contamination. If present these have the potential to leach from the soil and migrate downwards to the underlying secondary A aquifer (Bedrock) and laterally to Naden Brook and Woodhouse Lane Brook which are topographically lower than the site. Mobile contamination may also migrate laterally to the culverted watercourses and springs located on-site. Made Ground, current and historical filter tanks, ponds and reservoirs, the infilled sandstone quarry and the historical landfill are considered to be potential sources of hazardous ground gas. In addition, due to the historical uses on the site (bleaching, fulling dyeing and finishing mills, vehicle spray workshop, historical tanks and historical landfill), the Made Ground may be impacted by volatile contaminants (VOCs and SVOCs). If ground gases and volatile contaminants are present, these may pose a risk through inhalation or accumulation of gases / vapours within confined spaces.



GROUND INVESTIGATION

Ground Investigation Works	E3P has completed an intrusive ground investigation comprising: ✿ 30 x Mechanically Excavated Trial Pits; ✿ 24 x Window Sample Boreholes; ✿ 3 x Cable Percussion Boreholes; ✿ 2 x BRE 365 Soakaways; ✿ 5 x Hand Pits; and, ✿ Construction of environmental monitoring installations.
Ground Conditions	Made Ground – 0.00 to 5.80 m bgl Made Ground deposits were encountered within all exploratory hole locations to depths ranging between 0.00 m and 5.80 m bgl. However, in 34 locations, the full thickness of Made Ground could not be proven due to significant concrete and brick obstructions and basement features, which are indicative of relict foundations from the former buildings. The five hand pit locations within the eastern section of the Tack Lea Works area were all terminated within Made Ground. In all locations except WS101 and WS103 (central section of the Tack Lea Works area), concrete was encountered to a maximum proven depth of 0.68 m bgl (WS104). The concrete often contained rebar. In WS101 and WS103, dark brown clay with occasional rootlets (reworked topsoil) was encountered. In the majority of locations, the concrete was underlain by brown sandy gravel with gravels of sandstone, mudstone, limestone, concrete, and brick. Frequent fragments of ceramic, glass, wood, and metal were encountered within the Made Ground. Ash was also encountered in one location within the Tack Lea Works area (WS115) and one location in the Sheppard Mill area (WS123). Intact empty plastic bottles of fabric softener were also encountered in one location within the Tack Lea Works area (TP114). DRIFT – 0.50 to 15.00 m bgl Drift deposits were encountered within twenty-four exploratory hole locations between depths of 0.50 m and 15.00 m bgl. The drift deposits varied, with the majority comprising a brown gravelly CLAY with gravels of mudstone and sandstone. The strength of CLAY varied from soft to very stiff. In seven locations across the Tack Lea Works area (TP130, WS102, WS103, WS105, WS107, WS111 and WS114) and two locations within the Sheppard Mill area (WS119 and WS120), a brown clayey GRAVEL was encountered with gravels of sandstone and mudstone. In TP103 (south-western boundary of the Tack Lea Works area), a brown gravelly SAND was encountered with gravels of sandstone and mudstone.



Ground Conditions <i>Continued...</i>	SOLID The solid bedrock geology was not encountered during this phase of the investigation. There are no BGS boreholes within close proximity to the site. In the Encia Consulting 2006 Report, shallow bedrock of SANDSTONE was encountered in the central and western sections of the Tack Lea Works area at depths typically <2.00 m bgl. To the north of the Tack Lea Works area, bedrock can be seen outcropping in the valley and hillside. To the east of the former Tack Lea Mill Buildings and in the Sheppard Mill area, bedrock was found to be deeper and was encountered at depths ranging between 4.30 m and 5.00 m bgl. GROUNDWATER – Groundwater was encountered between 1.40–2.50 m bgl during the ground investigation with monitoring recording groundwater levels between 1.30–2.90 m bgl.
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CONTAMINATED LAND ASSESSMENT

Human Health	The Tier 1 human health risk assessment identified site-wide concentrations of heavy metals, asbestos, non-volatile PAHs, naphthalene, petroleum hydrocarbons, VOCs and SVOCs that would present unacceptable degrees of theoretical risk to the identified receptors associated with direct exposure pathways. The majority of the identified elevated concentrations have primary exposure pathways related to dermal contact and ingestion of soils, inhalation of particulate and consumption of homegrown vegetables; with naphthalene, petroleum hydrocarbons, VOCs and SVOCs having a primary exposure pathway related to volatilisation to indoor air risk. The risk to chronic human health associated with the elevated concentrations of inorganic heavy metals and non-volatile PAH compounds can be mitigated through the installation of a suitable cover system in all proposed private gardens, landscaping and public open space to remove any potential for direct exposure to impacted soils. The specific design and installation process for the appropriate cover systems will be clearly defined within the site remediation and enabling works strategy; however, industry best practice will require the following minimum depths of certified clean cover:  Private gardens – 600 mm  Landscaped areas– 300 mm  Public open space (POS) – 300 mm Asbestos in the form of chrysotile and amosite has been identified within localised areas in Made Ground deposits in the southern part of Sheppard Mill area (WS124 and WS18), the historical landfill in the eastern section of Tack Lea Works area (HP05) and the central section of Tack Lea Works (TP114 and TP116). Asbestos bulk fragments, in the form of hard cement were also identified in WS124, HP05 and WS10; and asbestos sheeting/board debris within HP05. Visual signs of ACM were encountered during the ground investigations in HP05. Impacted soils should be managed according to the asbestos risk mitigation conceptual site model.
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Human Health
Continued...

It is noted that the presence of asbestos sheeting and boarding will require a different remedial approach to those proposed within the asbestos risk mitigation conceptual site model (i.e., hand picking of visible bulk asbestos fragments). Where asbestos sheeting and boarding has previously been identified, any proposed earthworks within those areas may be required to be undertaken under license. In addition, any off-site disposal of materials from these areas would be considered hazardous unless the asbestos bulk fragments are pre-removed via hand picking techniques.

Elevated concentrations of mercury have been identified within two locations within the Tack Lea Works area (WS111 at 0.60 m bgl and WS9 at 0.50 m bgl); and one location within the Sheppard Mill area (WS25 at 0.70 m bgl). Mercury occurs in three different forms; elemental mercury, inorganic mercury and methyl mercury. Inorganic and methyl mercury have an exposure pathway of dermal contact and ingestion, whereas elemental mercury could present a potential volatilisation to indoor air risk.

During remediation and enabling works, speciated mercury analysis should be completed at the locations WS111, WS9 and WS25 to assess whether elemental mercury is present which may pose a risk to future site users through vapour inhalation. If elemental mercury is identified, it may be necessary to delineate and excavate the soils as a hotspot and place them in an area of low sensitivity such as beneath areas of public open space or removed from site. Alternatively, if it is proven that there is no elemental mercury, a clean cover system will be sufficient.

The elevated concentrations of naphthalene, TPH, and trichloroethene (TCE) identified within the Tack Lea Works area (TP116 and WS12) are considered to be localised occurrences and therefore this location can be treated as a localised hotspot. During a process of cut/fill enabling works, a hotspot removal should be undertaken where these soils may be chemically validated to assess chemical suitability for retention on-site in an area of no future sensitivity.

However, elevated concentrations of naphthalene, TPH, VOCs and SVOCs have been identified throughout the Shepherd Mill area, and these do not appear to be localised hotspots. A Tier II vapour risk assessment is required in this sector of the site to assess the level of risk to the future site users by volatilisation to indoor air.

The SVOCs identified in WS107 and TP116 within the Tack Lea Works area are not considered to pose a risk to future site users given the marginal concentrations.

Furthermore, with regards to the elevated volatile contaminants (naphthalene, TPH, VOCs and SVOCs) identified in the Tack Lea Works area and the Sheppard Mill area, vapour resistant membranes may be required to be installed during the build phase for any proposed buildings situated within the immediate vicinity of the contamination hotspot / impacted soils. A Detailed Quantitative Risk Assessment (DQRA) may also be required to determine if any risks to human health and controlled water receptors remains following the hotspot removal.

Chemical analysis of the natural subsoil deposits has indicated these soils to be acceptable for use within the proposed garden areas; however, further chemical validation samples will be required to confirm this. No suitable source of natural topsoil deposits has been identified on-site.



Controlled Waters

The ICSM developed within the context of the site setting has determined that the surface water features (Naden Brook, Woodhouse Lane Brook and the culverted water courses and springs) are the critical receptors at risk from a viable pollutant pathway, which would be the lateral migration of potentially mobile phase-soluble contaminants.

The presence of low permeability cohesive drift deposits across the site affords protection from vertical migration to the underlying Secondary A bedrock aquifer. As such, this receptor is considered to be at a low risk.

A comparison of leachate and groundwater samples taken by E3P and Encia to the Tier 1 assessment Criteria (Table 4.5) has shown exceedances for heavy metals & inorganics, non-volatile PAHs and naphthalene within soils and groundwater. Exceedances for TPHs were also identified within groundwater in the Sheppard Mill area.

The underlying Secondary A Aquifer is deemed to be at a low risk from on-site contamination given the presence of cohesive deposits in excess of 5.00 m; the proposed development will create new hardstanding which will reduce infiltration and the number of contaminants present in leachate migrating off-site; and the fact that the site is not located within a groundwater source protection zone and that no active groundwater abstraction points are located within a 1 km radius of the site.

A comparison of surface water samples taken by E3P and Encia from Naden Brook and Woodhouse Lane Brook to the Tier 1 assessment criteria (Table 4.6) has shown exceedances for copper and zinc within all samples upstream and downstream of the site. As a result of this, it can be said that elevated levels of these determinants cannot be attributed to the site due to their presence within upstream samples. The m-BAT assessment has also shown that within surface water samples taken by E3P, neither copper nor zinc are considered to be bioavailable.

Concentrations of chromium (III) were found to be in exceedance of the EQS within leachate samples taken by E3P and leachate, groundwater and surface water samples taken by Encia. Non-volatile PAHs were also identified within the chemical testing in surface water samples taken downstream of Woodhouse Lane Brook (E3P, Woodhouse Lane Downstream) and Naden Brook (Encia, W4). This shows lateral migration of contaminants identified within soils and groundwater is occurring at the site and causing a detrimental impact on the surface water receptors.

It is noted that mobile contaminants identified within the soils and groundwater (non-volatile PAHs, naphthalene and TPHs) have the potential to migrate laterally towards the surface water receptors as a result of the high permeability strata present beneath the site. The cohesive strata that is present beneath the site may also act as an impermeable barrier and channel mobile contaminants towards the surface water receptors. As such, the surface water receptors are deemed to be at a high risk from on-site contamination.

It is noted that limited groundwater sampling was undertaken during the monitoring programme. This was due to the majority of monitoring wells either having insufficient or no groundwater within them. As such, it has not been possible to determine a groundwater flow direction.



Controlled Waters <i>Continued...</i>	During the remediation and enabling works phase, the removal of the hardstanding currently present across the site may induce infiltration and potential mobilisation of contaminants present within the soils and groundwater directly into the surface water receptors. As such, it is recommended that further investigation, in the form of deep boreholes and monitoring well installations, with further groundwater and surface water monitoring and sampling is undertaken in order to develop a robust groundwater conceptual site model and controlled waters risk assessment for the site.
Ground Gas	Characteristic Situation 1 (pending completion of gas monitoring). CS2 measure recommended for the whole site due to the presence of the historical landfill (eastern section of the Tack Lea Works area). Elevated concentrations of volatile contaminants (naphthalene, TPHs, VOCs, SVOCs, and mercury) have been identified within the Made Ground on-site, which present a potential volatilisation to indoor air risk. Elevated concentrations of volatile contaminants in the Tack Lea Works area are considered to be localised occurrences and therefore these locations can be treated as hotspots. However, elevated concentrations of volatile contaminants have been identified throughout the Shepherd Mill area and these do not appear to be localised hotspots. Further assessment, in the form of a Tier II vapour risk assessment is required across the site to assess the level of risk to the future site users by volatilisation to indoor air. Subject to the findings of the vapour risk assessment, vapour resistant membranes may be required.
Potable Water Infrastructure	Based on the assessment of current site conditions, it is likely that barrier pipe will be required at the proposed development. Post-remediation and enabling works ground conditions may be different from those identified during this ground investigation.

GEOTECHNICAL ASSESSMENT

Underground Obstructions	Significant concrete and brick obstructions and basement features, which are indicative of relict foundations from former buildings have been encountered within the Made Ground. As such, the full thickness of the Made Ground could not be proven across the vast majority of the site. Further investigations will be required to prove the depth to Made Ground across the site. During a phase of cut-and-fill enabling works to create a developable platform, all below-ground obstructions will require grubbing out to the base of the Made Ground to enable the construction of proposed plots.
Allowable Bearing Pressure	Medium dense gravels identified between 1.00–4.00 m bgl has been assessed as having an ABP of 152 –278 kN/m². Dense gravel identified between 2.50–7.00 m bgl has been assessed as having an ABP of 322–456 kN/m². Loose gravels have also been identified between 1.00–2.00 m bgl in the central section of the Tack Lea Works area (WS102, WS103, and WS105) and at 3.00 m bgl in the central section of the Sheppard Mill area (CP103) has been assessed as having an ABP of 52–80 kN/m².



Allowable Bearing Pressure <i>Continued...</i>	Firm gravelly CLAY has been identified between 2.00–3.00 m bgl with a net ABP of 56–80 kN/m². Stiff silty CLAY identified at 1.00–9.50 m bgl has been assessed as having a net ABP of 83–154 kN/m². Very stiff gravelly CLAY has been identified at 2.70–15.00 m bgl and has a net ABP of 156–452 kN/m². Soft gravelly CLAY was also identified at 1.00 m bgl in the central section of the Tack Lea Works area (WS102) and has been assessed as having a net ABP of 31 kN/m².
Foundation Options	Given the significant topographical variances on the site, prior to the detailed design of a suitable foundation solutions, a programme of remediation and enabling works will be required to remove the extensive buried obstructions and cut/fill the site in order to create proposed development platform levels suitable for residential development. Following the removal of obstructions and subsequent engineering of soils to a specific performance specification, proposed plots could be constructed utilising vibro stone columns to support a suitably reinforced spread footing. Where tree influence is present and clays prone to volumetric instability, an alternative foundation solution may need to be adopted to deepen the foundation or the cohesive stratum may be removed and replaced with a granular material. The depth of the granular infill will be plot specific and require calculation on receipt of development levels. The use of vibro stone columns will also be dependent on the removal of clays that have a shear strength of <30kN/m². Where plots are in close proximity to slopes or the existing retaining walls, the proposed loadings may need to be transferred beneath the influencing depth of the retainer or slope to ensure no unacceptable loading is induced that would cause a geotechnical failure. Consideration should also be given to the historical landfill located in the eastern section of Tack Lea Works, as well as the potential presence of a quarry high wall associated with the historical sandstone quarry in the north of Tack Lea Works area. Where plots span such a feature, socketed piles into the bedrock will be required to reduce the risk of differential settlement. Therefore, upon completion of these enabling works, it is anticipated that the final foundation solution will be a combination of: ✿ Vibro Stone Columns (VSC) that will ensure a uniform ABP in the order of 100kN/m² for the construction of a doubly reinforced strip footing at ~600mm below remediated ground level (1050mm below FFL); ✿ Shallow strip foundations, where viable, bearing on localised areas of firm to very stiff clays, medium dense sands and shallow bedrock; ✿ Mass trench fill bearing on localised areas of firm to very stiff clays, medium dense sands and shallow bedrock; ✿ Piled foundations may be required where deep Made Ground and soft clays have been encountered; and for plots which span the historical sandstone quarry and associated high wall in the north-western section of the Tack Lea Works area; and ✿ Raft foundations may be required where obstructions cannot be removed.



Foundation Options <i>Continued...</i>	Foundation depths within the conjectured influence of former, existing or proposed trees will need to be deepened to ensure that structural loading bears within the underlying target founding stratum, which cannot be subject to volumetric instability associated with fluctuation in moisture content. It is recommended that, at working drawing stage, a foundation schedule is prepared for the development taking account of the physical change of natural clay soils and the current/proposed locations of trees.
Building Floor Slabs	Ground-bearing floor slabs are unlikely to be viable given the anticipated depths or reworked Made Ground > 600 mm and shallow cohesive soils.
Heave Precautions	Given that the underlying clay is of low volume change potential, heave precautions will not be required for the internal face of a foundation less than 1.5 m in depth. Heave precautions will be required to the underside of floor slabs (where there is no 200 mm void) and pile ground beams are required within the modelled influencing distance of trees.
Soakaway Drainage	The Made Ground and underlying granular soils are cohesive and impacted by low-level inorganic and petroleum hydrocarbons which would preclude the use of infiltration drainage systems.
Sulphate Assessment	E3P categorised the concrete requirements as DS-1 AC-1s. The LK Consult 2020 Report categorised the concrete requirement as DS-2 AC-3z in the Made Ground and DS-1 AC1 in the natural strata.
CBR Design %	Granular soils can be re-engineered to ensure 5% within the subgrade during favourable climatic conditions. Natural clay soils will provide a CBR in the order of 3–5% during drier climatic periods. However, if water is allowed to shed onto the formation, the CBR will reduce to < 2%, which will require specialist engineering of the subgrade.
Cut/Fill	Development levels are unknown at this time; however, significant cut-and-fill work will be required to prepare the development platform.
Civil Engineering Excavations	The E3P intrusive ground investigation has identified the presence of minor water ingress which may require localised dewatering/sump pumping during the construction of site drainage infrastructure. Due to the depth and variability of Made Ground and the likelihood of trench collapse, it is considered that all excavations are supported or battered back in accordance with the guidance contained in CIRIA R97.
Waste Characterisation	Any material that is to be disposed of off-site should undergo assessment using Technical Guidance WM3: <i>Waste Classification – Guidance on the classification and assessment of waste</i> .
Waste Management	The eastern section of the Tack Lea Works area is occupied by a historical landfill where the material was deposited under a Waste Management License. Materials originating from licensed landfills are regulated under the Waste Framework Directive (WFD). Furthermore, materials originating from future excavations (both during remediation or construction) cannot be recovered for re-use using the normal processes and protocols such as the CL:AIRE DoW CoP.



Waste Management <i>Continued...</i>	It is understood that this area will remain undeveloped with the exception of an access road, therefore the material should be retained in-situ where possible. Remediation options for this sector of the site warrant robust consideration given that options for re-use would either be an application for a new Environmental Permit (Deposit for Recovery – DFR) or alternatively the on-site processing of material to recover the fractions that would no longer cease to be a waste with the off-site disposal of all non-recoverable portions. E3P would recommend that a waste management and recovery strategy be defined to facilitate the safe and economic re-use of material from landfill. A volume of 'waste' will require removal from site, this should be considered as part of a site viability assessment. It is also noted that potential waste material may be present within former drains, the current and historical filter beds and tanks and at the base of the current and historical reservoirs located on-site. Further chemical analysis of these materials will be required to assess their chemical suitability for retention on-site in an area of no future sensitivity or off-site disposal.
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RECOMMENDATIONS

Based on the findings of the geoenvironmental site assessment, the following additional works are recommended to be completed in due course:

- ✿ Further investigation to confirm depth of Made Ground across the site;
- ✿ Further investigation (deep boreholes and monitoring well installations) with further groundwater and surface water monitoring and sampling to develop a robust groundwater conceptual site model and controlled waters risk assessment;
- ✿ Further investigation of inaccessible areas - central section of the Tack Lea Works area (current buildings); and eastern section of Tack Lea Works area (historical landfill area - for the estate road and connecting bridge construction);
- ✿ Tier II Vapour Risk Assessment for the Sheppard Mill area;
- ✿ Plot-specific foundation schedule (upon receipt of the final development levels);
- ✿ Application for a Flood Risk Activity Permit (FRAP);
- ✿ Arboricultural survey (undertaken by E3P, Report Ref: 80-742-R3-2, dated June 2022);
- ✿ Settlement Analysis for earthworks design;
- ✿ Slope stability assessment;
- ✿ A structural survey of Retaining Walls;
- ✿ Geotechnical earthworks strategy (infrastructure);
- ✿ Remediation and enabling works strategy;
- ✿ Construction phase Surface Water Management Plan; and,
- ✿ Waste management plan for any works in the area of the former historical landfill.



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DRAWING LIST

16-465-001 – Site Location Plan
16-465-002 – Proposed Development Plan
16-465-003 – Site Features Plan
16-465-004 – Historical Features Plan
16-465-005 – Exploratory Hole Location Plan
16-465-010 – Conceptual Site Model
16-465-015 – Development Constraints Plan
16-465-025 – Cross-Section Location Plan
16-465-027 – Contamination Issues Plan – TPH
16-465-028 – Contamination Issues Plan – VOCs
16-465-029 – Contamination Issues Plan – SVOCs
16-465-030 – Contamination Issues Plan – Heavy Metals
16-465-031 – Contamination Issues Plan – Naphthalene
16-465-032 – Contamination Issues Plan – Non-Volatile PAHs
16-465-033 – Contamination Issues Plan – Asbestos
16-465-034 – Contamination Issues Plan – Leachate
16-465-035 – Contamination Issues Plan – Groundwater
16-465-036 – Contamination Issues Plan – Surface Water
16-465-037 – Controlled Waters Conceptual Site Model



1. INTRODUCTION

1.1. BACKGROUND

Stonebond Properties Ltd has commissioned E3P to undertake a detailed Phase II Geoenvironmental Site Assessment for a semi-derelict former industrial land north of Greenbooth Road and Edenfield Road, Norden, Rochdale, OL12 7TD.

This report is required to determine potential contaminated land liabilities, remediation requirements and geotechnical engineering works that will be required as part of the proposed development.

1.2. PROPOSED DEVELOPMENT

Stonebond Properties Ltd intends to construct a low-rise residential development comprising 49 residential dwellings with associated gardens, estate roads, infrastructure, and a connecting bridge. Drawing 16-465-002 (Appendix III) identifies the proposed development layout.

A snapshot of the proposed development layout is indicated in Figure 1.1.

FIGURE 1.1 SNAPSHOT OF THE PROPOSED DEVELOPMENT



1.3. OBJECTIVES

The objectives of the geoenvironmental assessment are as follows:

- ✳ Review historical plans, geology, hydrogeology, site sensitivity, floodplain issues, mining records and any local authority information available in order to complete a desk study in line with Environment Agency (EA) document *Land Contamination: Risk Management (LCRM) (2019)*.
- ✳ Undertake a preliminary stage of sampling and analysis to provide an overview of the environmental issues identified.
- ✳ Assess the implications of any potential environmental risks, liabilities and development constraints associated with the site in relation to the site's future use and in relation to off-site receptors.
- ✳ Assess the geotechnical information and provide preliminary recommendations in relation to foundations, pavement construction and floor slabs.

Provide recommendations regarding future works required.

1.4. SCOPE OF WORKS

The scope of work includes the following elements:

- ✳ A detailed review of historical information;
- ✳ Design of suitable intrusive ground investigation;
- ✳ Window sample probeholes with, and construction of, environmental monitoring installations;
- ✳ Deep cable percussive boreholes with groundwater monitoring installations;
- ✳ Mechanically excavated trial pits;
- ✳ BRE365 Infiltration Testing;
- ✳ Hand pits;
- ✳ In-situ geotechnical testing;
- ✳ Chemical and geotechnical laboratory analysis;
- ✳ Surface sampling (earthen bund);
- ✳ Groundwater monitoring and sampling;
- ✳ Surface water sampling;
- ✳ Ground gas monitoring;
- ✳ Contamination risk assessment and conceptual site model;
- ✳ Geotechnical assessment and interpretation; and
- ✳ Factual and interpretive reporting.



1.5. LIMITATIONS

The limitations of this report are presented in Appendix I.

1.6. CONFIDENTIALITY

E3P has prepared this report solely for the use of the client and those parties with whom a warranty agreement has been executed, or with whom an assignment has been agreed. Should any third party wish to use or rely upon the contents of the report, written approval must be sought from E3P; a charge may be levied against such approval.



2. GROUND INVESTIGATION

2.1. PREVIOUS GROUND INVESTIGATIONS

- ✿ Encia Consulting Limited – Geoenvironmental Appraisal – Land at Greenbooth Road, Norden (Report Ref: 7112/1, June 2006); and,
- ✿ LK Consult – Geoenvironmental Risk Assessment – Land at Greenbooth Road, Norden (Report Ref: CL602-LKC 20 1618-01, September 2020).

The key findings of the previous ground investigation reports are summarised below, and where necessary, data used to support the E3P geoenvironmental site assessment.

2.1.1. ENCIA CONSULTING 2006 REPORT

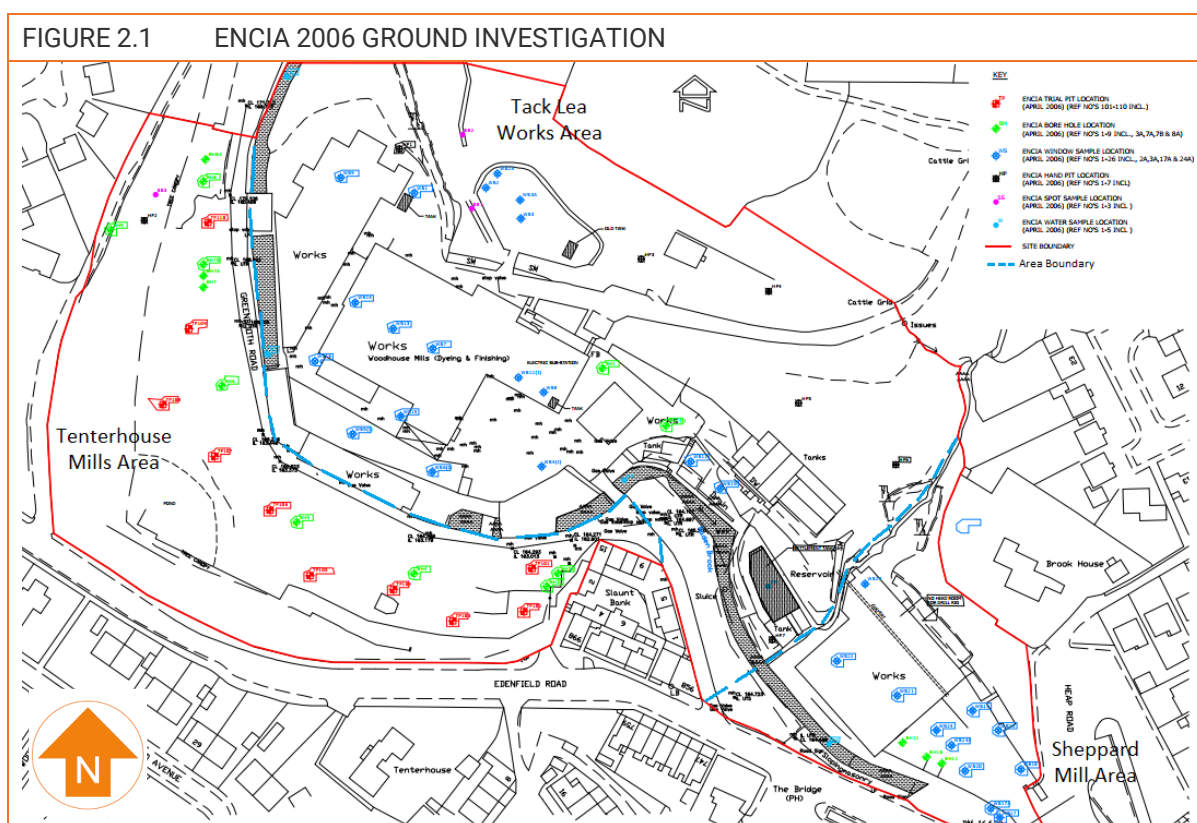
- ✿ Encia Consulting Limited (Encia), was commissioned to carry out a geo-environmental appraisal of land at Greenbooth Road, Norden, in support of proposals to develop the site for residential end use, comprising two to three-storey residential dwellings with associated gardens and adoptable roads and sewers.
- ✿ Encia's 2005 investigation covered three distinct areas; the Tack Lea Works area, the Sheppard Mill area and the Tenterhouse Mill area. Encia's 2006 report covered a wider area than is being considered within this E3P report, and as such, information relating to the Tenterhouse Mill area will not be discussed further unless considered pertinent to this report.
- ✿ Anecdotal evidence indicates the presence of a culverted watercourse running in a south-easterly direction beneath the former mill building in the Tack Lea Works area before discharging into Naden Brook. It is considered possible that this culvert channels water rising from a spring beneath the former mill building. Furthermore, it is understood that another 'spring' and stone-lined well is located in the basement area of the former dye house in the Tack Lea Works area.
- ✿ In the Tack Lea Works area, the old boiler house was noted to house an electricity sub-station and above-ground fuel tank.
- ✿ The eastern portion of the Tack Lea Works area is occupied by several disused filter beds/tanks which were formerly used to treat drainage from the mill building prior to discharge into the Naden Brook. It is understood that the current works are attached to the mains sewer drainage with an on-site pre-treatment facility located in the basement of the dye house.
- ✿ Conversations held with the site owner indicate that a culvert is located beneath the mill building in the Sheppard Mill area, running in a north-westerly direction before discharging into the Woodhouse Lane Brook.
- ✿ Japanese Knotweed was identified in parts of the Tenterhouse Mill area (located off-site to the southwest).
- ✿ Anecdotal evidence suggests that demolition materials were deposited in the eastern section of the Tack Lea Works area following the demolition of the old mill buildings. As such, deep-fill deposits are expected to be present adjacent to Naden Brook.
- ✿ Rochdale MBC hold records of one landfill site located in the eastern section of the Tack Lea Works area. The Waste Management License was issued on 1st June 1987 to Tack Lea Works. It is understood that the site was licensed to accept 'building wastes' to be used for 'land reclamation, tipping and landscaping'.



Encia's 2006 scope of works comprised of the following:

- Tack Lea Works area: three hand dug pits (HP1, HP5 & HP6; and 1 no. on Sheppard Mill area – HD7) to between 0.45 m and 0.80 m bgl; two cable percussive boreholes (BH1 & BH2) to between 0.40 m and 5.30 m bgl; and fourteen window sample boreholes (WS1, WS4-WS16) to between 0.65 m and 6.00 m bgl. Surface water samples were collected from Naden Brook (W4) and the setline tank/reservoir (W5). Groundwater was collected from BH10, BH12, WS19. Leaching tests were carried out on soil samples from WS17A, WS19, WS20, WS21 and WS25.
- Sheppard Mill area: one hand-dug pit (HP7) to a maximum depth of 0.50 m bgl; three cable percussive boreholes (BH10-BH12) to between 2.50 m and 4.32 m bgl; and eleven window sample boreholes (WS17, WS17A, WS18-WS24, WS24A & WS25) to between 0.40 m and 5.10 m bgl. Surface water samples were collected from Naden Brook (W1 to W3). Groundwater was collected from WS5 and WS12. Leaching tests were carried out on soil samples from HP1, BH2, WS4, WS6, WS8, WS9, WS11 and WS12.

A snapshot of the Encia 2006 Ground Investigation is indicated in Figure 2.1.



Hardstanding was found to be from 0.20 m to 0.30 m thick apart from beneath the main Tack Lea works building (Woodhouse Mills), with thicknesses of 0.70 m to 1.10 m of concrete slabs.

Made Ground was encountered in all exploratory hole locations reaching a maximum depth of 5.00 m bgl in BH2 (centre of the Tack Lea Works area) and 5.10 m bgl in WS17A (south-eastern section of the Sheppard Mill area). The base of the Made Ground could not be determined in a number of positions due to the presence of obstructions (e.g., concrete hardstanding, sandstone boulders). Made Ground was generally shallowest (< 1.00 m) in elevated locations above the valley floor (i.e., the north-western section of the Tack Lea Works area).



- ✚ In and around the Tack Lea Works area, Made Ground deposits were generally between 1.00 m and 2.00 m thick, although deeper Made Ground was encountered in the vicinity of the former boiler house (associated with infilled reservoir) and around the filter beds/tanks to the east. In these areas, Made Ground was found to range from 2.20 m to 5.00 m bgl. For the Sheppard Mill area, the Made Ground deposits were generally between 1.00 m and 2.00 m thick, although deeper Made Ground was encountered in the former reservoir areas in the south and southeast. In these areas, Made Ground was found to range from 2.50 m and 4.30 m bgl.
- ✚ The Made Ground on-site generally comprised a heterogeneous mixture of materials and was broadly categorised into three broad types:
 - Reworked Natural Soils – typically granular or cohesive deposits with occasional cobbles of sandstone and minimal potentially contaminative fragments (i.e., ash or clinker), present at shallow depth in undeveloped, vegetated, and wooded areas in the northern and eastern parts of the site and depth beneath the southern and western site areas.
 - Mixed Granular and Cohesive Ashy Fill – both granular and cohesive fill, containing fragments of ash, clinker, brick and concrete etc; present at various depths across much of the central, western, and southern parts of the site.
 - General Demolition Material – predominantly coarse fragments of concrete, brick and sandstone with many cobbles and boulders; interpreted as general demolition material; most extensive in the southern and south-eastern parts of the site (Shepherd Mill area).
- ✚ Natural drift deposits were found to be absent in the majority of locations within the Tack Lea Works and Sheppard Mill areas. Where drift deposits were encountered (southern boundary of Tack Lea Works area and north-eastern boundary of Sheppard Mill area), they typically comprised gravelly clay with cobbles of sandstone and saturated fine to coarse sand and gravel, extending vertically to depths of approximately 2.00 m to 4.00 m bgl.
- ✚ Shallow bedrock of sandstone was encountered in the central and western sections of the Tack Lea Works area at depths typically <2.00 m bgl. To the north of the Tack Lea Works area, bedrock can be seen outcropping in the valley and hillside. To the east of the Tack Lea Mill buildings and in the Shepherd Mill area, bedrock was found to be deeper and was encountered at depths ranging from 4.30 m (BH11) to 5.00 m bgl (BH2).
- ✚ Visual and olfactory evidence of contamination was identified in a number of locations within the Sheppard Mill area, comprising slightly to very strong hydrocarbon odours within the Made Ground between 0.20 m and 4.30 m bgl.
- ✚ Some perched groundwater was found to be present within the Made Ground beneath the site, ranging in depth between 1.60 m and 3.10 m bgl. However, the 'true' groundwater was found to be present within the natural drift strata in the southern section of the Tack Lea Works area, ranging in depth between 0.90m and 2.10 m bgl. Groundwater appears to be flowing in a southern direction and being in hydraulic continuity with the Naden Brook. Beneath the Sheppard Mill area, groundwater levels appear to be perched in nature and range between 1.90 m to 4.80 m bgl, albeit that hydraulic continuity is likely within proximity to Naden Brook.
- ✚ Chemical analysis of soils identified arsenic contamination within the Made Ground across the Tack Lea Works area between 0.40 m and 0.70 m bgl. Hotspots of lead and mercury were also identified within the Made Ground in the north-western section of the Tack Lea Works area (WS09 at 0.50 m bgl, associated with a former dye works). Hotspots of hydrocarbons were identified within the Made Ground beneath the Sheppard Mill area (associated with the infilled reservoirs and historical tank) between 0.40 m and 1.00 m bgl.



- ✿ Elevated concentrations of phytotoxic elements (copper, nickel, zinc, and total sulphate) were identified within the Made Ground on the Tack Lea Works area in the north-western (associated with the former dye works), southern, and eastern section (associated with the filter beds/tanks) between 0.40 m and 1.00 m bgl.
- ✿ Elevated concentrations of leachable PAH and copper were identified within the Made Ground beneath the Sheppard Mill area (associated with the infilled reservoirs) between 0.50 m and 0.90 m bgl.
- ✿ Significant chromium, PAH, DRO and slight LRO contaminated groundwater was identified beneath the Shepherd Mill area (associated with the infilled reservoirs and historical tank). Elevated chromium was also identified within groundwater beneath the Tack Lea Works area and surface water samples from Naden Brook. Elevated ammoniacal nitrogen was identified within one groundwater sample located along the southern boundary of the Tack Lea Works area (bordering Naden Brook) and one surface water sample (filter bed/pond in the eastern section of Tack Lea Works area). Elevated copper was also recorded in the centre of the Tack Lea Works area (associated with the old boiler house/infilled reservoir).
- ✿ As the former Tenterhouse Mill site was used as a tannery during the 1960s and 1970s, thirteen soil samples were taken from across the site and submitted for anthrax bacteria testing. Targeted tests were also performed on samples of 'old leather hides' found in and around a buried chamber in the north-western part of the Tenterhouse Mill site. The test results showed that no anthrax spores/bacteria were present in the samples submitted for analysis.
- ✿ Elevated carbon dioxide concentrations (i.e., above 1.5%) have been recorded in seven monitoring wells on at least one occasion to date. The maximum elevated concentration recorded was 6.8 % in WS19 (Sheppard Mill area). No elevated concentrations of methane have been detected. No significantly elevated positive gas flow rates have been recorded. An initial appraisal of the hazardous gas regime beneath the site indicated that Characteristic Situation 1 classification would apply for the site. However, due to the relatively short period of monitoring undertaken, Encia recommended that gas protective measures in general accordance with Characteristic Situation 2 classifications be adopted as a precaution in any future development at the site.
- ✿ In terms of proposed foundations, predominantly strip footings/trench fill were considered suitable for the western and central sections of the Tack Lea Works area with piled foundations for the eastern section of the Tack Lea Works area and Sheppard Mill area.

2.1.2. LK CONSULT 2020 REPORT

- ✿ LK Consult was commissioned to carry out a contemporary risk assessment of the existing desk study and chemical data from Encia's 2006 report for land at Greenbooth Road, Norden in support of proposals to develop the site for residential end-use with associated access, parking and landscaping.
- ✿ The site may be considered as two areas of land. The central and western area is the former Tack Lea Works area with the eastern area the former Shepherd Mill area. These areas are split by Woodhouse Lane Brook which flows south into Naden Brook.
- ✿ Tack Lea Works: Two buildings remnant with a coal bunker on the northern boundary. The majority of hardstanding remains. Slopes to the north and east are heavily vegetated.
- ✿ Shepherd Mill: No buildings remain, although substantial hardstanding remains. Slopes to the northeast and southwest are heavily vegetated.



- ✚ Anecdotal evidence suggests that demolition materials were deposited alongside Naden Brook following the demolition of the old mill buildings and as such, deep fill deposits are expected to be present adjacent to the brook. An online search of records held by Rochdale Metropolitan Borough Council indicated that a historical landfill was created on-site under planning permission for “reclamation, tipping and landscaping”. Existing settlement tanks were filled on the condition that building waste and subsoil from the curtilage of Woodhouse Mill should be used and no off-site import. GMWDA reported in May 1989 that they had no objection to the extension of time application and that the site had been operated to a satisfactory standard.
- ✚ The coal bunker in the Tack Lea Works area has a suspected asbestos cement roof.
- ✚ Radon and specific SVOCs/VOCs from dye-works, bleach works, and spray booth/vehicle repair, PCBs and mineral oils should be considered as potential contamination sources/types.
- ✚ Asbestos in the form of Amosite was identified in the south-eastern section of the Sheppard Mill area (WS18) at a depth of 0.60-0.70 m bgl. Asbestos in the form of cement (likely chrysolite) was encountered at the surface in the eastern section of the Tack Lea Works area (associated with the filter beds/tanks area). These detections of asbestos had not been discussed within the Encia 2006 report.
- ✚ Soil Risk Assessment: elevated concentrations of contaminants within the shallow Made Ground (<1.00 m) have been identified on-site:
 - Elevated levels of lead in the Tack Lea Works area in the north-western (associated with the former dye works), southern, and eastern sections (associated with the filter beds/tanks), as well as the south-eastern section of the Sheppard Mill area.
 - Elevated levels of benzo(a)pyrene (used as a surrogate marker) on the Tack Lea Works area in the central (associated with the old boiler house and infilled reservoir) and eastern section (associated with the filter beds/tanks), as well as the Sheppard Mill area in the southern (associated with the infilled reservoir) and south-eastern (associated with former tank and Works) sections.
 - Elevated levels of naphthalene on the Tack Lea Works area in the central section (associated with the old boiler house and infilled reservoir), as well as the Sheppard Mill area in the southern (associated with infilled reservoir) and south-eastern (associated with former tank and Works) sections.
 - Elevated levels of 2-methylnaphthalene on the Sheppard Mill area in the southern (associated with infilled reservoir) and south-eastern (associated with former tank and Works) sections.
 - Elevated levels of aromatic TPHs on the Sheppard Mill area within the south-eastern (associated with former tank and Works) sections.
 - Elevated levels of 1,2,4-trimethylbenzene on the Sheppard Mill area within the south-eastern section (associated with the former tank).
- ✚ The source of the contamination is expected to be the ash, clinker, hydrocarbons (Shepherd Mill area) and demolition materials noted in the Made Ground. In addition, asbestos fibres were detected in one location and pieces of suspected asbestos cement were identified at the surface of another sampling location; however, these were not tested. The probability of contamination affecting site users was considered likely and remediation was recommended.



- ☛ **Controlled Waters Risk Assessment:** Made Ground across the site appears to be a source of low levels of leachable copper and zinc. There was also sporadic lead and mercury detected in leaching tests. However, elevated concentrations are considered to be caused by the leaching test preparation.
- ☛ Similarly, low levels are present in the groundwater and surface water samples. Limited ammoniacal nitrogen in sample W5 is likely related to the water sitting and residing filter beds/settling tank and within the area of infilled ground. The elevated PAH and TPH contamination are generally located in the Sheppard Mill area and co-incidental with the visual and olfactory observations of hydrocarbon contamination (associated with the former tank and Works); remediation was recommended in the Sheppard Mill area.
- ☛ **Ground Gas Risk Assessment:** Previous monitoring covered a range of atmospheric pressures and was considered to be a reasonable characterisation of the gas risk. The maximum GSV was 0.0068l/hr which equates to CS1 / Green. Carbon dioxide concentrations were recorded above 5%v/v on two occasions in WS19 only (Sheppard Mill area, associated with the former tank). The levels are only marginally elevated (maximum 6.8%v/v), and the concentrations recorded were relatively consistent. Taking this into account and the very low flow rates recorded, CS1 classification was considered appropriate.
- ☛ **Concrete classification:** The concentrations of soluble sulphate in the soil when contrasted to BRE Digest 200535 categorise the concrete requirement as DS-2 AC-3z in the Made Ground and DS-1 AC1 in the natural strata.
- ☛ **Potable Water Supply:** Probability of organic contaminants affecting potable water pipes is considered likely; remediation (i.e., barrier pipe) was likely to be required (subject to further risk assessment).
- ☛ **Phytotoxic Risk Assessment:** Sporadic elevated zinc concentrations in north-western and southern sections of the Tack Lea Works area were identified. Probability of phytotoxic contaminants affecting vegetation was considered likely; minor remediation (cover system) recommended.
- ☛ Remedial measures recommended for the site included earthworks inspections, hydrocarbon removal/treatment on Sheppard Mill, further chemical analysis and generic risk assessment of surface waters, an environmental cover system, basic Radon protective measures, and grubbing out of in-ground structures.
- ☛ In relation piling in contaminated land, given the depth of Made Ground, it is expected that some buildings may be piled into the bedrock. This may provide a preferential pathway for any mobile contaminants not previously identified to the Secondary A Aquifer. Once the method of piling has been determined, good practice for the drilling of piles on contaminated sites should be adhered to, such as guidance provided by the Environment Agency.

2.2. GENERAL OVERVIEW

The E3P ground investigation has been designed based on the findings of the desk study, with exploratory holes advanced to target specific potential contaminant sources identified within the previous ground investigations. The investigation has also been used to collect geotechnical information to assist in the design and construction of the proposed development.

Exploratory fieldwork was completed between 15th November -18th November 2022. The works are summarised in Table 2.1.



2.3. LIMITATIONS OF THE INVESTIGATION

Access to the eastern section of the Tack Lea Works area was limited due to dense vegetation, variable topographical level changes, existing structures (former filter beds/tanks and reservoirs) and Woodhouse Lane Brook, which separates the Tack Lea Works area and Sheppard Mill area.

Five former buildings were present in the central section of the Tack Lea Works area; no access was gained to the interiors of these buildings during the investigation.

Access to the northern and eastern sections of the Tack Lea Works area and the northern section of the Sheppard Mill area was limited due to significant topographical level changes (i.e., slopes).

Due to significant concrete and brick obstructions and basement features, which are indicative of relict foundations from former buildings, the full thickness of the Made Ground could not be proven across the vast majority of the site. Further investigations will be required to prove the depth to Made Ground across the site.

E3P were unable to identify the locations of the culverted watercourses and springs associated with the former mill buildings believed to be present on-site. However, during the site walkover, a spring was identified in the far northwest part of the Tack Lea works area within an area of outcropping bedrock.

2.4. SCOPE OF INVESTIGATION

TABLE 2.1 SUMMARY OF FIELDWORK IN TACK LEA WORKS AREA

POTENTIAL SOURCE/RATIONALE	LOCATION HOLE	TYPE	MAXIMUM DEPTH (m bgl)	MONITORING WELLS RESPONSE ZONE (m bgl)
General Ground Conditions, Including the Presence/Nature of Obstructions	WS107	Window Sample Borehole	3.70	1.00 – 3.00
	WS108		1.25	0.50 – 1.00
	WS113		0.40	N/A
	WS114		3.09	1.00 – 3.00
	WS115		3.45	1.00 – 3.00
	TP106	Mechanically Excavated Trial Pit	1.80	N/A
	TP107		1.10	N/A
	TP108		1.20	N/A
	TP116		1.40	N/A
	TP119		1.60	N/A
	TP120		0.90	N/A
	CP101	Cable Percussion Borehole	15.00	1.00 – 5.00



POTENTIAL SOURCE/RATIONALE	LOCATION HOLE	TYPE	MAXIMUM DEPTH (m bgl)	MONITORING WELLS RESPONSE ZONE (m bgl)
Former Buildings	WS101	Window Sample Borehole	4.50	1.00 – 3.00
	WS103		3.45	N/A
	WS105		2.58	1.00 – 2.50
	WS106		0.30	N/A
	WS106a		0.68	N/A
	WS109		0.60	N/A
	WS109a		0.50	N/A
	WS110		0.65	N/A
	WS110a		0.63	N/A
	WS111		4.65	N/A
	WS112		3.00	N/A
	WS116		0.78	N/A
	TP103	Mechanically Excavated Trial Pit	1.90	N/A
	TP104		0.80	N/A
	TP105		1.20	N/A
	TP109		0.70	N/A
	TP110		1.50	N/A
	TP111		0.50	N/A
	TP112		0.40	N/A
	TP113		1.10	N/A
	TP114		1.50	N/A
	TP117		2.10	N/A
	TP118		0.80	N/A
	CP102	Cable Percussion Borehole	7.00	N/A
Former Reservoir	WS102	Window Sample Borehole	3.45	N/A
	WS104		0.68	N/A
BRE 365 Soakaways	TP101	Mechanically Excavated Trial Pit	2.10	N/A
	TP115		2.20	N/A



POTENTIAL SOURCE/RATIONALE	LOCATION HOLE	TYPE	MAXIMUM DEPTH (m bgl)	MONITORING WELLS RESPONSE ZONE (m bgl)
Former landfill	HP101	Hand pit	0.60	N/A
	HP102		0.70	
	HP103		0.50	
	HP104		0.40	
	HP105		0.20	
Earthen Bund	Bund01	Surface sample	N/A	N/A

TABLE 2.2 SUMMARY OF FIELDWORK IN THE SHEPPARD MILL AREA

POTENTIAL SOURCE/RATIONALE	LOCATION HOLE	TYPE	MAXIMUM DEPTH (m bgl)	MONITORING WELLS RESPONSE ZONE (m bgl)
General Ground Conditions Including the Presence/Nature of Obstructions (including former buildings)	TP102	Mechanically Excavated Trial Pit	2.00	N/A
	TP121		0.60	N/A
	TP122		2.20	2.00 – 4.00
	TP123		2.20	N/A
	TP124		1.60	N/A
	TP125		2.10	N/A
	TP126		1.60	N/A
	TP127		1.90	N/A
	TP128		1.80	N/A
	TP129		1.90	N/A
	TP130		1.50	N/A
	WS117	Window Sample Borehole	5.45	1.00 – 3.00
	WS118		0.40	N/A
	WS118a		0.40	N/A
	WS122		4.45	N/A
	WS123		1.65	N/A
	WS119		1.45	N/A
	WS120		0.80	N/A
	WS121		0.50	N/A
	WS124		3.45	0.50 – 1.50
	CP103	Cable Percussion Borehole	13.20	3.00 – 4.80



Mechanically excavated trial pits were advanced to investigate ground conditions and to retrieve environmental and geotechnical samples, spatially distributed to offer the maximum site coverage whilst also being advanced to target specific contaminant sources.

Window sample probeholes were advanced to undertake in-situ detailed geotechnical testing, obtain environmental and geotechnical samples and install groundwater and ground gas monitoring wells.

Cable percussion boreholes were advanced to investigate deeper soil horizons and retrieve environmental and geotechnical samples.

Hand pits were advanced to investigate ground conditions within the historical landfill in the eastern section of the Tack Lea Works area to retrieve environmental samples. Due to dense vegetation, variable topographical level changes and existing structures (former filter beds/tanks and reservoirs) in the eastern section of the Tack Lea Works area, ground investigations within this area were limited to hand pits only.

The sampling locations are illustrated in Drawing 16-465-005 (Appendix III). The ground conditions encountered are indicated on the logs, which are provided in Appendix V.

Return visits were made to monitor installations for groundwater level and gas concentrations. In addition, selected wells were purged, and samples of groundwater were recovered for chemical analysis. Surface water samples were also taken from Naden Brook and Woodhouse Lane Brook.

E3P was unable to locate and collect water samples from the culverted water courses and springs associated with the former mill buildings believed to be located on-site. With regards to the spring identified in the far northwest part of the Tack Lea works area within an area of outcropping bedrock, there was insufficient water present to collect suitable water samples.

2.5. IN-SITU STANDARD PENETRATION TESTING (SPT)

In-situ geotechnical testing was conducted using the standard penetration test (SPT) and, where the ground is granular, a 60° cone (SPT(S)) was used instead of the sampling tube. The results are shown in the probehole logs in Appendix V, presented in Table 3.6, and discussed in Section 5.

2.6. PERMEABILITY TESTS

BRE 365 Soakaway testing was undertaken over a 24-hour period within the trial pits completed as TP101 and TP115. The results are presented in Table 3.10 and the test certificates are included in Appendix IX.

2.7. LABORATORY ANALYSIS

Selected soil samples were submitted for a range of chemical analyses comprising:

-  Metals;
-  pH, total sulphate, water-soluble sulphate (2:1 extract);
-  Sulphide;
-  Cyanide;
-  Phenols;



- ✦ Total and speciated polycyclic aromatic hydrocarbons (PAHs);
- ✦ Semi-Volatile Organic Compounds (SVOC);
- ✦ Volatile Organic Compounds (VOC);
- ✦ Asbestos identification and quantification;
- ✦ Speciated and banded total petroleum hydrocarbon (TPH); and,
- ✦ Polychlorinated Biphenyls (PCBs).

I2 Analytical undertook the analytical work and the testing results are included in Appendix VI and discussed in Section 4.

Selected groundwater and surface water samples were submitted for a range of chemical analysis comprising:

- ✦ Metals;
- ✦ Cyanide;
- ✦ Phenols;
- ✦ Total and speciated polycyclic aromatic hydrocarbons (PAHs);
- ✦ Semi-Volatile Organic Compounds (SVOC);
- ✦ Volatile Organic Compounds (VOC); and,
- ✦ PFAS / PFOS.

I2 Analytical undertook the analytical work and testing results are indicated in Appendix VI and discussed in Section 4.

Selected samples were submitted to PSL Laboratory where the following geotechnical tests were undertaken:

- ✦ Moisture Content;
- ✦ Atterberg limits determinations;
- ✦ Particle Size Distributions; and,
- ✦ One-Dimensional Consolidation Tests.

Laboratory analysis sheets are included in Appendix VIII and are summarised in Section 5.



3. GROUND AND GROUNDWATER CONDITIONS

3.1. SUMMARY OF GROUND CONDITIONS

The ground investigation generally confirms the published geology and identifies the strata set out in Table 3.1.

TABLE 3.1 SUMMARY OF STRATA

HOLE	DEPTH TO STRATUM (m bgl)				
	MADE GROUND	SOFT TO FIRM CLAY	STIFF TO VERY STIFF CLAY	GRAVEL	SAND
WS101	0.00-3.00	3.00-4.00	4.00-4.50	-	-
WS102	0.00-0.80	0.80-2.00	-	2.00-3.45	-
WS103	0.00-0.60	-	-	0.60-2.45	-
WS104	0.00-0.68*	-	-	-	-
WS105	0.00-1.00	-	-	1.00-2.50	-
WS106	0.00-0.30*	-	-	-	-
WS106a	0.00-0.68*	-	-	-	-
WS107	0.00-2.00	2.00-3.00	-	3.00-3.70	-
WS108	0.00-1.25*	-	-	-	-
WS109	0.00-0.60*	-	-	-	-
WS109a	0.00-0.60*	-	-	-	-
WS110	0.00-0.60*	-	-	-	-
WS110a	0.00-0.63*	-	-	-	-
WS111	0.00-1.00	-	1.00-3.00	3.00-4.65	-
WS112	0.00-1.20	-	1.20-3.00	-	-
WS113	0.00-0.40*	-	-	-	-
WS114	0.00-0.50	0.50-1.00	-	1.00-4.08	-
WS115	0.00-3.45*	-	-	-	-
WS116	0.00-0.50	-	0.50-0.78	-	-
WS117	0.00-3.00	-	3.00-5.45	-	-
WS118	0.00-0.40*	-	-	-	-
WS118a	0.00-0.40*	-	-	-	-
WS119	0.00-0.80	0.80-1.00	-	1.00-1.45	-
WS120	0.00-0.50	-	-	0.50-0.80	-
WS121	0.00-0.50*	-	-	-	-
WS122	0.00-2.00	2.00-4.00	4.00-4.45	-	-
WS123	0.00-1.65*	-	-	-	-
WS124	0.00-3.45*	-	-	-	-



HOLE	DEPTH TO STRATUM (m bgl)				
	MADE GROUND	SOFT TO FIRM CLAY	STIFF TO VERY STIFF CLAY	GRAVEL	SAND
TP101	0.00-0.80	-	0.80-2.10	-	-
TP102	0.00-2.00*	-	-	-	-
TP103	0.00-1.10	-	-	-	1.10-1.90
TP104	0.00-0.80*	-	-	-	-
TP105	0.00-1.20*	-	-	-	-
TP106	0.00-1.80*	-	-	-	-
TP107	0.00-1.10*	-	-	-	-
TP108	0.00-1.20*	-	-	-	-
TP109	0.00-0.70*	-	-	-	-
TP110	0.00-1.50	1.50-1.60	-	-	1.60-1.80
TP111	0.00-0.50*	-	-	-	-
TP112	0.00-0.40*	-	-	-	-
TP113	0.00-1.10*	-	-	-	-
TP114	0.00-1.50*	-	-	-	-
TP115	0.00-1.10	1.10-2.20	-	-	-
TP116	0.00-1.40*	-	-	-	-
TP117	0.00-1.00	1.00-2.10	-	-	-
TP118	0.00-0.80*	-	-	-	-
TP119	0.00-1.50	-	-	1.50-1.60	-
TP120	0.00-0.90*	-	-	-	-
TP121	0.00-0.60*	-	-	-	-
TP122	0.00-1.50	1.50-2.20	-	-	-
TP123	0.00-2.20	-	-	-	-
TP124	0.00-0.50	0.50-1.60	-	-	-
TP125	0.00-1.00	1.00-2.10	-	-	-
TP126	0.00-1.60*	-	-	-	-
TP127	0.00-1.90*	-	-	-	-
TP128	0.00-1.80*	-	-	-	-
TP129	0.00-1.90*	-	-	-	-
TP130	0.00-1.20	-	-	1.20-1.50	-
CP101	0.00-3.70	-	4.90-15.00	3.70-4.90	-
CP102	0.00-5.80	-	-	5.80-7.00	-
CP103	0.00-3.00	-	4.80-12.10 12.30-13.20	3.00-4.80 12.10-12.30	-



HOLE	DEPTH TO STRATUM (m bgl)				
	MADE GROUND	SOFT TO FIRM CLAY	STIFF TO VERY STIFF CLAY	GRAVEL	SAND
HP101	0.00-0.60*	-	-	-	-
HP102	0.00-0.70*	-	-	-	-
HP103	0.00-0.50*	-	-	-	-
HP104	0.00-0.40*	-	-	-	-
HP105	0.00-0.20*	-	-	-	-

*Denotes Base of Made Ground not found

3.2. MADE GROUND

Made Ground deposits were encountered within all exploratory hole locations to depths ranging between 0.00 m and 5.80 m bgl. However, in 34 locations, the full thickness of Made Ground could not be proven due to significant concrete and brick obstructions and basement features, which are indicative of relict foundations from the former buildings. The five hand pit locations within the eastern section of the Tack Lea Works area were all terminated within Made Ground.

In all locations except WS101 and WS103 (central section of the Tack Lea Works area), concrete was encountered to a maximum proven depth of 0.68 m bgl (WS104). The concrete often contained rebar. In WS101 and WS103, dark brown clay with occasional rootlets (reworked topsoil) was encountered.

In the majority of locations, the concrete was underlain by brown sandy gravel with gravels of sandstone, mudstone, limestone, concrete, and brick.

In two locations in the Tack Lea Works area (TP118, and TP120) and one location in the Sheppard Mill area (TP121) a brown gravelly sand was encountered.

In five locations in the Tack Lea Works area (WS101, WS102, WS103, WS107 and WSS14) and three locations in the Sheppard Mill area (WS119, WS122 and WS124) a brown gravelly clay was encountered underneath the sandy gravel.

In one location within the Tack Lea Works area (TP113), a dark brown blackish slightly clayey slightly gravelly silt and a white sandy silt was encountered.

Frequent fragments of ceramic, glass, wood, and metal were encountered within the Made Ground. Ash was also encountered in one location within the Tack Lea Works area (WS115) and one location in the Sheppard Mill area (WS123). Intact empty plastic bottles of fabric softener were also encountered in one location within the Tack Lea Works area (TP114).

A Depth of Made Ground Plan is presented as Drawing 16-465-006 in Appendix III.

3.3. DRIFT DEPOSITS

Drift deposits were encountered within twenty-four exploratory hole locations between depths of 0.50 m and 15.00 m bgl. The drift deposits varied, with the majority comprising a brown gravelly CLAY with gravels of mudstone and sandstone. The strength of CLAY varied from soft to very stiff.

In seven locations across the Tack Lea Works area (TP130, WS102, WS103, WS105, WS107, WS111 and WS114) and two locations within the Sheppard Mill area (WS119 and WS120), a brown clayey GRAVEL was encountered with gravels of sandstone and mudstone.



In TP103 (south-western boundary of the Tack Lea Works area), a brown gravelly SAND was encountered with gravels of sandstone and mudstone.

3.4. SOLID GEOLOGY

The solid bedrock geology was not encountered during this phase of investigation. There are no BGS boreholes within close proximity to the site.

In the Encia Consulting 2006 Report, shallow bedrock of sandstone was encountered in the central and western sections of the Tack Lea Works area at depths typically <2.00 m bgl. To the north of the Tack Lea Works area, bedrock can be seen outcropping in the valley and hillside. To the east of the former Tack Lea Mill Buildings and in the Sheppard Mill area, bedrock was found to be deeper and was encountered at depths ranging between 4.30 m and 5.00 m bgl.

3.5. GROUNDWATER

Groundwater strikes were encountered as seepages. The depth of the seepages is shown on the exploratory hole records in Appendix V and are summarised in Table 3.2.

TABLE 3.2 SUMMARY GROUNDWATER STRIKES

LOCATION	DEPTH TO STRIKE (m bgl)	NOTES
TP103	1.50	Seepage
TP114	1.50	Seepage
TP119	1.50	Moderate ingress
TP130	1.40	Seepage
WS122	2.50	Seepage with sheen

3.6. VISUAL AND OLFACTORY EVIDENCE OF CONTAMINATION

Visual and olfactory evidence of potential contamination has been identified during the ground investigation and these are summarised in Table 3.3.

TABLE 3.3 SUMMARY OF VISUAL AND OLFACTORY EVIDENCE OF CONTAMINATION

LOCATION	DEPTH (m bgl)	STRATUM	NOTES
TP116	1.10	Made Ground	Slight hydrocarbon odour
TP122	0.60	Made Ground	Slight hydrocarbon odour
TP123	0.60	Made Ground	Slight hydrocarbon odour
TP124	0.60	Made Ground	Slight hydrocarbon odour
TP125	1.00	Made Ground	Slight hydrocarbon odour
TP126	0.70	Made Ground	Slight hydrocarbon odour
WS107	2.00	CLAY	Slight hydrocarbon odour
WS117	2.00	Made Ground	Slight hydrocarbon odour
WS122	2.00	CLAY	Slight hydrocarbon odour and sheen
CP103	3.00	GRAVEL	Slight hydrocarbon odour



LOCATION	DEPTH (m bgl)	STRATUM	NOTES
HP105	0.20	Made Ground	Asbestos Containing Material

3.7. SOIL CONSISTENCY

Undrained shear strength values were measured using both field hand shear vane tests and laboratory undrained triaxial tests. Results of the tests are presented in Table 3.4 and Table 3.5, which indicate the clay soils to vary between stiff and very stiff. Strength test data is generally consistent with the field descriptions of the aforementioned soils.

TABLE 3.4 SUMMARY OF HAND SHEAR VANE TESTS

LOCATION	DEPTH (m bgl)	SHEAR STRENGTH (kPa)	CALCULATED ALLOWABLE BEARING PRESSURE (kN/m ²)	CLASSIFICATION
TP101	1.00	134	314.90	Stiff high strength CLAY
TP101	1.50	137	321.95	Stiff high strength CLAY
TP101	1.90	142	333.70	Stiff high strength CLAY
TP110	1.50	43	101.05	Firm medium strength CLAY
TP110	1.00	52	122.20	Firm medium strength CLAY
TP115	1.50	20	47.00	Soft low strength CLAY
TP115	2.00	27	63.45	Soft low strength CLAY
TP117	1.50	54	126.90	Firm medium strength CLAY
TP117	2.00	34	79.90	Soft low strength CLAY
TP122	2.00	18	42.30	Very soft very low strength CLAY
TP124	1.00	38	29.30	Soft low strength CLAY
TP124	1.50	40	94.00	Firm medium strength CLAY
TP125	1.50	53	124.55	Firm medium strength CLAY
TP125	2.00	63	148.05	Firm medium strength CLAY

Notes

ABP Calculated using Stroud and Butler et al 1974.



TABLE 3.5 SUMMARY OF UNDRAINED SHEAR STRENGTH TEST RESULTS

LOCATION	SAMPLE DEPTH (m bgl)	LAB DESCRIPTION	UNDRAINED SHEAR STRENGTH (kN/m ²)	CONSISTENCY
CP101	8.00	Firm brown slightly gravelly very sandy CLAY	65	Firm

Results of the standard penetration tests, including undrained shear strengths derived from SPTs, are included in Table 3.6.

3.8. SIDE STABILITY AND EASE OF EXCAVATION

The sides of the exploratory trial pit excavations appeared to be generally stable during natural strata excavation and unstable within Made Ground.

The presence of brick and concrete cobbles within the Made Ground deposits meant that excavation was slow through the Made Ground and in some places, Made Ground could not be fully penetrated. The natural strata were excavated with relative ease.



TABLE 3.6 STANDARD/CONE PENETRATION TEST RESULTS

BOREHOLES	DEPTH (m bgl)	MATERIAL FIELD DESCRIPTION	CPT/SPT "N" VALUE	CORRECTED "N" VALUE (N ₁) ₆₀	TERZAGHI & PECK RELATIVE DENSITY (SANDS)	EUROCODE SOIL STRENGTH	CONSISTENCY (BS 5930)	TERZAGHI & PECK APPROXIMATE UNDRAINED SHEAR STRENGTH (kN/m ²)	ALLOWABLE BEARING PRESSURE (kN/m ²)*
CP101	1	Made Ground	8	16.13	Loose	N/A	N/A	N/A	80.65
CP101	2	Made Ground	7	19.18	Loose	N/A	N/A	N/A	63.95
CP101	3	Made Ground	6	20.87	Loose	N/A	N/A	N/A	52.18
CP101	4	Sandy GRAVEL	50	211.21	Dense	N/A	N/A	N/A	422.43
CP101	5	Gravelly CLAY	14	69.69	N/A	Medium strength	Stiff	58.07	119.40
CP101	6.5	Gravelly CLAY	14	80.01	N/A	Medium strength	Stiff	57.15	117.49
CP101	9.5	Gravelly CLAY	17	109.61	N/A	Medium strength	Stiff	68.50	140.85
CP101	11	Gravelly CLAY	35	243.61	N/A	High strength	Very Stiff	135.34	278.26
CP101	12.5	Gravelly CLAY	51	372.61	N/A	Very high strength	Very Stiff	186.31	383.05
CP101	14	Gravelly CLAY	50	380.99	N/A	Very high strength	Very Stiff	173.18	356.06
CP101	15	Gravelly CLAY	50	401.79	N/A	Very high strength	Very Stiff	167.41	344.20
CP102	1.00	Made Ground	39	39.32	Dense	N/A	N/A	N/A	393.18
CP102	2.00	Made Ground	35	31.97	Dense	N/A	N/A	N/A	319.74



BOREHOLES	DEPTH (m bgl)	MATERIAL FIELD DESCRIPTION	CPT/SPT "N" VALUE	CORRECTED "N" VALUE (N ₁) ₆₀	TERZAGHI & PECK RELATIVE DENSITY (SANDS)	EUROCODE SOIL STRENGTH	CONSISTENCY (BS 5930)	TERZAGHI & PECK APPROXIMATE UNDRAINED SHEAR STRENGTH (kN/m ²)	ALLOWABLE BEARING PRESSURE (kN/m ²)*
CP102	3.00	Made Ground	50	43.48	Dense	N/A	N/A	N/A	434.83
CP102	4.00	Made Ground	24	20.28	Medium Dense	N/A	N/A	N/A	202.76
CP102	5.00	Made Ground	24	19.91	Medium Dense	N/A	N/A	N/A	199.11
CP102	6.00	Sandy GRAVEL	50	40.99	Dense	N/A	N/A	N/A	409.94
CP102	7.00	Sandy GRAVEL	50	40.68	Dense	N/A	N/A	N/A	406.78
CP103	1.00	Made Ground	18	18.15	Medium Dense	N/A	N/A	N/A	181.47
CP103	2.00	Made Ground	19	17.36	Medium Dense	N/A	N/A	N/A	173.57
CP103	3.00	Sandy GRAVEL	8	6.96	Loose	N/A	N/A	N/A	69.57
CP103	4.00	Sandy GRAVEL	21	17.74	Medium Dense	N/A	N/A	N/A	177.42
CP103	5.00	Gravelly CLAY	14	11.61	N/A	Medium strength	Stiff	58.07	119.40
CP103	6.50	Gravelly CLAY	20	16.33	N/A	High strength	Very Stiff	81.64	167.85
CP103	9.50	Gravelly CLAY	22	17.73	N/A	High strength	Very Stiff	88.65	182.27
CP103	11.00	Gravelly CLAY	50	38.67	N/A	Very high strength	Very Stiff	193.34	397.51



BOREHOLES	DEPTH (m bgl)	MATERIAL FIELD DESCRIPTION	CPT/SPT "N" VALUE	CORRECTED "N" VALUE (N ₁) ₆₀	TERZAGHI & PECK RELATIVE DENSITY (SANDS)	EUROCODE SOIL STRENGTH	CONSISTENCY (BS 5930)	TERZAGHI & PECK APPROXIMATE UNDRAINED SHEAR STRENGTH (kN/m ²)	ALLOWABLE BEARING PRESSURE (kN/m ²)*
CP103	12.50	Gravelly CLAY	50	36.53	N/A	Very high strength	Very Stiff	182.65	375.53
CP103	13.20	Gravelly CLAY	50	35.62	N/A	Very high strength	Very Stiff	178.10	366.17
WS101	1.00	Made Ground	1	1.01	Very Loose	N/A	N/A	N/A	10.08
WS101	2.00	Made Ground	8	7.31	Loose	N/A	N/A	N/A	73.08
WS101	3.00	Gravelly CLAY	9	7.83	N/A	Low Strength	Firm	39.13	80.46
WS101	4.00	Gravelly CLAY	28	23.66	N/A	High Strength	Very stiff	118.28	243.18
WS101	4.20	Gravelly CLAY	50	42.06	N/A	Very High Strength	Very stiff	210.30	432.38
WS102	1.00	Gravelly CLAY	3	3.02	N/A	Very low strength	Soft	15.12	31.09
WS102	2.00	Clayey GRAVEL	8	7.31	Loose	N/A	N/A	N/A	73.08
WS102	3.00	Clayey GRAVEL	50	43.48	Dense	N/A	N/A	N/A	434.83
WS103	1.00	Clayey GRAVEL	7	7.06	Loose	N/A	N/A	N/A	70.57
WS103	2.00	Clayey GRAVEL	50	45.68	Dense	N/A	N/A	N/A	456.77
WS105	1.00	Clayey GRAVEL	6	6.05	Loose	N/A	N/A	N/A	60.49
WS105	2.00	Clayey GRAVEL	17	15.53	Medium Dense	N/A	N/A	N/A	155.30
WS105	2.50	Clayey GRAVEL	50	44.41	Dense	N/A	N/A	N/A	444.09



BOREHOLES	DEPTH (m bgl)	MATERIAL FIELD DESCRIPTION	CPT/SPT "N" VALUE	CORRECTED "N" VALUE (N ₁) ₆₀	TERZAGHI & PECK RELATIVE DENSITY (SANDS)	EUROCODE SOIL STRENGTH	CONSISTENCY (BS 5930)	TERZAGHI & PECK APPROXIMATE UNDRAINED SHEAR STRENGTH (kN/m ²)	ALLOWABLE BEARING PRESSURE (kN/m ²)*
WS107	1.00	Made Ground	10	10.08	Medium Dense	N/A	N/A	N/A	100.81
WS107	2.00	Silty CLAY	6	5.48	N/A	Low Strength	Firm	27.41	56.35
WS107	3.00	Clayey GRAVEL	37	32.18	Dense	N/A	N/A	N/A	321.77
WS107	3.40	Clayey GRAVEL	50	42.91	Dense	N/A	N/A	N/A	429.09
WS108	1.00	Made Ground	50	50.41	Dense	N/A	N/A	N/A	504.07
WS111	1.00	Silty CLAY	8	8.07	N/A	Medium Strength	Stiff	40.33	82.91
WS111	2.00	Silty CLAY	11	10.05	N/A	Medium Strength	Stiff	50.24	103.30
WS111	3.00	Sandy GRAVEL	32	27.83	Medium Dense	N/A	N/A	N/A	28.29
WS111	4.00	Sandy GRAVEL	18	15.21	Medium Dense	N/A	N/A	N/A	152.07
WS111	4.45	Sandy GRAVEL	50	41.82	Dense	N/A	N/A	N/A	418.18
WS112	1.00	Made Ground	11	11.09	Medium Dense	N/A	N/A	N/A	110.90
WS112	2.00	Silty CLAY	13	11.88	N/A	Medium Strength	Stiff	59.38	122.09
WS112	2.70	Silty CLAY	50	44.01	N/A	Very High Strength	Very Stiff	220.03	452.37



BOREHOLES	DEPTH (m bgl)	MATERIAL FIELD DESCRIPTION	CPT/SPT "N" VALUE	CORRECTED "N" VALUE (N ₁) ₆₀	TERZAGHI & PECK RELATIVE DENSITY (SANDS)	EUROCODE SOIL STRENGTH	CONSISTENCY (BS 5930)	TERZAGHI & PECK APPROXIMATE UNDRAINED SHEAR STRENGTH (kN/m ²)	ALLOWABLE BEARING PRESSURE (kN/m ²)*
WS114	1.00	Sandy GRAVEL	25	25.20	Medium Dense	N/A	N/A	N/A	252.04
WS114	2.00	Sandy GRAVEL	17	15.53	Medium Dense	N/A	N/A	N/A	155.30
WS114	3.00	Clayey GRAVEL	19	16.52	Medium Dense	N/A	N/A	N/A	165.23
WS114	4.00	Clayey GRAVEL	50	42.24	Dense	N/A	N/A	N/A	422.43
WS115	1.00	Made Ground	2	2.02	Very Loose	N/A	N/A	N/A	20.16
WS115	2.00	Made Ground	5	4.57	Loose	N/A	N/A	N/A	45.68
WS115	3.00	Made Ground	50	43.48	Dense	N/A	N/A	N/A	434.83
WS117	1.00	Made Ground	19	19.15	Medium Dense	N/A	N/A	N/A	191.55
WS117	2.00	Made Ground	9	8.22	N/A	Medium Strength	Stiff	41.11	84.52
WS117	3.00	Silty CLAY	17	14.8	N/A	Medium Strength	Stiff	73.92	151.98
WS117	4.00	Silty CLAY	18	15.21	N/A	High Strength	Very Stiff	76.04	156.33
WS117	5.00	Silty CLAY	18	14.93	N/A	Medium Strength	Stiff	74.67	153.51
WS119	1.00	Clayey GRAVEL	50	50.41	Dense	N/A	N/A	N/A	504.07
WS122	1.00	Made Ground	0	0.00	N/A	N/A	N/A	N/A	N/A



BOREHOLES	DEPTH (m bgl)	MATERIAL FIELD DESCRIPTION	CPT/SPT "N" VALUE	CORRECTED "N" VALUE (N ₁) ₆₀	TERZAGHI & PECK RELATIVE DENSITY (SANDS)	EUROCODE SOIL STRENGTH	CONSISTENCY (BS 5930)	TERZAGHI & PECK APPROXIMATE UNDRAINED SHEAR STRENGTH (kN/m ²)	ALLOWABLE BEARING PRESSURE (kN/m ²)*
WS122	2.00	Gravelly CLAY	7	6.39	N/A	Low Strength	Firm	31.97	65.74
WS122	3.00	Gravelly CLAY	8	6.96	N/A	Low Strength	Firm	34.79	71.52
WS122	4.00	Gravelly CLAY	50	42.24	N/A	Very High Strength	Very Stiff	211.21	434.25
WS123	1.00	Made Ground	37	37.30	Dense	N/A	N/A	N/A	373.02
WS123	1.50	Made Ground	50	47.51	Dense	N/A	N/A	N/A	475.08
WS124	1.00	Made Ground	10	10.08	Medium Dense	N/A	N/A	N/A	100.81
WS124	2.00	Made Ground	4	3.65	Very Loose	N/A	N/A	N/A	36.54
WS124	3.00	Made Ground	50	43.48	Dense	N/A	N/A	N/A	434.83

NOTES

* The Allowable Bearing Pressure (ABP) should be considered indicative.

The interpretation of in situ mass undrained shear strength (cu) data from SPT Blow Count (N) results and the influence of the Plasticity Index (PI) was reported in Standard Penetration Test in Insensitive Clays and Soft Rocks. Stroud (1974). The standard penetration test and the engineering properties of glacial materials subsequently. Stroud and Butler (1975) and (1989).

Allowable bearing pressure on sands. Soil Mechanics in Engineering Practice Terzaghi, K. & Peck, R.B. 1996.

Bold text denotes soft/loose/low strength soils.



3.9. CONSOLIDATION

Two undisturbed samples of CLAY were submitted for oedometer analysis. The results are provided in Table 3.7. The full results can be found in Appendix VIII.

TABLE 3.7 OEDOMETER CONSOLIDATION RESULTS

LOCATION	DEPTH (m)	SAMPLE TYPE	MOISTURE CONTENT (%)	OEDOMETER CONSOLIDATION		
				PRESSURE RANGE (kPa)	M _v (m ² /MN)	C _v (m ² /year)
CP101	8.00	U100	15	0–165	0.249	0.708
				165-330	0.087	0.944
				330-660	0.055	1.042
				660-1320	0.032	1.322
				1320-165	0.013	1.828
CP103	8.00	U100	15	0–165	0.220	0.936
				165-330	0.091	1.013
				330-660	0.057	1.246
				660-1320	0.032	1.588
				1320-165	0.011	1.495

The coefficient of volume compressibility (M_v) ranged from 0.011 m²/MN up to 0.249 m²/MN. When considering the overburden pressure of 160 kPa with an additional load of 100 kPa from construction, the coefficient of volume compressibility (M_v) ranges between 0.087 m²/MN and 0.091 m²/MN, which corresponds with a low compressibility.

The rate at which settlement is likely to occur is determined by the coefficient of consolidation (C_v). As shown in Table 3.7, the coefficient ranges from 0.944 m²/yr to 1.013 m²/yr, i.e., within 13 months.

3.10. PARTICLE SIZE DISTRIBUTION

Particle Size Distribution Tests have been undertaken on selected samples of granular material via wet sieve to obtain information on the soil fractions. The results are included in Table 3.8. The full results can be found in Appendix VIII.

TABLE 3.8 SUMMARY OF PARTICLE SIZE DISTRIBUTION TEST RESULTS

LOCATION	DEPTH (m)	SOIL FRACTION (%)			
		COBBLES	GRAVEL	SAND	SILT/CLAY
TP110	1.70	0	12	50	38
TP119	1.50	17	60	12	11
CP101	1.00	13	29	36	22
CP101	3.00	0	71	26	3
CP101	4.00	9	14	33	44
CP103	1.00	21	44	28	7
CP103	4.00	0	86	11	3



3.11. SOIL DENSITY/MOISTURE CONTENT RELATIONSHIP

Dry density/moisture content relationship analysis has been conducted on soils via proctor compaction tests utilising a 4.5 kg rammer. The results of the tests have been summarised in Table 3.9. The full test results can be found in Appendix VIII.

TABLE 3.9 SUMMARY DRY DENSITY AND MOISTURE CONTENT

LOCATION	LABORATORY DESCRIPTION	TOP DEPTH (m bgl)	METHOD OF COMPACTION	INITIAL MOISTURE CONTENT (%)	OPTIMUM MOISTURE CONTENT (%)	MATERIAL RETAINED ON 37.5 mm SIEVE (%)	MAX DRY DENSITY (mg/m ³)	MATERIAL RETAINED ON 20.0 mm TEST SIEVE (%)
CP101	Brown very sandy very clayey GRAVEL with cobbles.	1.00	4.5kg	24	12	26	1.93	8
CP101	Brown very sandy slightly clayey GRAVEL	3.00	4.5kg	6.8	9	14	2.08	23
CP101	Brown very gravelly very sandy CLAY with cobbles.	4.00	4.5kg	19	13	12	1.90	1
CP103	Brown very sandy clayey GRAVEL with many cobbles.	1.00	4.5kg	16	10	28	1.98	8
CP103	Brown sandy slightly silty GRAVEL.	4.00	4.5kg	12	10	24	2.03	36
TP110	Brown gravelly very sandy CLAY.	1.70	4.5kg	25	16	4	1.79	2
TP119	Brown sandy clayey GRAVEL with cobbles.	1.50	4.5kg	24	12	39	1.86	19

The proctor compaction tests have indicated that the materials on-site are variable with the material in all locations being wet of the optimum, except for CP101 at 3.00 m bgl. It should be noted that if this material is excavated for use in a cut/fill operation, careful consideration should be taken in the stabilisation of this material.

Engineering of this type of material will need to be completed during dry weather periods only.

3.12. SOIL INFILTRATION

Two In-situ BRE 365 Soakaway tests were undertaken over a 48-hour period within trial pits completed as TP101 and TP115.

The results are presented in Table 3.10 below and the test certificates are included within Appendix IX.



TABLE 3.10 BRE365 SOAKAWAY TESTING RESULTS

LOCATION	DEPTH (m)	MATERIAL	TEST NO.	SOIL INFILTRATION RATE (m/s)
TP101	2.00	Gravelly CLAY	Test No.1	N/A
TP115	1.90	Sandy CLAY	Test No.1	-1.66E-04
TP115	1.90	Sandy CLAY	Test No.2	8.89E-05
TP115	1.90	Sandy CLAY	Test No.3	9.85E-05

Soil infiltration was taken over the wetted area from between 75% and 25% of the effective depth. In TP101 where clay drift deposits were present, soakage potential was significantly reduced.

In TP115, the trial pit collapsed during the first test, the second and third tests were then undertaken within the granular Made Ground.

It is considered that soakaway drainage is not suitable for the proposed development. However, the application of soakaway drainage will ultimately be dependent on the specific requirements of the development. All soakaways should be designed in accordance with BRE Special Digest 365 – *Soakaway Design*.

3.13. SOIL PLASTICITY

The Atterberg limits determinations, summarised in Table 3.11, show the clay to be of predominantly low plasticity with discrete areas of moderate plasticity clay.

TABLE 3.11 SUMMARY OF PLASTICITY INDEX TEST RESULTS

LOCATION	DEPTH (m)	NATURAL MOISTURE CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	PASSING 425 µm SIEVE (%)	MODIFIED PLASTICITY INDEX	NHBC VOLUME CHANGE POTENTIAL
WS101	4.00	17	NP*					
WS102	1.00	28	22	41	19	64	12.16	LOW
WS105	2.00	22	20	38	18	83	14.94	LOW
WS117	4.00	15	14	27	14	81	11.34	LOW
CP101	5.00	14	15	32	17	85	14.45	LOW
CP101	8.00	14	14	29	15	81	12.15	LOW
CP101	9.50	28	15	30	15	92	13.80	LOW
CP101	12.50	16	16	34	18	80	14.40	LOW
CP101	14.00	14	14	30	16	83	13.28	LOW
CP103	5.00	21	16	31	15	85	12.75	LOW



LOCATION	DEPTH (m)	NATURAL MOISTURE CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	PASSING 425 µm SIEVE (%)	MODIFIED PLASTICITY INDEX	NHBC VOLUME CHANGE POTENTIAL
CP103	6.50	20	15	29	14	87	12.18	LOW
CP103	11.00	25	16	30	14	83	11.62	LOW
CP103	12.50	27	13	27	14	81	11.34	LOW

*NP = Non-Plastic

The results of the Atterberg limits testing confirmed that the soils would be deemed to be “Low Volume Change Potential” in accordance with the classification system utilised by the LABC/NHBC industry guidance.

3.14. pH AND SULPHATE

Chemical analyses for pH and soluble sulphate content contained in Appendix V (summarised in Table 3.12), shows that the soils at the site generally meet Class DS-1, Aggressive Chemical Environment for Concrete Classification (ACEC) AC-1s in accordance with BRE *Special Digest 1* (2005).

In the LK Consultant 2020 Report, concentrations of soluble sulphate in the soil when contrasted to BRE Digest 200535 categorised the concrete requirements as DS-2 AC-3z in the Made Ground and DS-1 AC-1 in the natural strata.

TABLE 3.12 SUMMARY OF pH AND SULPHATE DATA

LOCATION	DEPTH (m)	SO ₄ IN 2:1 WATER/SOIL (g/l)	pH VALUE	CLASSIFICATION
Bund01	-	0.042	8	DS-1, AC-1
WS105	2.60	0.016	7.9	DS-1, AC-1
WS107	2.50	0.045	7.5	DS-1, AC-1
WS110	0.50	0.016	8.5	DS-1, AC-1
WS111	0.60	0.015	8.2	DS-1, AC-1
WS112	2.60	0.074	8.2	DS-1, AC-1
WS115	1.70	0.048	8.6	DS-1, AC-1
WS116	0.80	0.031	7.7	DS-1, AC-1
WS117	3.20	0.11	7.9	DS-1, AC-1
WS122	3.20	0.03	7.8	DS-1, AC-1
WS124	3.60	0.03	7.8	DS-1, AC-1
TP108	0.70	0.17	10.3	DS-1, AC-1
TP110	1.00	0.094	10.5	DS-1, AC-1
TP113	0.90	0.022	11.6	DS-1, AC-1
TP114	1.00	0.35	10.1	DS-1, AC-1
TP115	0.80	0.081	10	DS-1, AC-1



LOCATION	DEPTH (m)	SO ₄ IN 2:1 WATER/SOIL (g/l)	pH VALUE	CLASSIFICATION
TP116	1.20	0.33	8.4	DS-1, AC-1
TP120	0.20	0.003	8.4	DS-1, AC-1
TP122	1.00	0.1	8.1	DS-1, AC-1
TP123	0.80	0.14	8.7	DS-1, AC-1
TP124	1.40	0.02	7.6	DS-1, AC-1
TP125	1.00	0.04	7.8	DS-1, AC-1
TP126	0.90	0.085	8.0	DS-1, AC-1



4. TIER I QUALITATIVE CONTAMINATED LAND RISK ASSESSMENT

E3P has undertaken a Tier 1 qualitative risk assessment to determine if any potential contaminants within the underlying soils and groundwater pose an unacceptable level of risk to the identified receptors.

4.1. HUMAN HEALTH RISK ASSESSMENT

At Tier 1 stage, the long-term (chronic) human health toxicity of the soil has been assessed by comparing the on-site concentrations of organic and inorganic compounds with reference values published in LQM/CIEH S4UL (S4UL3267).

Where Tier 1 screening values are not provided by LQM, other screening values have been used and these are referenced in Table 4.1.

The results of this comparison have been summarised within Table 4.1.

TABLE 4.1 SUMMARY OF INORGANIC AND HYDROCARBON TOXICITY ASSESSMENT FOR A RESIDENTIAL END USE

DETERMINANT	UNIT	GAC	N	MC	LOC. OF EX	PATH-WAY	ASSESSMENT
Arsenic	mg/kg	37	25	40	TP113 WS110	1	Further Action
Cadmium	mg/kg	11	25	1.6	-	1	No further action
Chromium (VI)	mg/kg	6.0	25	2.8	-	1	No further action
Lead***	mg/kg	200	25	610	Bund01 WS101 WS110 TP113 TP115 TP116 TP122 TP126	1	Further Action
Mercury	mg/kg	1.2	25	7.8	WS111	4	Further Action
Nickel	mg/kg	130	25	69	-	1	No further action
Selenium	mg/kg	250	25	<1.0	-	1	No further action
Copper	mg/kg	2400	25	240	-	1	No further action
Zinc	mg/kg	3700	25	280	-	1	No further action
Cyanide – Total	mg/kg	791	25	<1.0	-	1	No further action
Phenols – Total	mg/kg	120	23	3	-	1	No further action
Asbestos	Fibres	NFD	23	Chrysotile, Amosite	WS124 HP05 TP114 TP116	3	Further Action
Naphthalene	mg/kg	2.3	15	12	WS117 WS122 TP122 TP123 TP126	4	Further Action
Acenaphthylene	mg/kg	170	15	0.22	-	2	No further action
Acenaphthene	mg/kg	210	15	24	-	1	No further action



DETERMINANT	UNIT	GAC	N	MC	LOC. OF EX	PATH-WAY	ASSESSMENT
Fluorene	mg/kg	170	15	22	-	1	No further action
Phenanthrene	mg/kg	95	15	110	TP123	2	Further Action
Anthracene	mg/kg	2400	15	29	-	2	No further action
Fluoranthene	mg/kg	280	15	110	-	2	No further action
Pyrene	mg/kg	620	15	95	-	2	No further action
Benzo(a)Anthracene	mg/kg	7.2	15	57	WS117 TP122 TP123 TP126	2	Further Action
Chrysene	mg/kg	15	15	48	TP122 TP123	2	Further Action
Benzo(b)Fluoranthene	mg/kg	2.6	15	60	WS117 TP115 TP116 TP122 TP123 TP126	2	Further Action
Benzo(k)Fluoranthene	mg/kg	77	15	25	-	2	No further action
Benzo(a)Pyrene	mg/kg	2.2	15	53	Bund01 WS117 TP115 TP116 TP122 TP123 TP126	2	Further Action
Indeno(123-cd)Pyrene	mg/kg	27	15	24	-	2	No further action
Dibenzo(a,h)Anthracene	mg/kg	0.24	15	6.8	Bund01 WS117 TP115 TP116 TP122 TP123 TP126	2	Further Action
Benzo(ghi)Perylene	mg/kg	320	15	27	-	2	No further action
TPH C5-C6 (aliphatic)*	mg/kg	42	9	0	-	4	No further action
TPH C6-C8 (aliphatic)*	mg/kg	100	9	0	-	4	No further action
TPH C8-C10 (aliphatic)*	mg/kg	27	9	0.82	-	4	No further action
TPH C10-C12 (aromatic)*	mg/kg	74	9	23.1	-	4	No further action
TPH C12-C16 (aromatic)*	mg/kg	140	9	220	WS122 TP122	4	Further Action
TPH C16-C21 (aromatic)*	mg/kg	260	9	520	WS122 TP116 TP122	1	Further Action
TPH C21-C35 (aromatic)*	mg/kg	1100	9	850	-	1	No further action
Benzene	mg/kg	0.087	10	<0.001	-	4	No further action
Toluene	mg/kg	130	10	<0.001	-	4	No further action
Ethylbenzene	mg/kg	47	10	0.017	-	2	No further action
m/p-Xylene	mg/kg	56	10	0.026	-	2	No further action



DETERMINANT	UNIT	GAC	N	MC	LOC. OF EX	PATH-WAY	ASSESSMENT
o-Xylene	mg/kg	60	10	0.039	-	2	No further action
Isopropylbenzene**	mg/kg	46.9	10	0.100	-	4	No further action
n-Propylbenzene#	mg/kg	34	10	0.061	-	4	No further action
1,2,4-Trimethylbenzene**	mg/kg	1.17	10	0.750	-	4	No further action
1,3-Dichlorobenzene	mg/kg	0.40	10	0.40	-	4	No further action
2-Methylphenol**	mg/kg	93.7	10	1.7	-	4	No further action
4-Methylphenol**	mg/kg	92.2	10	3.7	-	4	No further action

Notes

PL1 = soil ingestion, PL2 = dermal contact and ingestion, PL3 = dust inhalation; PL4 = Vapour/Gas Inhalation; PL5 = Vertical / Lateral Migration; PL6 = Corrosion of concrete; PL7=Tainting of water supply; PL8 = Uptake by plants

Abbreviations: GAC = general assessment criteria, n = number of samples, MC = maximum concentration; Loc of Ex = location of exceedance; NFD = no fibres detected.

* The Tier 1 GAC for the hydrocarbon fraction is derived from the CIEH assessment for petroleum hydrocarbons Criteria Working Group (CWG) for both aliphatic and aromatic compounds. E3P has utilised the Tier 1 values for aliphatic compounds for the volatile and semi-volatile fractions (C5-C12) and the Tier 1 values for aromatic compound for the non-volatile fractions (C12-C35). The comparison of a total (aliphatic/aromatic) compounds to an individual fraction is considered to be a conservative approach and satisfactory for the protection of human health.

** Atkins ATRISK

*** CL:AIRE C4SL

CL:AIRE Soil Generic Assessment Criteria for Human Health Risk Assessment, January 2010

Referring to Table 4.1, the results of this direct comparison indicate that the data exceeds the screening criteria for a residential end-use for the following contaminants:

- ✳ **Arsenic** (WS110 at 0.50m bgl and TP113 0.90 m bgl).
- ✳ **Lead** (Bund01, WS101 at 0.80 m bgl, WS110 at 0.50 m bgl, TP113 at 0.90 m bgl, TP115 0.80 m bgl, TP116 1.20 m bgl, TP122 1.00 m bgl and TP126 0.90 m bgl).
- ✳ **Mercury** (WS111 0.60 m bgl).
- ✳ **Asbestos** (Chrysotile and Amosite) HP05 at 0.10 m bgl, TP114 at 1.00 bgl, TP116 at 1.20 m bgl, and WS124 at 3.40 m bgl).
- ✳ **Naphthalene** (WS117 at 3.20 m bgl, WS122 at 3.20 m bgl, TP122 at 1.00 m bgl, TP123 at 0.80 m bgl and TP126 at 0.90 m bgl).
- ✳ **Phenanthrene** (TP123 at 0.80 m bgl).
- ✳ **Benzo(a)anthracene** (WS117 at 3.20 m bgl, TP122 at 1.00 m bgl, TP123 at 0.80 m bgl and TP126 at 0.90 m bgl).
- ✳ **Chrysene** (TP122 at 1.00 m bgl and TP123 at 0.80 m bgl).
- ✳ **Benzo(b)fluoranthene** (WS117 at 3.20m bgl, TP115 at 0.80 m bgl, TP116 at 1.20 m bgl, TP122 at 1.00 m bgl, TP123 at 0.80 m bgl, and TP126 at 0.90 m bgl).



- ✳ **Benzo(a)pyrene** (Bund01, WS117 at 3.20 m bgl, TP115 at 0.80 m bgl, TP116 at 1.20 m bgl, TP122 at 1.00 m bgl, TP123 at 0.80 m bgl and TP126 at 0.90 m bgl).
- ✳ **Dibenzo(a,h)anthracene** (Bund01, WS117 at 3.20 m bgl, TP115 at 0.80 m bgl, TP116 at 1.20 m bgl, TP122 at 1.00 m bgl, TP123 at 0.80 m bgl and TP126 at 0.90 m bgl).
- ✳ **TPH C12 – C16 (aromatic)** (WS122 at 3.20 m bgl and TP122 at 1.00 m bgl).
- ✳ **TPH C16 – C21 (aromatic)** (WS122 at 3.20 m bgl, TP116 at 1.20 m bgl, and TP122 at 1.00 m bgl).

Asbestos in the form of chrysotile hard/cement was identified within the Made Ground in WS124 at 3.40 m bgl (south of Sheppard Mill area) and HP05 at 0.10 m bgl (historical landfill in the eastern section of Tack Lea Works area). Asbestos in the form of chrysotile sheeting/board debris and loose fibrous debris was also identified in HP05 at 0.10 m bgl. Chrysotile and Amosite loose fibres were identified in TP114 at 1.00 m bgl and TP116 at 1.20 m bgl (central section of Tack Lea Works area).

Quantification testing was undertaken with the highest concentration recorded in WS124 at 0.705%. The remaining samples had concentrations of 0.002% (TP116), 0.011% (TP114) and 0.036% (HP05).

Exceedances of the heavy metal arsenic have been identified within the central section of the Tack Lea Works area (WS110 and TP113).

Exceedances of the heavy metal lead have been identified within the Tack Lea Works area (earthen bund sample, WS101, WS110, TP113, TP115 and TP116) and the Sheppard Mill area (TP122 and TP126).

Exceedances of the heavy metal mercury have been identified in WS111 (south-western section of the Tack Lea Works area).

Exceedances of volatile PAHs (naphthalene) have been identified in the Sheppard Mill area (WS117, WS122, TP122, TP123 and TP126).

Exceedances of non-volatile PAHs (phenanthrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(a)pyrene and dibenzo(a,h)anthracene) have been identified within the Tack Lea Works area (earthen bund sample, TP115 and TP116) and the Sheppard Mill area (WS117, TP122, TP123 and TP126).

Exceedances for volatile petroleum hydrocarbons (TPH C12-C16) have been identified within the Sheppard Mill area (WS122 and TP122). Exceedances for non-volatile petroleum hydrocarbons (TPH C16-C21) have been identified within the Tack Lea Works area (TP116) and the Sheppard Mill area (WS122 and TP122).

VOCs (including ethylbenzene, p & m-xylene, o-xylene, isopropylbenzene, n-propylbenzene, 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene, sec-butylbenzene and p-isopropyltoluene) have been identified above the limit of detection within TP122 and WS122 in the Shepherd Mill area. Concentrations have been screened against the LQM reference values; and where no values are currently available, concentrations have been screened against generic assessment criteria provided within the CL:AIRE guidance document, Soil Generic Assessment Criteria for Human Health Risk Assessment (January 2010) or ATKINS ATRISK Soil Screening Values.

SVOCs (including aniline, phenol, 1,3-dichlorobenzene, 2-methylphenol, 4-methylphenol, 2,4-dimethylphenol, 2-methylnaphthalene, dibenzofuran, carbazole, dibutyl phthalate and anthraquinone) have been identified above the limit of detection within the central section of the Tack Lea Works area (WS107 and TP116) and the Shepherd Mill area (WS117, WS122, WS124, TP122, TP123, TP124 and TP126). Concentrations have been screened against the LQM reference values; and where no values are currently available, concentrations have been screened against generic assessment criteria provided within the CL:AIRE guidance document, Soil Generic Assessment Criteria for Human Health Risk Assessment (January 2010) or ATKINS ATRISK Soil Screening Values.



In addition, a number of VOC and SVOC compounds which currently do not have any screening values available have also been recorded at concentrations above the laboratory limit of detection (LOD). These are summarised in Table 4.2 below:

TABLE 4.2 SUMMARY OF VOC AND SVOC COMPOUNDS ABOVE LABORATORY LIMIT OF DETECTION

DETERMINANT	UNIT	LOD	N	LOCATION OF COMPOUND ABOVE LOD	CONC. OF COMPOUND ABOVE LOD (mg/kg)
1,3,5-Trimethylbenzene	mg/kg	0.005	2	WS122	0.26
				TP122	0.11
sec-Butylbenzene	mg/kg	0.005	1	WS122	0.03
P-Isopropyltoluene	mg/kg	0.005	1	WS122	0.13
Aniline	mg/kg	0.1	4	WS107	0.20
				WS117	0.20
				TP123	2.00
				TP126	0.30
2,4-Dimethylphenol	mg/kg	0.3	1	TP123	3.70
2-Methylnaphthalene	mg/kg	0.1	8	WS117	1.40
				WS122	13
				WS124	0.40
				TP116	0.30
				TP122	14
				TP123	14
				TP124	0.20
				TP126	2.60
Dibenzofuran	mg/kg	0.2	8	WS117	1.90
				WS122	6.70
				WS124	0.70
				TP116	0.30
				TP122	7.20
				TP123	19
				TP124	0.30
				TP126	2.40
Carbazole	mg/kg	0.3	5	WS117	1.60
				WS122	1.70
				TP122	4.10
				TP123	20
				TP126	2.30
Dibutyl phthalate	mg/kg	0.2	1	TP122	1.90



DETERMINANT	UNIT	LOD	N	LOCATION OF COMPOUND ABOVE LOD	CONC. OF COMPOUND ABOVE LOD (mg/kg)
Anthraquinone	mg/kg	0.3	2	TP123	5.30
				TP126	1.50

PCB analysis on a sample taken from TP118 which is located in the vicinity of the former electricity substation in the Tack Lea Works area showed no exceedances.

Chemical analysis on the sample taken from the earthen bund showed exceedances for the heavy metal lead and PAHs Benzo(a)pyrene and Dibenzo(a,h)anthracene.

The laboratory analysis confirms the assessment within the initial conceptual site model that the main constituents of concern were likely to be asbestos, heavy metals, PAHs, petroleum hydrocarbons, VOCs and SVOCs.

Encia Consulting identified the following exceedances of the GAC within the subject site boundary:

- ✳ **Lead** (HP7 0.25 m bgl, WS5 0.70 m bgl, WS9 0.50 m bgl, WS10 0.40 m bgl, WS25 0.70 m bgl);
- ✳ **Mercury** (WS9 0.50 m bgl, WS25 0.70 m bgl);
- ✳ **Asbestos** (Amosite Fibres - WS18 D2 0.60-0.70 m bgl);
- ✳ **Naphthalene** (WS12 0.70 m bgl, WS19 0.90 m bgl, WS19 D6 3.70 m bgl, WS21 0.50 m bgl, WS22 0.70 m bgl, WS19 0.40 m bgl, WS19 0.80 m bgl, WS25 0.50 m bgl);
- ✳ **Non-volatile PAHs:** BH10 1.00 m bgl, WS10 0.40 m bgl, WS12 0.70 m bgl, WS17A D1, WS12 0.80 m bgl, WS19 0.90 m bgl, WS20 D1 0.60 m bgl, WS22 0.70 m bgl, WS19 0.40 m bgl, WS24 A 0.30 m bgl);
- ✳ **TPH C16-C21 Aromatic** (BH10 1.00 m bgl, WS19 0.40 m bgl);
- ✳ **TPH C21-C35 Aromatic** (WS19 0.40 m bgl);
- ✳ **Trichloroethene (TCE)** (WS12 0.80 m bgl); and
- ✳ **1,2,4-Trimethylbenzene** (WS19 0.40 m bgl).

Elevated trichloroethene (TCE) was recorded in WS12 at 0.80 m bgl. Tetrachloroethene (PCE) was recorded above the limit of detection, however the concentration does not exceed the residential GAC. Elevated 1,2,4-Trimethylbenzene was recorded in WS19 at 0.40 m bgl. Additional VOCs including benzene, toluene, ethylbenzene, m/p-xylene, styrene, o-xylene, isopropylbenzene, propylbenzene, 1,2,4 trimethylbenzene, 4-isopropyltoluene, 1,3,5 trimethylbenzene, sec-butylbenzene, n-butylbenzene were recorded above the limit of detection in WS19 at 0.40 m bgl, WS19 0.80 m bgl and WS25 0.50 m bgl.

SVOCs including 2-methylnaphthalene, carbazole and dibenzofuran were recorded in WS19 at 0.40 m bgl, WS19 at 0.80 m bgl and WS25 at 0.50 m bgl.

Potential visible asbestos was noted in WS10 as likely chrysotile cement.

Contamination Issues Plans for heavy metals, asbestos, non-volatile PAHs, Naphthalene, TPHs, VOCs and SVOCs in soils are presented as Drawings 16-465-027 to 16-465-033 in Appendix III, and snapshots are included in Figure 4.1 to Figure 4.7 below.



FIGURE 4.1 CONTAMINATION ISSUES PLAN – HEAVY METALS

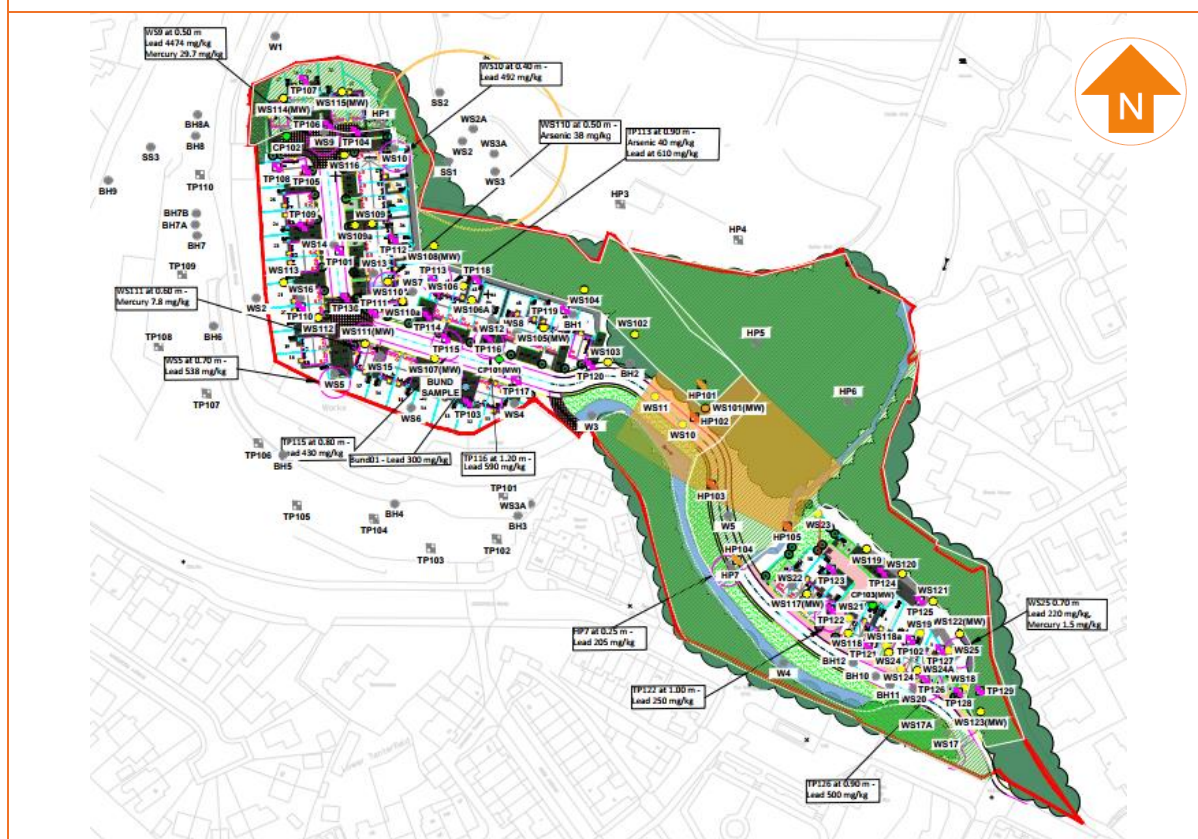


FIGURE 4.2 CONTAMINATION ISSUES PLAN – ASBESTOS

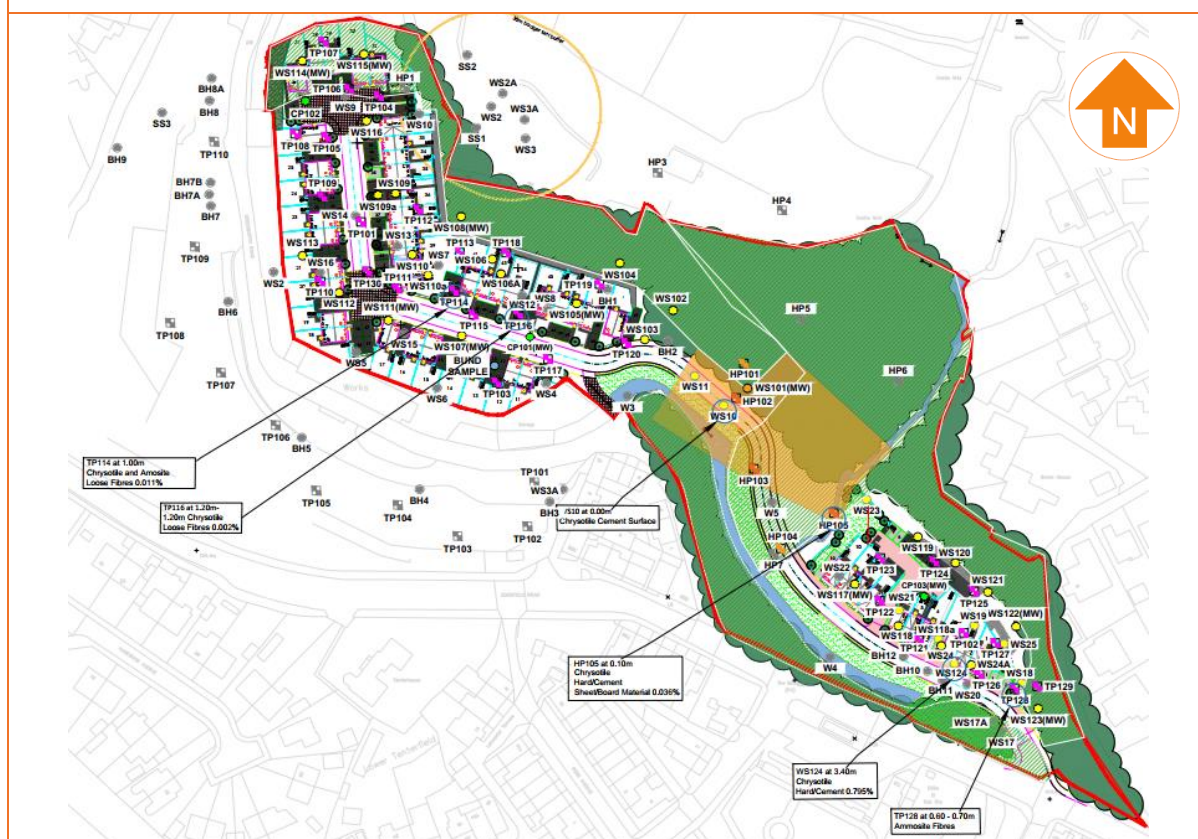


FIGURE 4.3 CONTAMINATION ISSUES PLAN – NON-VOLATILE PAH

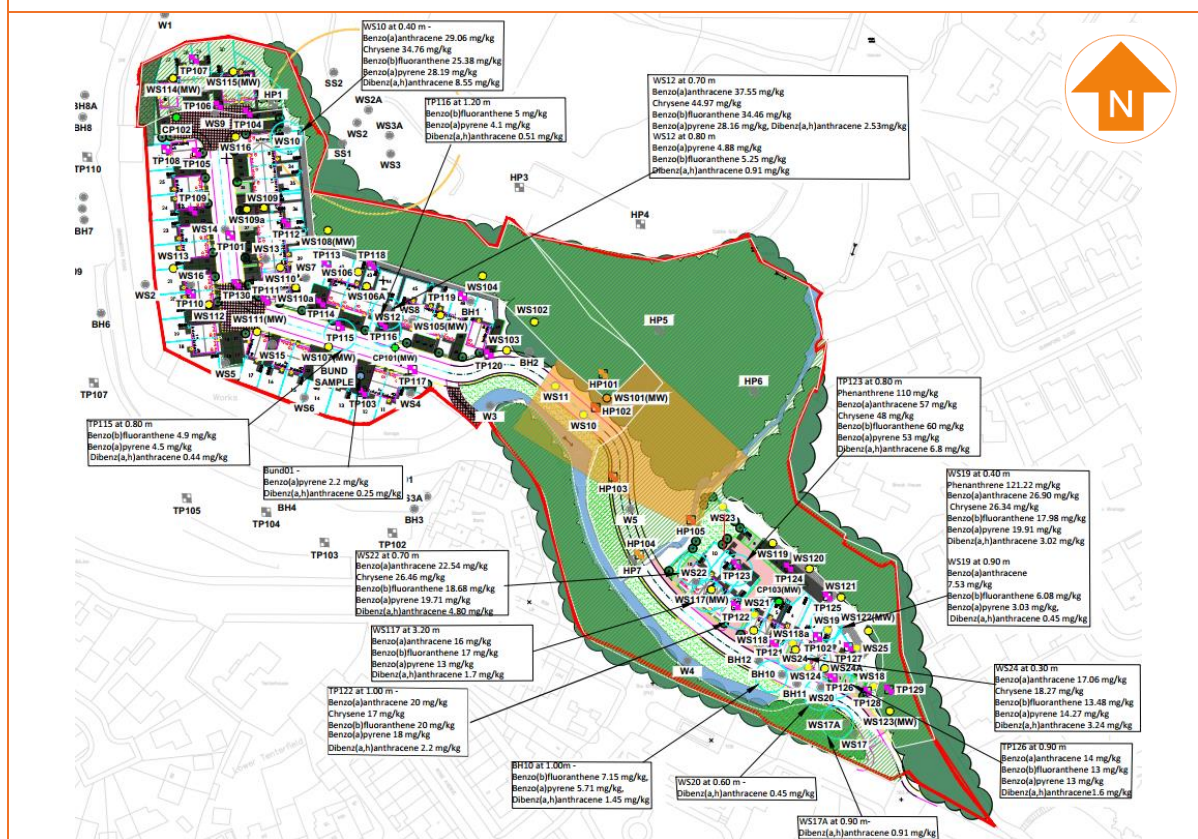


FIGURE 4.4 CONTAMINATION ISSUES PLAN – NAPHTHALENE

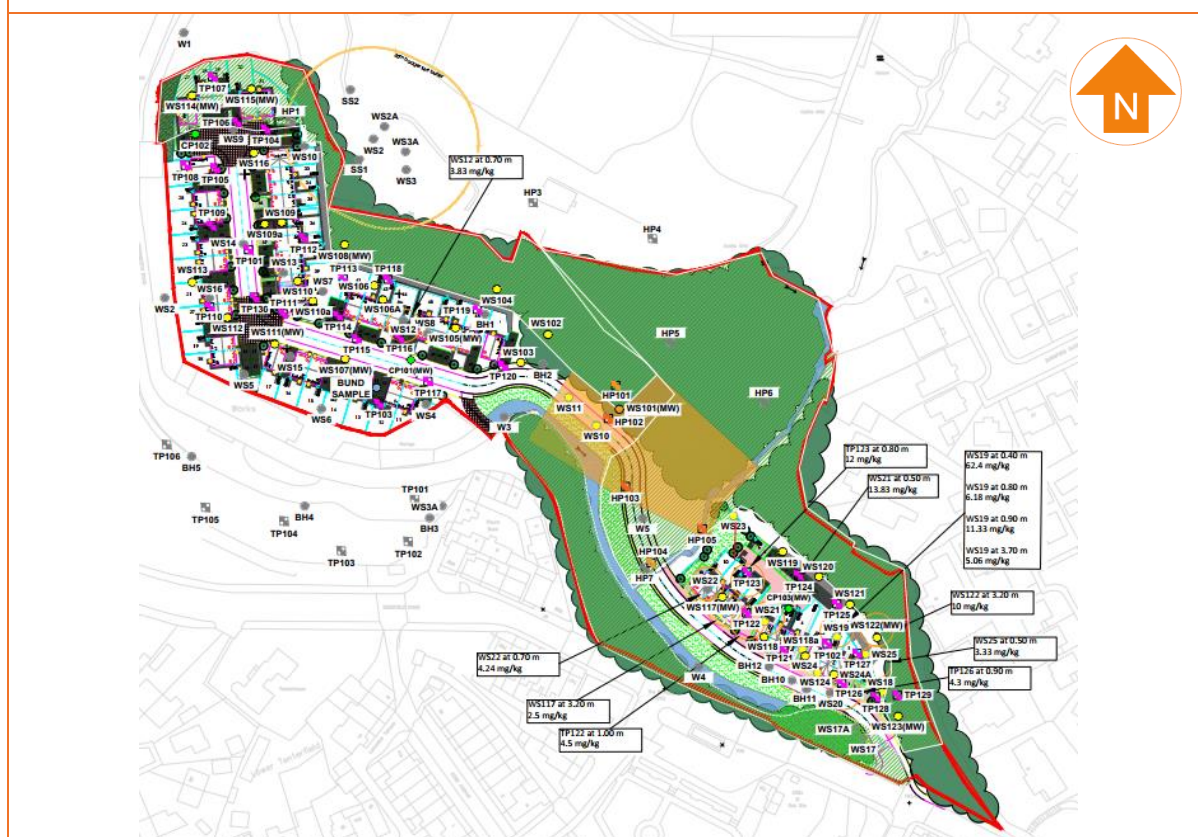


FIGURE 4.5 CONTAMINATION ISSUES PLAN – TPH

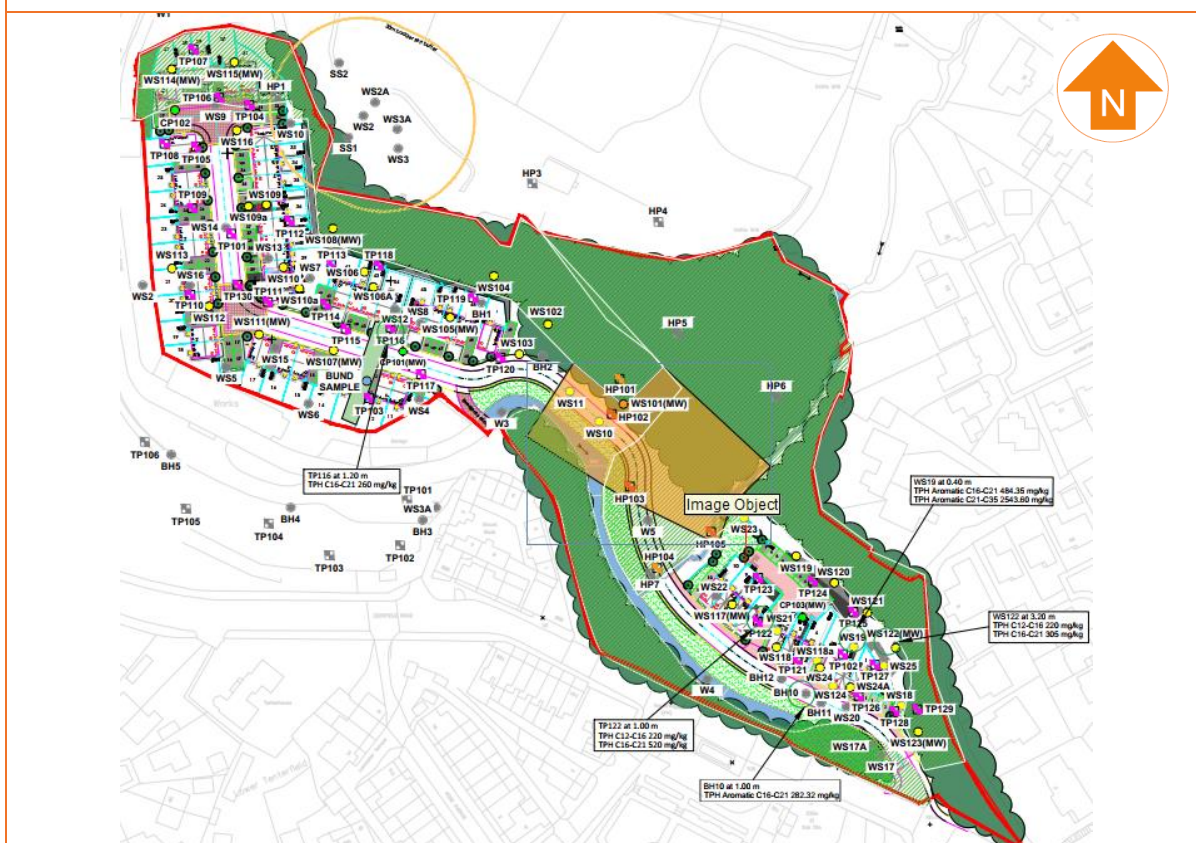


FIGURE 4.6 CONTAMINATION ISSUES PLAN – VOC

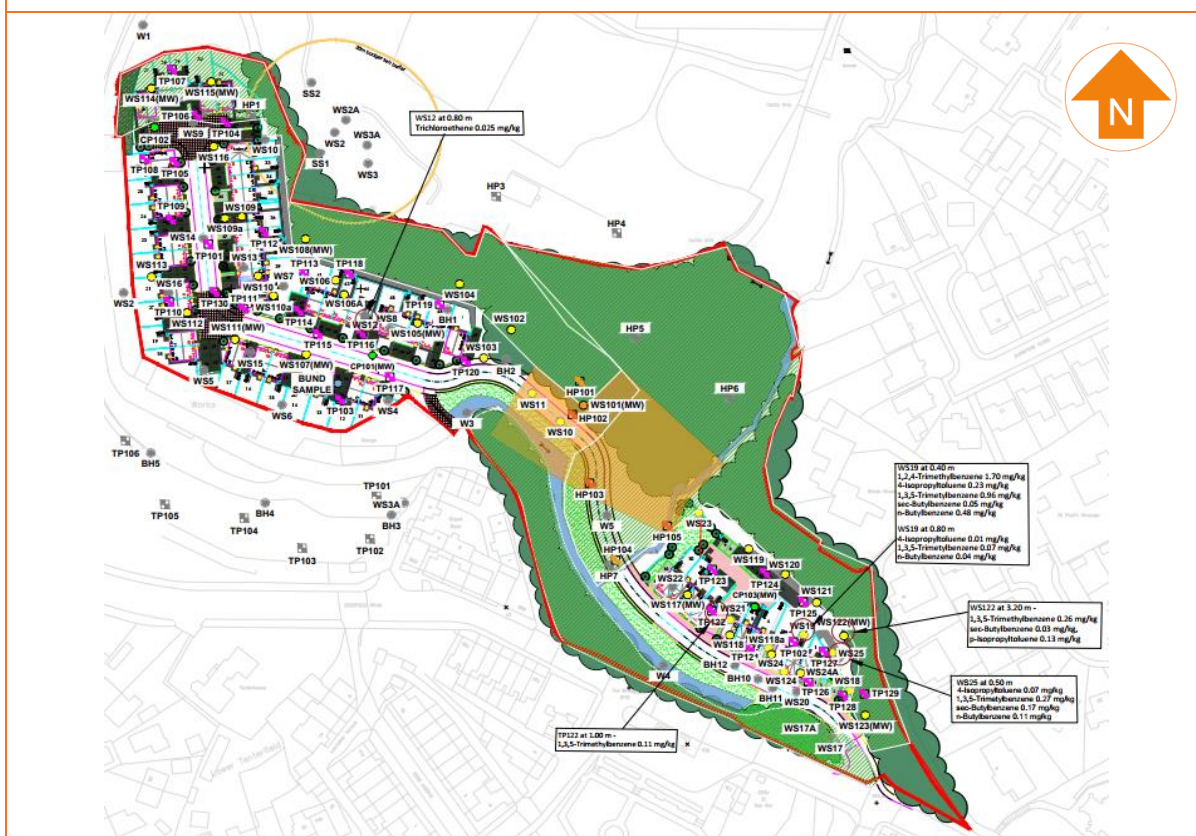
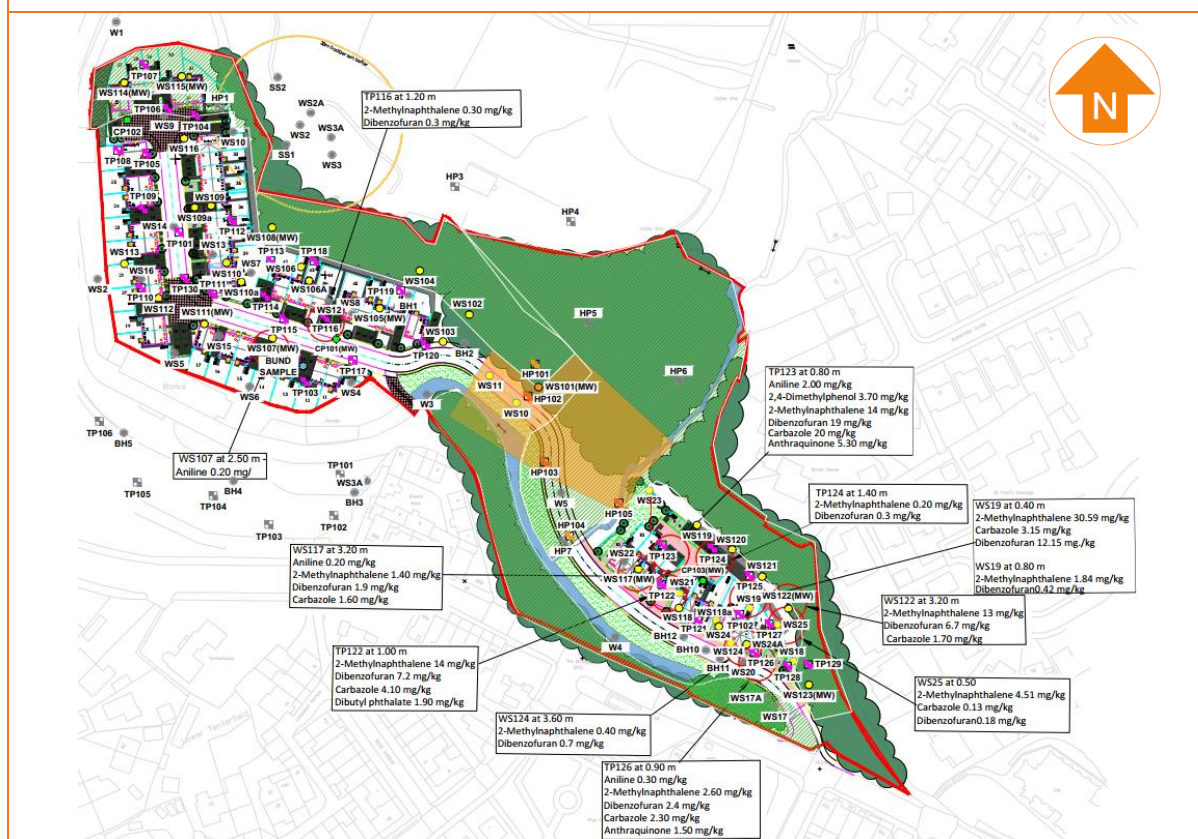


FIGURE 4.7 CONTAMINATION ISSUES PLAN – SVOC



In relation to these exceedances, the following can be determined:

- The main exposure pathways based on the Tier I exceedances are:
 - Soil ingestion;
 - Vapour inhalation (indoor);
 - Dermal contact and ingestion;
 - Consumption of homegrown vegetables; and
 - Fibre/dust inhalation.

HUMAN HEALTH RISK ASSESSMENT AND MITIGATION

The majority of the identified elevated concentrations have primary exposure pathways related to dermal contact and ingestion of soils, inhalation of particulate and consumption of homegrown vegetables; with naphthalene, petroleum hydrocarbons, VOCs and SVOCs having a primary exposure pathway related to volatilisation to indoor air risk.

The risk to chronic human health associated with the elevated concentrations of inorganic heavy metals and non-volatile PAH compounds can be mitigated through the installation of a suitable cover system in all proposed private gardens, landscaping and public open space to remove any potential for direct exposure to impacted soils.

- Private gardens – 600 mm
- Landscaped areas– 300 mm
- Public open space (POS) – 300 mm

Asbestos bulk fragments, in the form of hard cement were also identified in WS124, HP05 and WS10; and asbestos sheeting/board debris within HP05. Visual signs of ACM were encountered during the ground investigations in HP05.

FIGURE 4.8 ASBESTOS RISK MITIGATION CONCEPTUAL SITE MODEL



0.001% Soils may contain $\leq 0.001\%$ asbestos using composite testing to ensure there is no potential risk to human health. This value is present within areas where there may be a short-term low-level exposure of soils containing trace asbestos fibres by construction workers where an appropriate level of asbestos management is employed (dust suppression)

0.1% Soils at a depth of $>1.00\text{m}$ bgl may contain $<0.1\%$ asbestos using composite testing where they will not be likely to be disturbed in the future and will therefore be in an area of low sensitivity. Risk assessment completed in accordance with Asbestos JIWG risk assessment tools.



Undefined- this will be dependent upon soils encountered during earthworks, which may be placed at these depths to ensure no potential risk to human health.

It is noted that the presence of asbestos sheeting and boarding will require a different remedial approach to those proposed within Figure 4.8 (i.e., hand picking of visible bulk asbestos fragments). Where asbestos sheeting and boarding has previously been identified, any proposed earthworks within those areas may be required to be undertaken under license. In addition, any off-site disposal of materials from these areas would be considered hazardous unless the asbestos bulk fragments are pre-removed via hand picking techniques.

Elevated concentrations of mercury have been identified within two locations within the Tack Lea Works area (WS111 at 0.60 m bgl and WS9 at 0.50 m bgl); and one location within the Sheppard Mill area (WS25 at 0.70 m bgl). Mercury occurs in three different forms; elemental mercury, inorganic mercury and methyl mercury. Inorganic and methyl mercury have an exposure pathway of dermal contact and ingestion, whereas elemental mercury could present a potential volatilisation to indoor air risk.

During remediation and enabling works, speciated mercury analysis should be completed at the locations WS111, WS9 and WS25 to assess whether elemental mercury is present which may pose a risk to future site users through vapour inhalation. If elemental mercury is identified, it may be necessary to delineate and excavate the soils as a hotspot and place them in an area of low sensitivity such as beneath areas of public open space or removed from site. Alternatively, if it is proven that there is no elemental mercury, a clean cover system will be sufficient.

The elevated concentrations of naphthalene, TPH, and trichloroethene (TCE) identified within the Tack Lea Works area (TP116 and WS12) are considered to be localised occurrences and therefore this location can be treated as a localised hotspot. During a process of cut/fill enabling works, a hotspot removal should be undertaken where these soils may be chemically validated to assess chemical suitability for retention on-site in an area of no future sensitivity.

However, elevated concentrations of naphthalene, TPH, VOCs and SVOCs have been identified throughout the Shepherd Mill area and these do not appear to be localised hotspots. A Tier II vapour risk assessment is required in this sector of the site to assess the level of risk to the future site users by volatilisation to indoor air.

The SVOCs identified in WS107 and TP116 within the Tack Lea Works area are not considered to pose a risk to future site users given the marginal concentrations. Screening criteria are not currently available for the identified SVOCs. Therefore further discussion for these compounds is included below:

Aniline

Aniline is a clear to slightly yellow liquid with a characteristic odour. It does not readily evaporate at room temperature, is slightly soluble in water and mixes readily with most organic solvents. Aniline is used to make a wide variety of products such as polyurethane foam, agricultural chemicals, synthetic dyes, antioxidants, stabilizers for the rubber industry, herbicides, varnishes and explosives.

This compound was detected at a concentration of 0.20 mg/kg in WS107 at 2.50 m bgl.

Aniline's production and use as a chemical intermediate in the synthesis of rubber accelerators and antioxidants, dyes and intermediates, photographic chemicals, isocyanates for urethane foams, pharmaceuticals, explosives, petroleum refining, diphenylamine, phenolics, herbicides, and fungicides and its use as a solvent and in the manufacture of dyes, medicinals, resins, varnishes, perfumes, and shoe blacks may result in its release to the environment through various waste streams.

If released to air, a vapor pressure of 0.667 mm Hg at 25 °C indicates aniline will exist solely as a vapor in the atmosphere. Vapor-phase aniline will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 4 hours.



If released to soil, aniline is expected to have very high to moderate mobility based upon measured Koc values of 43.8 to 497.7. The pKa of aniline is 4.60, indicating that this compound may exist partially in cation form in the environment and cations generally adsorb more strongly to soils containing organic carbon and clay than their neutral counterparts. Anilines are expected to bind strongly to humus or organic matter in soils due to the high reactivity of the aromatic amino group, suggesting that mobility may be much lower in some soils. Volatilization of the neutral species from moist soil surfaces is expected to be an important fate process based upon a Henry's Law constant of 2.02×10^{-6} atm-cu m/mole. Aniline has a vapor pressure close to 1 mm Hg and exists as a liquid under environmental conditions; therefore, aniline may volatilize from dry soil. Utilizing the Japanese MITI test, 85% of the Theoretical BOD(NH₃) was reached in 2 weeks indicating that biodegradation is an important environmental fate process in soil and water.

If released into water, aniline is not expected to adsorb to suspended solids and sediment based upon its Koc range. Volatilization of the neutral species from water surfaces is expected to be an important fate process based upon this compound's Henry's Law constant. Estimated volatilization half-lives for a model river and model lake are 17.6 and 131 days, respectively. Measured BCF values of less than 1 suggest bioconcentration in aquatic organisms is low. Aniline has a reported aqueous hydrolysis half-life of greater than 50 years suggesting that hydrolysis is not an important environmental fate process.

Occupational exposure to aniline may occur through inhalation and dermal contact with this compound at workplaces where aniline is produced or used. Monitoring data indicate that the general population may be exposed to aniline via inhalation of ambient air, ingestion of food and drinking water contaminated with this chemical, dermal contact with consumer products containing aniline and via inhalation of tobacco smoke. (SRC)

The US EPA has classified aniline as a Group B2, probable human carcinogen.

No screening values are currently available for Aniline. It is noted that the concentration identified within WS107 at 2.50 m bgl is only marginally above the laboratory LOD. It is also noted that only a single detection of Aniline was recorded within the Tack Lea Works area, and that no detections have been identified within groundwater and surface water samples taken from across the site.

Therefore within the context of the developed site CSM and the lines of evidence approach, it can be determined that the residual compound in this instance is highly unlikely to pose any risk in terms of vapour migration and ingress to the dwelling.

2-Methylnaphthalene

2-methylnaphthalene is a white crystalline solid compound. This determinant is classified as a non-threshold substance, therefore even the smallest amount of exposure is considered to pose a theoretical risk to the critical receptor within the context of the developed CSM.

This compound was detected at a concentration of 0.30 mg/kg in TP116 at 1.20 m bgl.

The vapour pressure of 2-methylnaphthalene is 0.055 mm Hg at 25°C which is slightly lower than that of naphthalene (0.085 mm Hg @ 25°C). It is therefore determined that the compound is less volatile than naphthalene. This data is obtained from Pub Chem.

The Tier 1 CIEH / LQM S4UL for naphthalene is 2.3 mg/kg for a residential development scenario, however this assessment assumes dermal contact, inhalation of particulate and other direct exposure pathways. The developed CSM for the subject site will incorporate a clean cover systems in landscaped areas to ensure no direct exposure pathways.

When considering that 2-Methylnaphthalene has a notably reduced vapour pressure to that of naphthalene, the absence of the compound in the vast majority of samples tested and in due consideration of the maximum concentration of the determinant being only 1.40 mg/kg (with exception of TP126, WS122, TP122 and TP123), the potential for this compound to enter the vapour phase from soil with temperatures ~10°C is low.



There is no justifiable or peer reviewed toxicological data for an inhalation pathway for 2- methylnaphthalene, therefore it is not possible to develop a robust site-specific risk assessment model given the absence of suitable input parameters.

In light of the above, we must consider the lines of evidence to hand and given that the compound is a non-threshold substance with no peer reviewed, robust or justifiable toxicological data the suggested method to ensure safe regeneration is the adoption of the As Low As Reasonably Possible (ALARP) approach.

In this instance, the methodology for the analytical technique is considered to be the lowest reasonably possible method of determining the presence of the non-threshold substance and mitigating risk to the lowest practicable level.

The US national library for medicine confirms:

If released to soil, 2-methylnaphthalene is expected to have slight to no mobility based upon log K_{oc} values of 3.00-5.96. Volatilization from moist soil surfaces is expected based upon a Henry's Law constant of 5.18×10^{-4} atm-cu m/mole. However, adsorption to soil is expected to attenuate volatilization. 2- Methylnaphthalene is not expected to volatilize from dry soil surfaces based upon its vapor pressure.

This compound has a very low to no actual volatility, there is no inhalation of dust (indoor or outdoor air) or inhalation of vapour (indoor or outdoor) exposure. The total inhalation background is 1.52%. As discussed, herein it is highly unlikely that this compound can enter the vapour phase in the soil. Furthermore, the presence of a passively ventilated sub-floor void with a reasonable volume change potential (24hr) will ensure that in the extremely unlikely event that this compound could volatilise and migrate, the standard mitigation measure would ensure there is absolutely no potential for ingress into the habitable space.

It is noted that the concentration identified within TP116 at 1.20 m bgl is only marginally above the laboratory LOD. It is also noted that only a single detection of 2- methylnaphthalene was recorded within the Tack Lea Works area, and that no detections have been identified within groundwater and surface water samples taken from across the site.

Therefore within the context of the developed site CSM and the lines of evidence approach, it can be determined that the residual compound in this instance is highly unlikely to pose any risk in terms of vapour migration and ingress to the dwelling.

Dibenzofuran

Dibenzofuran is a white solid compound generally derived from coal tar.

This compound was detected at a concentration of 0.30 mg/kg in TP116 at 1.20 m bgl.

The US EPA have determined a threshold value of 7.8 mg/kg. As such, the concentrations within TP116, is not considered to be exceeding and will not present a risk to future end users.

In addition to the above, the relatively low volatility of this compound within soils with a temperature of ~10°C all but inhibits any volatilisation potential.

The US national library for medicine confirms:

Volatilisation from moist soil surfaces is expected to be an important fate process based upon an estimated Henry's Law constant of 2.1×10^{-4} atm-cu m/mole. However, adsorption to soil is expected to attenuate volatilisation. Dibenzofuran is not expected to volatilise from dry soil surfaces (SRC) based upon its vapour pressure.



It is noted that the concentration identified within TP116 at 1.20 m bgl is only marginally above the laboratory LOD. It is also noted that only a single detection of dibenzofuran was recorded within the Tack Lea Works area, and that no detections have been identified within groundwater and surface water samples taken from across the site.

Therefore within the context of the developed site CSM and the lines of evidence approach, it can be determined that the residual compound in this instance is highly unlikely to pose any risk in terms of vapour migration and ingress to the dwelling. There is not considered to be a risk to the future end user.

Furthermore, with regards to the elevated volatile contaminants (naphthalene, TPH, VOCs and SVOCs) identified in the Tack Lea Works area and the Sheppard Mill area, vapour resistant membranes may be required to be installed during the build phase for any proposed buildings situated within the immediate vicinity of the contamination hotspot / impacted soils. A Detailed Quantitative Risk Assessment (DQRA) may also be required to determine if any risks to human health and controlled water receptors remains following the hotspot removal.

Chemical analysis of the natural subsoil deposits has indicated these soils to be acceptable for use within the proposed garden areas; however, further chemical validation samples will be required to confirm this.

No suitable source of natural topsoil deposits has been identified on-site.



4.2. CONTROLLED WATERS RISK ASSESSMENT

E3P has undertaken a controlled waters risk assessment for the site based on the consideration of the conceptual site model and the sensitive receptors which are summarised in Table 4.3.

TABLE 4.3 CONTROLLED WATERS CONCEPTUAL MODEL AND SENSITIVITY PROFILE

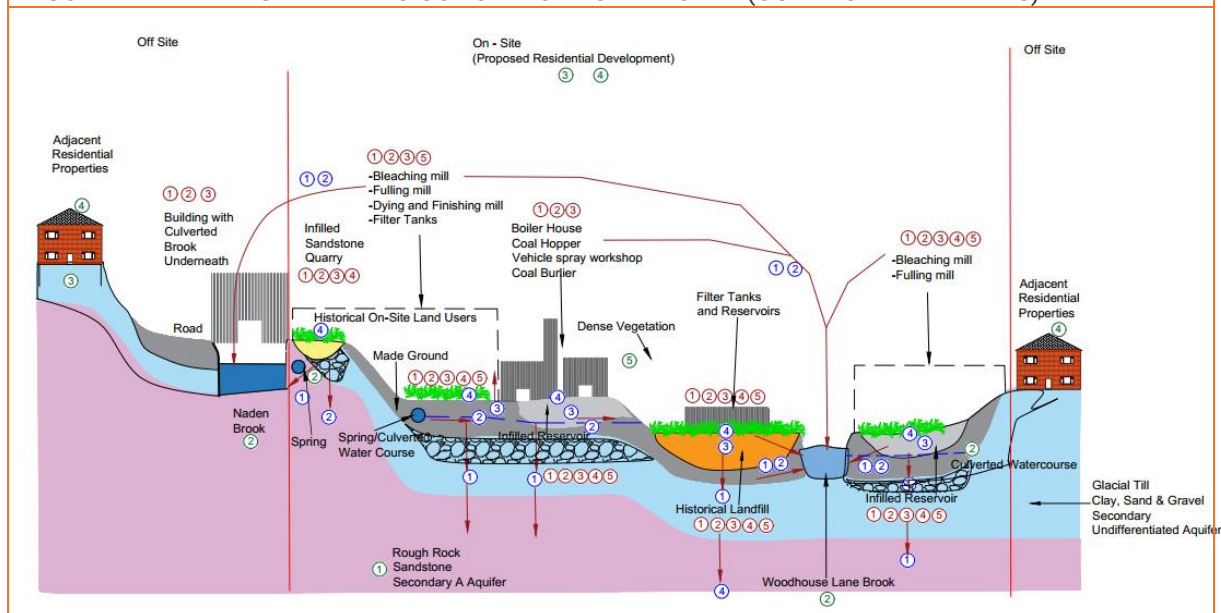
DISCUSSION		SENSITIVITY RATING
Contaminant Source		
Made Ground Made Ground has been encountered to depths up to 5.80 m bgl. Heavy metals, PAHs, hydrocarbons, VOCs and SVOCs exceedances have been encountered within this material. The Made Ground infill material is from historical features on-site, including historical buildings, infilled reservoirs and filter beds/tanks across the site.		High
Bleaching, fulling, dyeing and finishing mills, and vehicle spray workshop The presence of these former works on-site would have produced contaminants which may have entered soils historically.		High
Filter beds, tanks and reservoirs (current and historical) The presence of these on-site may produce hazardous ground gases (carbon dioxide and methane) as well as heavy metals.		High
Historical Tanks A number of tanks were present on-site in the north and central sections of the Tack Lea Works area and the south-eastern section of the Sheppard Mill area; these are likely sources of hydrocarbons, VOCs and SVOCs.		High
Pathway		
Vertical Migration CLAY deposits are present underneath the Made Ground. The presence of this low permeability drift will restrict the migration of contaminants into the Secondary A aquifer. This aquifer was not encountered during the ground investigation. However, the absence of drift deposits in certain locations on-site (NW part of Tack Lea Works area) means that the Made Ground may be in direct contact with the bedrock.		Medium
Lateral migration Lateral migration of contaminants is considered possible due to the presence of granular alluvium deposits across the site. Naden Brook is located on the southern and western boundary of the site and Woodhouse Lane Brook runs through the centre of the site. Naden Brook is classified by the EA as a Statutory Main River. Culverted watercourses and springs associated with the former mill buildings are also believed to be present on-site, though these were not identified during the ground investigation. During the site walkover, a spring was identified in the far northwest part of the Tack Lea works area within an area of outcropping bedrock.		High
Receptor		
Aquifer Classification in Superficial Drift Deposits	Secondary undifferentiated	Low
Aquifer Classification in Bedrock	Secondary A	Medium
Groundwater Source Protection Zone or Drinking Water Safeguard Zone	The site is not affected	Low



DISCUSSION	SENSITIVITY RATING
Distance to the Closest Groundwater Abstraction Point	No active groundwater abstraction points identified within a 1 km radius. The nearest active surface water abstraction point is located 498 m northwest of site (United Utilities) – located upstream of site. Low
Is the Site Located Within 50 m of a Surface Watercourse?	Woodhouse Lane brook is recorded in the centre of the site and runs north to south. Naden Brook is located along the western and southern boundaries of the site. Naden Brook is classified by the EA as a Statutory Main River. Culverted water courses and springs associated with the former mill buildings are also believed to be present on-site, though these were not identified during the ground investigation. During the site walkover, a spring was identified in the far northwest part of the Tack Lea works area within an area of outcropping bedrock. High
The ICSM developed within the context of the site setting has identified a viable pollutant pathway, which would be the lateral migration of potentially mobile phase-soluble contaminants towards Woodhouse Lane Brook and Naden Brook as well as the culverted watercourses and springs located on-site. The presence of low permeability cohesive drift deposits across the site will inhibit vertical migration to the underlying Secondary A bedrock aquifer.	

In addition to above, E3P has developed a diagrammatic conceptual model which considers the factors in Table 4.3. This is available as Drawing 16-465-037 and a snapshot is included in Figure 4.9.

FIGURE 4.9 DIAGRAMMATIC CONCEPTUAL SITE MODEL (CONTROLLED WATERS)



To ensure a robust appraisal of the identified risk to controlled waters, E3P has identified the sources of potential contamination that represent a risk to controlled waters from the initial CSM, we have then assessed the availability of ground investigation data in the form of analysis of the solid phase (soil) and dissolved phase within the perched groundwater or aquifer. The results of this assessment are presented in Table 4.4.

TABLE 4.4 QUALITATIVE RISK TO CONTROLLED WATERS FROM SOIL ANALYTICAL RESULTS

CONTAMINANT	ASSESSMENT RATING	DISCUSSION
BTEX > 1 mg/kg	The soil data analysis has identified concentrations of VOCs above 1 mg/kg in WS19.	Further discussion
Total VOC > 1 mg/kg		
Total SVOC > 1 mg/kg	The soil data analysis has identified concentrations of SVOCs above 1 mg/kg in WS117, WS122, TP122, TP123, TP126, WS19 and WS25.	Further discussion
C5-C10 > 5 mg/kg	All concentrations are below the laboratory LOD.	None
C10-C12 > 10 mg/kg	All concentrations are below or slightly exceeding the laboratory LOD.	None
C12-C16 > 50 mg/kg	The soil data analysis has identified concentrations of TPH C12-C16 above 50 mg/kg in WS122, TP116, TP122, BH10 and WS19.	Further discussion
Phenols > 2 mg/kg	All concentrations are below or slightly exceeding the laboratory LOD.	None
Naphthalene > 2 mg/kg	Concentrations of naphthalene above 2 mg/kg have been recorded in WS117, WS122, TP122, TP123, TP126, WS12, WS19, WS21, WS22 and WS25.	Further discussion
Total PAH > 10 mg/kg	Total concentrations of low-solubility PAH compounds greater than 10 mg/kg have been recorded in WS117, TP116, TP122, TP123, TP126, BH10, WS10, WS12, WS19, WS22 and WS24, with a maximum concentration recorded in TP123 at 334.80 mg/kg.	Further discussion
PCB > 1 mg/kg	No potential sources of PCB have been identified.	None
Heavy metals > 500 mg/kg	Concentrations of heavy metals above 500 mg/kg have been recorded in TP113, TP116, TP126, WS5 and WS9.	Further discussion

The Tier I assessment has included a comparison of leachate analysis from samples of the Made Ground, groundwater samples and surface water samples to environmental quality standards (EQS) due to Naden Brook, Woodhouse Lane Brook, and the culverted watercourses and springs located on-site.

These are presented in Table 4.5 and Table 4.6.

A comparison to Drinking Water Standards (DWS) has not been undertaken as part of this Tier I assessment due to the fact that the site is not located within a groundwater source protection zone and no active groundwater abstraction points are located within 1 km of the site. In the absence of EQS values, the data has been compared to the DWS.



TABLE 4.5 COMPARISON OF GROUNDWATER AND LEACHATE ANALYSIS WITH TIER 1 SCREENING LEVELS

DETERMINAND	UNIT	EQS ^{1,2}	DWS ^{3,4}	NO. OF GW SAMPLES	MAX CONC. IN GROUNDWATER	LOCATION OF EXCEEDANCE	NO. OF LEACHATE SAMPLES	MAX CONC. IN LEACHATE	LOCATION OF EXCEEDANCE	ASSESSMENT
		AA								
Arsenic	µg/l	50	10	2	0.74	-	3	25	-	No Further Action
Cadmium	µg/l	0.08-0.25	5	2	0.04	-	3	<0.08	-	No Further Action
Chromium (VI)	µg/l	3.4	–	2	<5.0	-	3	32	TP108	Further Action
Chromium (III)	µg/l	4.7	50	2	0.7	-	3	62	TP108	Further Action
Copper	µg/l	1	2000	2	2.1	CP101	3	26	TP108 TP115 TP126	Further Action
Total Cyanide	µg/l	1	50	2	<1.0	-	3	5.5	TP115	Further Action
Lead	µg/l	1.2	10	2	<0.2	-	3	15	TP126	Further Action
Mercury	µg/l	–	1.0	2	<0.05	-	3	<0.50	-	No Further Action
Nickel	µg/l	4	20	2	2.1	-	3	2.2	-	No Further Action
Selenium	µg/l	–	10	2	0.6	-	3	<4.0	-	No Further Action
Zinc	µg/l	10.9	–	2	8.3	-	3	18	TP126	Further Action
pH	-	6–9		2	7.7	-	3	11.1	TP108 TP115	Further Action
Polycyclic Aromatic Hydrocarbons										
Naphthalene	µg/l	2	10	2	<0.01	-	3	<0.01	-	No Further Action
Anthracene	µg/l	0.1		2	<0.01	-	3	<0.01	-	No Further Action
Benzo[b]fluoranthene	µg/l	0.00017*		2	<0.01	-	3	<0.01	-	No Further Action
Benzo[k]fluoranthene	µg/l	0.00017*		2	<0.01	-	3	<0.01	-	No Further Action
Benzo(a)pyrene	µg/l	0.00017*		2	<0.01	-	3	<0.01	-	No Further Action



Land at Greenbooth Road and Edenfield Road, Norden

Phase II Geoenvironmental Site Assessment

June 2023

DETERMINAND	UNIT	EQS ^{1,2}	DWS ^{3,4}	NO. OF GW SAMPLES	MAX CONC. IN GROUNDWATER	LOCATION OF EXCEEDANCE	NO. OF LEACHATE SAMPLES	MAX CONC. IN LEACHATE	LOCATION OF EXCEEDANCE	ASSESSMENT
		AA								
Indeno(123-cd)pyrene	µg/l	0.00017*	10	2	<0.01	-	3	<0.01	-	No Further Action
Fluoranthene	µg/l	0.0063		2	0.51	CP103	3	<0.01	-	Further Action
Benzo(ghi)perylene	µg/l	1.7–4		2	<0.01	-	3	<0.01	-	No Further Action
Aromatic Hydrocarbon										
TPH C5-C7 (benzene)	µg/l	10	1	2	<1.0	-	3	<1.0	-	No Further Action
TPH C7-C8 (toluene)	µg/l	74	700	2	<1.0	-	3	<1.0	-	No Further Action
TPH C8-C10 (xylene)	µg/l	30	300	2	<1.0	-	3	<1.0	-	No Further Action
TPH C10-C12 (naphthalene)	µg/l	2	90	2	<0.01	-	3	<0.01	-	No Further Action
TPH C12-C16	µg/l	-	90	2	<10	-	3	<10	-	No Further Action
TPH C16-C35	µg/l	-	90	2	<10	-	3	<10	-	No Further Action
Aliphatic Hydrocarbon										
TPH C5-C6	µg/l	–	1000 ⁵	2	<1.0	-	3	<1.0	-	No Further Action
TPH C6-C8	µg/l	–	1000 ⁵	2	<1.0	-	3	<1.0	-	No Further Action
TPH C8-C10	µg/l	–	300	2	<1.0	-	3	<1.0	-	No Further Action
TPH C10-C12	µg/l	–	300	2	<10	-	3	<10	-	No Further Action
TPH C12-C16	µg/l	–	300	2	<10	-	3	<10	-	No Further Action
TPH C16-C21	µg/l	–	300**	2	<10	-	3	<10	-	No Further Action
TPH C21-C35	µg/l	–	300**	2	<10	-	3	<10	-	No Further Action
Volatile Organic Compounds										



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DETERMINAND	UNIT	EQS ^{1,2}	DWS ^{3,4}	NO. OF GW SAMPLES	MAX CONC. IN GROUNDWATER	LOCATION OF EXCEEDANCE	NO. OF LEACHATE SAMPLES	MAX CONC. IN LEACHATE	LOCATION OF EXCEEDANCE	ASSESSMENT
		AA								
Tetrachloroethylene	µg/l	0.4	10	-	-	-	-	-	-	-
Trichloroethylene	µg/l	10	10	-	-	-	-	-	-	-
Trichlorobenzene	µg/l	0.4	-	-	-	-	-	-	-	-
Trichloromethane	µg/l	2.5	-	-	-	-	-	-	-	-
Dichloromethane	µg/l	20	200	-	-	-	-	-	-	-
Carbon Tetrachloride	µg/l	12	3	-	-	-	-	-	-	-
Vinyl Chloride	µg/l	-	0.3	-	-	-	-	-	-	-

Notes

Solubility <0.01µg/l

AA – Annual Average

* Polyaromatic hydrocarbons (PAH) - Benzo(a)pyrene (BaP), Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(g,h,i)-perylene and Indeno(1,2,3-cd)-pyrene. Benzo(a)pyrene can be considered as a marker for the other PAHs, hence only benzo(a)pyrene needs to be monitored for comparison with the biota EQS or the corresponding AA-EQS in water

** There are no WHO Guideline Values for aliphatic fractions C16-C21 and C21-C35, therefore the guideline value for aliphatic fractions inclusive of C8-C16 (300µg/l) has been applied.

1. [The Water Framework Directive \(Standards and Classification\) Directions \(England and Wales\) 2015 \(legislation.gov.uk\)](#)
2. [The Water Supply \(Water Quality\) Regulations 2018 \(legislation.gov.uk\)](#)
3. [Guidelines for drinking-water quality, 4th edition, incorporating the 1st addendum \(who.int\)](#)
4. [CL:AIRE publishes Petroleum Hydrocarbons in Groundwater guidance \(claire.co.uk\)](#)
5. A total TPH criteria of 1000 mg/kg will act as a surrogate criterion for remaining aliphatic and aromatic TPH fractions.



TABLE 4.6 COMPARISON OF SURFACE ANALYSIS WITH TIER 1 SCREENING LEVELS

COMPARISON OF CONCENTRATIONS WITH THEIR SCREENING LEVELS								
DETERMINAND	UNIT	EQS ^{1, 2}	DWS ^{3, 4}	NO. OF SAMPLES	MAXIMUM CONCENTRATION IN SURFACE WATER		LOCATION OF EXCEEDANCE	ASSESSMENT
		AA			Woodhouse Lane Brook	Naden Brook		
Arsenic	µg/l	50	10	5	0.41	0.49	-	No Further Assessment
Cadmium	µg/l	0.08-0.25	5	5	0.05	0.06	-	No Further Assessment
Chromium (VI)	µg/l	3.4	–	5	<5.0	<5.0	-	No Further Assessment
Chromium (III)	µg/l	4.7	50	5	0.3	0.5	-	No Further Assessment
Copper	µg/l	1	2000	5	4.2	5.1	Woodhouse Lane Brook (U + D) Naden Brook (U, M and D)	Further Assessment
Total Cyanide	µg/l	1	50	5	1.0	<1.0	-	No Further Assessment
Lead	µg/l	1.2	10	5	<0.2	<0.2	-	No Further Assessment
Mercury	µg/l	–	1.0	5	<0.05	<0.05	-	No Further Assessment
Nickel	µg/l	4	20	5	3	1.8	-	No Further Assessment
Selenium	µg/l	–	10	5	<0.6	<0.6	-	No Further Assessment
Zinc	µg/l	10.9	–	5	11	10	Woodhouse Lane Brook (U)	Further Assessment
pH	-	6–9		5	7.8	7.9	-	No Further Assessment
Polycyclic Aromatic Hydrocarbons								
Naphthalene	µg/l	2	10	5	<0.01	<0.01	-	No Further Assessment
Anthracene	µg/l	0.1		5	0.16	<0.01	Woodhouse Lane Brook (D)	Further Assessment
Benzo[b]fluoranthene	µg/l	0.00017*		5	0.44	<0.01	Woodhouse Lane Brook (D)	Further Assessment
Benzo[k]fluoranthene	µg/l	0.00017*		5	0.16	<0.01	Woodhouse Lane Brook (D)	Further Assessment
Benzo(a)pyrene	µg/l	0.00017*		5	0.3	<0.01	Woodhouse Lane Brook (D)	Further Assessment
Indeno(123-cd)pyrene	µg/l	0.00017*		5	<0.01	<0.01	-	No Further Assessment



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DETERMINAND	UNIT	EQS ^{1, 2}	DWS ^{3,4}	NO. OF SAMPLES	MAXIMUM CONCENTRATION IN SURFACE WATER		LOCATION OF EXCEEDANCE	ASSESSMENT
		AA			Woodhouse Lane Brook	Naden Brook		
Fluoranthene	µg/l	0.0063	10	5	0.83	<0.01	Woodhouse Lane Brook (D)	Further Assessment
Benzo(ghi)perylene	µg/l	1.7–4		5	<0.01	<0.01	-	No Further Assessment
Aromatic Hydrocarbon								
TPH C5-C7 (benzene)	µg/l	10	1	5	<1.0	<1.0	-	No Further Assessment
TPH C7-C8 (toluene)	µg/l	74	700	5	<1.0	<1.0	-	No Further Assessment
TPH C8-C10 (xylene)	µg/l	30	300	5	<1.0	<1.0	-	No Further Assessment
TPH C10-C12 (naphthalene)	µg/l	2	90	5	<0.01	<0.01	-	No Further Assessment
TPH C12-C16	µg/l	-	90	5	15	<10	-	No Further Assessment
TPH C16-C35	µg/l	-	90	5	40	<10	-	No Further Assessment
Aliphatic Hydrocarbon								
TPH C5-C6	µg/l	–	1000 ⁵	5	<1.0	<1.0	-	No Further Assessment
TPH C6-C8	µg/l	–	1000 ⁵	5	<1.0	<1.0	-	No Further Assessment
TPH C8-C10	µg/l	–	300	5	<1.0	<1.0	-	No Further Assessment
TPH C10-C12	µg/l	–	300	5	<10	<10	-	No Further Assessment
TPH C12-C16	µg/l	–	300	5	<10	<10	-	No Further Assessment
TPH C16 – C21	µg/l	–	300**	5	<10	<10	-	No Further Assessment
TPH C21-C35	µg/l	–	300**	5	<10	<10	-	No Further Assessment
Volatile Organic Compounds								
Tetrachloroethylene	µg/l	0.4	10	-	-	-	-	-



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DETERMINAND	UNIT	EQS ^{1, 2}	DWS ^{3, 4}	NO. OF SAMPLES	MAXIMUM CONCENTRATION IN SURFACE WATER		LOCATION OF EXCEEDANCE	ASSESSMENT
		AA			Woodhouse Lane Brook	Naden Brook		
Trichloroethylene	µg/l	10	10	-	-	-	-	-
Trichlorobenzene	µg/l	0.4	-	-	-	-	-	-
Trichloromethane	µg/l	2.5	-	-	-	-	-	-
Dichloromethane	µg/l	20	200	-	-	-	-	-
Carbon Tetrachloride	µg/l	12	3	-	-	-	-	-
Vinyl Chloride	µg/l	-	0.3	-	-	-	-	-

Notes

Solubility <0.01µg/l

AA – Annual Average

* Polyaromatic hydrocarbons (PAH) - Benzo(a)pyrene (BaP), Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(g,h,i)-perylene and Indeno(1,2,3-cd)-pyrene. Benzo(a)pyrene can be considered as a marker for the other PAHs, hence only benzo(a)pyrene needs to be monitored for comparison with the biota EQS or the corresponding AA-EQS in water

** There are no WHO Guideline Values for aliphatic fractions C16-C21 and C21-C35, therefore the guideline value for aliphatic fractions inclusive of C8-C16 (300µg/l) has been applied.

1. [The Water Framework Directive \(Standards and Classification\) Directions \(England and Wales\) 2015 \(legislation.gov.uk\)](#)
2. [The Water Supply \(Water Quality\) Regulations 2018 \(legislation.gov.uk\)](#)
3. [Guidelines for drinking-water quality, 4th edition, incorporating the 1st addendum \(who.int\)](#)
4. [CL:AIRE publishes Petroleum Hydrocarbons in Groundwater guidance \(claire.co.uk\)](#)
5. A total TPH criteria of 1000 mg/kg will act as a surrogate criterion for remaining aliphatic and aromatic TPH fractions.



4.2.1. CONTROLLED WATER RISK ASSESSMENT AND MITIGATION

This comparison indicates that the data exceeds the EQS values for the following inorganic compounds:

- ✳ **Chromium (VI)** (Leachate – TP108 at 0.70 m);
- ✳ **Chromium (III)** (Leachate – TP108 at 0.70 m);
- ✳ **Copper** (Leachate – TP108 at 0.70 m, TP115 at 0.80 m and TP126 at 0.90 m; Groundwater - CP101 & CP103, Surface Water - Woodhouse Lane U + D and Naden Brook U, M and D);
- ✳ **Cyanide** (Leachate – TP115 at 0.80 m);
- ✳ **Lead** (Leachate – TP115 at 0.80 m and TP126 at 0.90 m);
- ✳ **Zinc** (Leachate – TP126 at 0.90 m; Surface Water - Woodhouse Lane U);
- ✳ **pH** (Leachate – TP108 at 0.70 m and TP115 at 0.80 m);
- ✳ **Anthracene** (Surface Water - Woodhouse Lane D);
- ✳ **Benzo(b)fluoranthene** (Surface Water - Woodhouse Lane D);
- ✳ **Benzo(k)fluoranthene** (Surface Water - Woodhouse Lane D);
- ✳ **Benzo(a)pyrene** (Surface Water - Woodhouse Lane D); and,
- ✳ **Fluoranthene** (Groundwater - CP103; Surface Water - Woodhouse Lane D).

Encia Consulting identified the following exceedances of the EQS within the subject site boundary:

- ✳ **Chromium (III)** (Leachate – BH2 at 0.50 m, WS8 at 0.40 m, WS9 at 0.50 m and WS11 at 0.60 m; Groundwater – BH10, BH12, WS4, WS5, WS12 and WS19; Surface Water – W1, W3, W4 and W5);
- ✳ **Copper** (Leachate – BH2 at 0.50 m, HP1 at 0.50 m, WS6 at 1.00 m, WS8 at 0.40 m, WS9 at 0.50 m, WS11 at 0.60 m, WS12 at 0.70 m, WS17A at 4.80 m, WS19 at 0.90 m, WS20 at 0.60 m, WS21 at 0.50 m and WS25 at 0.70 m; Groundwater – BH10 and WS12; Surface Water – W1, W3, W4);
- ✳ **Lead** (Leachate – HP1 at 0.50 m, WS4 at 0.50 m, WS6 at 1.00 m, WS11 at 0.60 m, WS19 at 0.90 m, WS20 at 0.60 m and WS25 at 0.70 m);
- ✳ **Nickel** (Leachate – WS21 at 0.50 m);
- ✳ **Zinc** (Leachate – BH2 at 0.50 m, HP1 at 0.50 m, WS4 at 0.50 m, WS8 at 0.40 m, WS9 at 0.50 m, WS11 at 0.60 m, WS12 at 0.70 m, WS19 at 0.90 m and WS20 at 0.60 m; Groundwater – BH10, BH12, WS4, WS5, WS12 and WS19; Surface Water – W1, W3, W4 and W5);
- ✳ **Naphthalene** (Leachate – WS21 at 0.50 m; Groundwater – WS19);
- ✳ **Anthracene** (Leachate – WS19 at 0.90 m, WS21 at 0.50 m and WS25 at 0.70 m; Groundwater – BH12 and WS19);



- ✚ **Benzo(b)fluoranthene** (Leachate – WS21 at 0.50 m; Groundwater – BH12, WS4 and WS12; Surface Water – W4);
- ✚ **Benzo(k)fluoranthene** (Leachate – WS21 at 0.50 m; Groundwater – BH12, WS4 and WS12; Surface Water – W4);
- ✚ **Benzo(a)pyrene** (Leachate – WS21 at 0.50 m; Groundwater – BH12, WS4 and WS12; Surface Water – W4);
- ✚ **Indeno(123cd)pyrene** (Leachate – WS21 at 0.50 m; Groundwater – BH12, WS4 and WS12; Surface Water – W4);
- ✚ **Fluoranthene** (Leachate – WS4 at 0.50 m, WS8 at 0.40 m, WS9 at 0.50 m, WS12 at 0.70 m, WS17A at 4.80 m, WS19 at 0.90 m, WS20 at 0.60 m, WS21 at 0.50 m and WS25 at 0.70 m; Groundwater – BH10, BH12, WS4, WS12 and WS19; Surface Water – W4);
- ✚ **m&p-xylene** (Groundwater – WS19);
- ✚ **o-xylene** (Groundwater – BH12 and WS19);
- ✚ **TPH Aromatics C8-C10, C10-C12, C12-C16, C16-C21 and C21-C35** (Groundwater – BH12 and WS19);
- ✚ **TPH Aliphatic C8-C10** (Groundwater – BH12) (*Screened against DWS in absence of EQS value*);
- ✚ **TPH Aliphatic C10-C12** (Groundwater – BH12 and WS19) (*Screened against DWS in absence of EQS value*); and,
- ✚ **TPH Aliphatic C12-C16** (Groundwater – BH12) (*Screened against DWS in absence of EQS value*).

Note – Leachate sample WS21 underwent 25 times dilution and Water sample WS19 underwent 200 times dilution for PAH analysis.

Contamination Issues Plans for leachate, groundwater and surface water are presented as Drawings 16-465-034 to 16-465-036 in Appendix III, and snapshots are included in Figure 4.10 to Figure 4.12 below.



FIGURE 4.10 CONTAMINATION ISSUES PLAN – LEACHATE

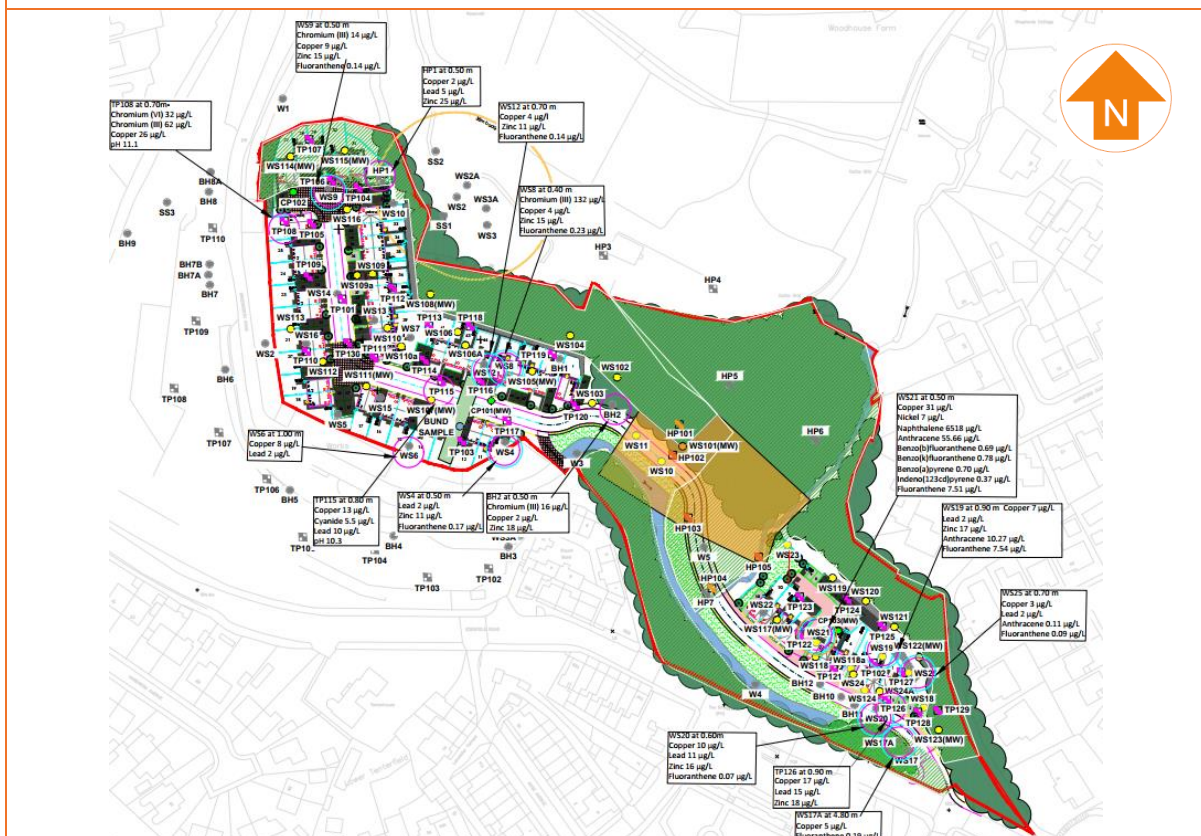


FIGURE 4.11 CONTAMINATION ISSUES PLAN – GROUNDWATER

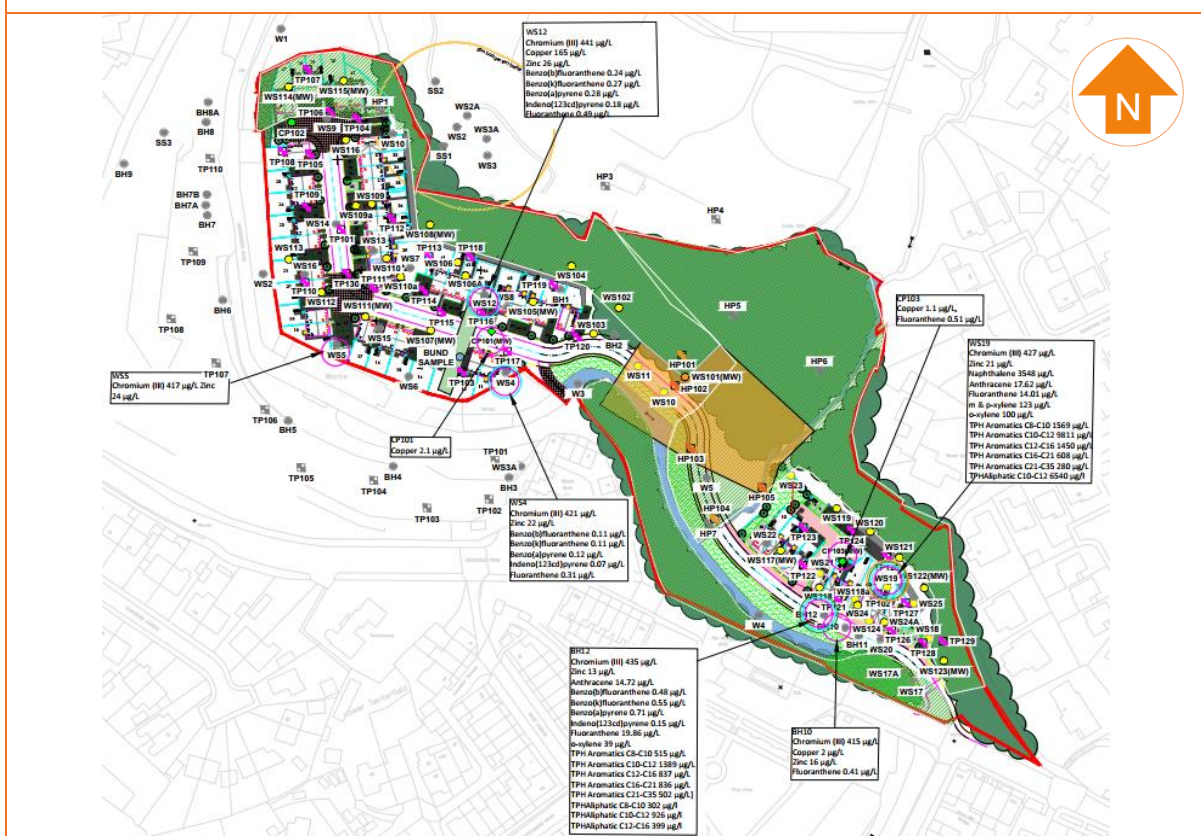
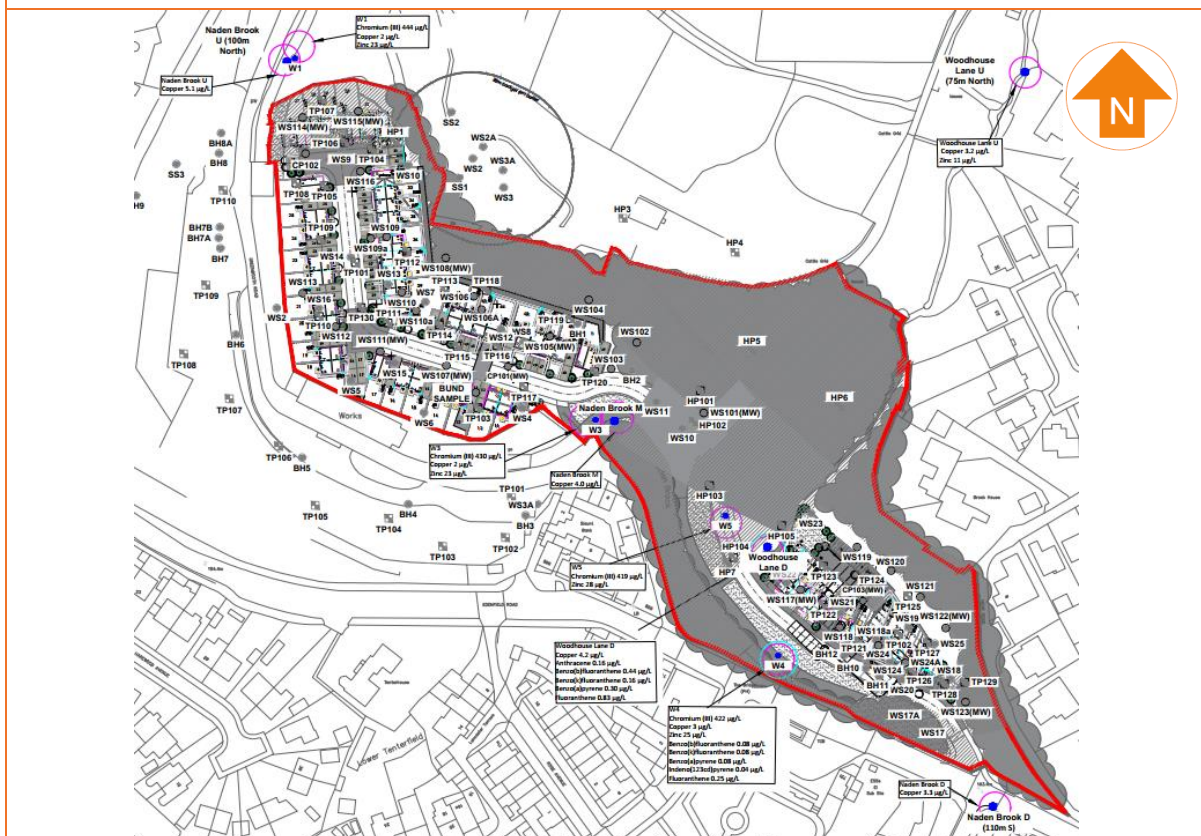


FIGURE 4.12 CONTAMINATION ISSUES PLAN – SURFACE WATER



4.2.2. M-BAT ASSESSMENT

Due to exceedances of the EQS for copper and zinc, an m-BAT assessment has been completed to assess the bioavailability of the metals with respect to surface water receptors (Naden Brook and Woodhouse Lane Brook). The chemical values from the surface water analysis have been input into the assessment.

It is noted that E3P have been unable to undertake an m-BAT assessment on the Encia surface water sample data due to incomplete testing parameters (i.e., DOC and Ca).

Where the Risk Characterisation Ratio (RCR) is greater than 1, this indicates the bioavailable concentration is above the EQS and the receptor is therefore at risk. In this instance, all surface water samples were imputed to the M-BAT assessment as throughout copper was observed above the EQS values and zinc was observed above the EQS values in TP126.

The m-BAT assessment has confirmed that no RCR exceedances have been identified within surface water samples taken from Woodhouse Lane Brook and Naden Brook, and as such, the concentrations of copper and zinc identified within these samples are not considered to be bioavailable.

1. Woodhouse Lane Upstream
 - Copper (0.17)
 - Zinc (0.41)
 - Nickel (0.25)
2. Woodhouse Lane Downstream
 - Copper (0.22)
 - Zinc (0.34)



- Nickel (0.27)
3. Naden Brook Upstream
 - Copper (0.22)
 - Zinc (0.27)
 - Nickel (0.14)
 4. Naden Brook Midstream
 - Copper (0.23)
 - Zinc (0.14)
 - Nickel (0.12)
 5. Naden Brook Downstream
 - Copper (0.16)
 - Zinc (0.42)
 - Nickel (0.15)

Furthermore, this assessment is considered to be conservative given that several concentrations of copper, nickel and zinc within Naden Brook and Woodhouse Lane Brook are greater than concentrations encountered within groundwater, based on the analysis completed to date.

In light of the above assessment, E3P does not consider the site to pose an unacceptable level of risk to surface waters for copper and zinc. It should also be noted that the proposed development will largely encapsulate the site, thus limiting the potential for infiltration and therefore leaching potential.

However, further analysis of Naden Brook and Woodhouse Lane Brook should be undertaken as groundworks progress, to ensure no future mobilisation of contaminants is caused, which may pose a risk to the watercourse.

4.2.3. DISCUSSION OF CONTROLLED WATERS RISK ASSESSMENT

Historically, the site has been subjected to extensive infilling and a number of industrial uses including a bleaching and dyeing mill, filter beds/tanks and infilled reservoirs. Chemical by-products of manufacturing processes and compounds within the Made Ground may have subsequently leached down into the underlying ground and contaminated groundwater both within Made Ground and natural drift deposits.

The Tier I controlled waters risk assessment identified exceedances of the EQS for heavy metals (chromium (III), copper, and zinc), non-volatile PAHs (anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(123cd)pyrene, and fluoranthene) and naphthalene in both the leachate and dissolved phases.

Exceedances of the EQS for chromium (VI), cyanide, lead, nickel and pH were also identified in the leachate phase only.

Exceedances of the EQS for TPHs (m&p-xylene, o-xylene, TPH Aromatic C8-C35 and Aliphatic C8-C16) were also identified in the dissolved phase only, within groundwater samples taken by Encia in the Sheppard Mill area (BH12 and WS19).

No significant concentrations of VOCs or SVOCs were identified within samples submitted for analysis.

PFAS/PFOS testing on groundwater and surface water samples had no detections above the laboratory LOD.

Secondary A Aquifer (Bedrock)



A comparison of leachate and groundwater samples taken by E3P and Encia to the Tier 1 assessment Criteria (Table 4.5) has shown exceedances for heavy metals & inorganics, non-volatile PAHs and naphthalene within soils and groundwater. Exceedances for TPHs were also identified within groundwater in the Sheppard Mill area.

The site is underlain by mixed geology, with cohesive clay and granular sand and gravel across the site.

The granular deposits will afford less protection to the underlying Secondary A aquifer in the bedrock, whereas clay deposits have been identified in excess of 5.00 m in areas, which will restrict the migration of contaminants.

Also, the proposed development will create hardstanding cover across the site, thus reducing the amount of infiltration generated. This will, in turn, reduce the number of contaminants present in leachate off the site and reduce the risk further to the underlying aquifer and on-site stream.

The sensitivity of the aquifer is further reduced given that the site is not located within a groundwater source protection zone and that no active groundwater abstraction points are located within a 1 km radius of the site. The closest active potable abstraction point is a surface water abstraction point located 498 m northwest of the site. It is noted that this abstraction point is located upstream of the site.

As such, the underlying Secondary A Aquifer is deemed to be at a low risk from on-site contamination.

Surface Water Receptor

A comparison of surface water samples taken by E3P and Encia from Naden Brook and Woodhouse Lane Brook to the Tier 1 assessment criteria (Table 4.6) has shown exceedances for copper and zinc within all samples upstream and downstream of the site. As a result of this, it can be said that elevated levels of these determinants cannot be attributed to the site, due to their presence within upstream samples. The m-BAT assessment has also shown that within surface water samples taken by E3P, neither copper nor zinc are considered to be bioavailable.

Concentrations of chromium (III) were found to be in exceedance of the EQS within leachate samples taken by E3P and leachate, groundwater and surface water samples taken by Encia. Chromium (III) is generally considered to be of low solubility and mobility. However, concentrations were noted to be significantly elevated within groundwater and surface water samples (417-444 µg/l) when compared to leachate samples (14-132 µg/l). It is also noted that the elevated concentrations were present within Encia's surface water samples both upstream and downstream of the site (419-444 µg/l). As such, there is the potential that the chromium (III) contamination within the groundwater (on-site) and surface water is migrating from a currently unknown off-site source through the site and into the surface water receptors. However, given the site's history as a dyeing mill (where chromium (III) was actively used in certain dyeing agents), and the fact that concentrations within groundwater and surface water samples are similar, there is the possibility that the chromium (III) contamination is coming from site, and laterally migrating into the surface water courses, thus causing a detrimental impact on the surface water receptors.

The other contaminants of concern, non-volatile PAHs, were identified within the chemical testing in surface water samples taken downstream of Woodhouse Lane Brook (E3P, Woodhouse Lane Downstream) and Naden Brook (Encia, W4). This shows lateral migration of contaminants identified within soils and groundwater is occurring at the site and causing a detrimental impact on the surface water receptors.



It is also noted that mobile contaminants identified within the soils and groundwater (non-volatile PAHs, naphthalene and TPHs) have the potential to migrate laterally towards the surface water receptors as a result of the high permeability strata present beneath the site. The cohesive strata that is present beneath the site may also act as an impermeable barrier and channel mobile contaminants towards the surface water receptors. As such, the surface water receptors are deemed to be at a high risk from on-site contamination.

Conclusions & Recommendations

Though the risk to the underlying bedrock Secondary A aquifer is considered to be low, the risk to the surface water receptors is considered to be high, due to the presence of impacted soils and groundwater within close proximity of surface water features, and the presence of high permeability strata beneath the site which would afford the lateral and vertical migration of contaminants.

It is noted that limited groundwater sampling was undertaken during the monitoring programme. This was due to the majority of monitoring wells either having insufficient or no groundwater within them. As such, it has not been possible to determine a groundwater flow direction.

During the remediation and enabling works phase, the removal of the hardstanding currently present across the site may induce infiltration and potential mobilisation of contaminants present within the soils and groundwater directly into the surface water receptors.

As such, it is recommended that further investigation, in the form of deep boreholes and monitoring well installations, with further groundwater and surface water monitoring and sampling is undertaken in order to develop a robust groundwater conceptual site model and controlled waters risk assessment for the site.

4.3. GROUND GAS RISK ASSESSMENT METHODOLOGY

The potential impact on the development from ground gases has been assessed with reference to standards and guidelines published in:

- ✳ CIRIA Report 665 – Assessing risks posed by hazardous ground gases to buildings (2007)
- ✳ BS8485:2015+A1:2019 – Code of Practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings

BS8485 provides guidance on the level of gas protection requirements based upon the characteristic situation (CS) and the proposed development based on building type.

Therefore, in accordance with BS8485, based on the measured flow rates and hazardous gas concentrations, individual hazardous gas flow rates (Q_{hg}) shall be derived for each monitoring point, from which the site characteristic hazardous gas flow rate (Q_{hgs}), and then the Characteristic Situation (CS) can be determined.

The following equation should be utilised:

$$Q_{hg} = q \left(\frac{C_{hg}}{100} \right)$$

Where:

q is the measured flow rate (in litres per hour) of combined gases from the monitoring standpipe
 C_{hg} is the measured hazardous gas concentration (in percentage volume/volume).



The subsequent derived gas screening value (GSV) should be the maximum Q_{hg} (flow rate x concentration as a percentage volume) for all the monitoring events.

A 'worst case check' may be carried out using the maximum recorded flow in any hole with the maximum concentration in any hole to present the plausible worst-case conditions. Adoption of the worst-case Q_{hg} requires thorough justification and reference to the CSM.

The final derived GSV can then be used to characterise the site as summarised in Table 4.7.

TABLE 4.7 SITE CHARACTERISATION BY GSV (BS8485:2015)

CS	HAZARD POTENTIAL	GSV (l/hr) FOR METHANE AND CARBON DIOXIDE	ADDITIONAL FACTORS
CS1	Very Low	< 0.07	Typically <1% methane concentration and <5% carbon dioxide concentration (otherwise consider an increase to CS2)
CS2	Low	< 0.70	Typical measured flow rate <70 l/h (otherwise consider an increase to CS3)
CS3	Moderate	< 3.5	N/A
CS4	Moderate to High	< 15	N/A
CS5	High	< 70	N/A
CS6	Very High	> 70	N/A

Notes

1. The CS is equivalent to the characteristic GSV in CIRIA C665.
2. The worst-case ground gas regime identified on the site, either methane or carbon dioxide, at the worst-case temporal conditions that the site may be expected to encounter should be considered.
3. Gas Screening Value is the Borehole Gas Volume Flow Rate, in litres per hour, multiplied by the concentration in the air stream of the particular gas being considered.
4. The Gas Screening Value thresholds should not generally be exceeded without the completion of a detailed ground gas risk assessment taking into account site-specific conditions.

4.4. MONITORING METHODOLOGY

Concentrations of methane (CH_4), carbon dioxide (CO_2) and oxygen (O_2) were measured using a calibrated infrared gas analyser (GFM435) with gas flow rates measured using an integrated flow meter.

Gas measurements were recorded for a minimum of 500 seconds at each location, at which point the maximum concentration of CH_4 and CO_2 , together with the lowest concentration of O_2 were recorded.

The results of the ground gas monitoring are presented in Table 4.8.

In addition to the raw data, the results for each individual standpipe have been assessed with reference to guidance provided in BS8485:2015+A1:2019. Based on the initial peak measured flow rates and hazardous gas concentrations, individual hazardous gas flow rates (Q_{hg}) have been derived for each monitoring point, from which an individual Characteristic Situation (CS) can ultimately be determined.



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TABLE 4.8 SUMMARY OF GROUND GAS MONITORING RESULTS

WELL	STRATA	DATE	CH ₄ PEAK (%V/V)	CH ₄ STEADY (%V/V)	CH ₄ Q _{hg} (l/hr)	CO ₂ PEAK (%V/V)	CO ₂ STEADY (%V/V)	CO ₂ Q _{hg} (l/hr)	O ₂ (%V/V)	ATMOS (mb)	ATMOS. DYNAMIC	PEAK FLOW (l/hr)	STEADY FLOW (l/hr)	RESPONSE ZONE (m bgl)	DEPTH TO BASE (m bgl)	DEPTH TO WATER (m bgl)
WS101	MG	29/11/2022	0.1	0.1	0.0001	0.1	0.1	0.0001	19.5	1001	Steady	0.1	0.1	1.00-3.00	2.85	DRY
		12/12/2022	0.1	0.1	0.0001	0.1	0.1	0.0001	20	986	Steady	0.1	0.1		2.85	DRY
WS105	GRAVEL	29/11/2022	0.1	0.1	0.0001	0.1	0.1	0.0001	19.6	1001	Steady	0.1	0.1	1.00-2.50	2.25	1.70
		12/12/2022	0.1	0.1	0.0001	0.1	0.1	0.0001	19.9	987	Steady	0.1	0.1		2.35	1.88
WS107	MG	29/11/2022	0.1	0.1	0.0001	0.1	0.1	0.0001	19.6	1000	Steady	0.1	0.1	0.50-1.55	1.40	1.30
		12/12/2022	0.1	0.1	0.0001	0.1	0.1	0.0001	20.1	986	Steady	0.1	0.1		1.53	1.40
WS108	MG	29/11/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	19.6	1000	Steady	0.1	0.1	0.50-1.00	0.80	DRY
		12/12/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	20.1	986	Steady	0.1	0.1		0.85	DRY
WS111	MG	29/11/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	19.5	1000	Steady	0.1	0.1	0.50-1.00	1.90	DRY
		12/12/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	20	986	Steady	0.1	0.1		2.00	DRY
WS114	GRAVEL	29/11/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	19.5	1000	Steady	2.6	0.1	1.00-3.00	2.55	DRY
		12/12/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	20	985	Steady	0.1	0.1		2.65	DRY
WS115	MG	29/11/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	19.5	1000	Steady	0.1	0.1	1.00-3.00	1.70	DRY
		12/12/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	20.1	985	Steady	0.1	0.1		1.85	DRY
WS117	MG	29/11/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	19.5	1001	Steady	0.1	0.1	1.00-3.00	2.70	2.35
		12/12/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	19.8	987	Steady	0.1	0.1		2.80	2.48
WS122	CLAY	29/11/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	19.5	1001	Steady	0.1	0.1	2.00-4.00	3.25	2.80
		12/12/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	19.8	988	Steady	0.1	0.1		3.32	2.90
WS123	MG	29/11/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	19.5	1001	Steady	0.1	0.1	0.50-1.50	1.30	DRY
		12/12/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	19.7	988	Steady	0.1	0.1		1.40	DRY
CP101	MG	29/11/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	19.5	1001	Steady	0.1	0.1	1.00-5.00	4.10	1.65
		12/12/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	20	988	Steady	0.1	0.1		4.34	1.80



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WELL	STRATA	DATE	CH ₄ PEAK (%V/V)	CH ₄ STEADY (%V/V)	CH ₄ Q _{hg} (l/hr)	CO ₂ PEAK (%V/V)	CO ₂ STEADY (%V/V)	CO ₂ Q _{hg} (l/hr)	O ₂ (%V/V)	ATMOS (mb)	ATMOS. DYNAMIC	PEAK FLOW (l/hr)	STEADY FLOW (l/hr)	RESPONSE ZONE (m bgl)	DEPTH TO BASE (m bgl)	DEPTH TO WATER (m bgl)
CP103	GRAVEL	29/11/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	19.5	1001	Steady	0.3	0.1	3.00-4.80	4.80	2.00
		12/12/2022	0.1	10.1	0.0001	0.1	0.1	0.0001	19.8	988	Steady	0.1	0.1		4.97	2.40

Notes

CIRIA Characteristic Situation

Q_{hg}

CS1

<0.07

Typical Max CO₂ <5 % Typical Max CH₄ <1 %

Values in **BOLD** exceed CS1 Thresholds

CS2

<0.7

Flow rate not to exceed 70 l/hr otherwise consider increase to CS3

Values in **BLUE** denote water above level of response zone (flooded)

CS3

<3.5

CS4

<15

Quantitative Risk Assessment required to evaluate scope of protective measures



4.5. SUMMARY OF MONITORING RESULTS

4.5.1. GROUNDWATER

Water levels have been observed to fall within five monitoring wells across the first two monitoring visits undertaken to date. Six wells were observed to be dry during the first two monitoring visits. Monitoring well CP103 was observed to be flooded during the first two monitoring visits. The shallowest water was recorded in WS107 at 1.30 m bgl during the first round of monitoring and the deepest water level recorded was in WS122 at 2.90 m bgl during the second round of monitoring.

4.5.2. BAROMETRIC PRESSURE

The first two monitoring visits were undertaken during a period of steady pressure, with atmospheric pressures ranging between 1000–1001 mbar during the first round of monitoring, and 985–988 mbar during the second round of monitoring.

Supplementary gas monitoring visits should be undertaken during a period of low (<1000 mb) and falling atmospheric pressure to allow for monitoring under representative conditions.

4.5.3. GAS FLOW

Throughout the monitoring period, flow rates were recorded to be 0.1 l/hr (limit of detection of the analyser).

4.5.4. GAS CONCENTRATIONS

The maximum methane and carbon dioxide value recorded within the monitoring wells was 0.1% v/v (limit of detection of the analyser).

4.6. CONCLUSION

The determined Characteristic Situation for each standpipe for each visit is presented in Table 4.9. This indicates that based on the peak flow rates the majority of the monitoring visits classify as Characteristic Situation (CS)1 – Very Low Gas Risk.

TABLE 4.9 GAS RISK PROFILE AND LOCATION

WELL	DATE	DEPTH TO WATER (m bgl)	MAX FLOW (l/hr)	MAX CH ₄ (%V/V)	MAX CH ₄ Q _{hg} (l/hr)	MAX CO ₂ (%V/V)	MAX CO ₂ Q _{hg} (l/hr)	CHARACTERISTIC SITUATION	NHBC TRAFFIC LIGHT
WS101	29/11/2022	DRY	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
	12/11/2022	DRY	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
WS105	29/11/2022	1.70	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
	12/11/2022	1.88	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
WS107	29/11/2022	1.30	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
	12/11/2022	1.40	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
WS108	29/11/2022	DRY	0.1	0.1	0.0001	0.1	0.0001	CS1	Green



WELL	DATE	DEPTH TO WATER (m bgl)	MAX FLOW (l/hr)	MAX CH ₄ (%V/V)	MAX CH ₄ Q _{hg} (l/hr)	MAX CO ₂ (%V/V)	MAX CO ₂ Q _{hg} (l/hr)	CHARACTERISTIC SITUATION	NHBC TRAFFIC LIGHT
WS111	12/11/2022	DRY	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
	29/11/2022	DRY	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
	12/11/2022	DRY	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
WS114	29/11/2022	DRY	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
	12/11/2022	DRY	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
WS115	29/11/2022	DRY	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
	12/11/2022	DRY	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
WS117	29/11/2022	2.35	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
	12/11/2022	2.48	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
WS122	29/11/2022	2.80	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
	12/11/2022	2.90	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
WS128	29/11/2022	DRY	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
	12/11/2022	DRY	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
CP101	29/11/2022	1.65	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
	12/11/2022	1.80	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
CP103	29/11/2022	2.00	0.1	0.1	0.0001	0.1	0.0001	CS1	Green
	12/11/2022	2.40	0.1	0.1	0.0001	0.1	0.0001	CS1	Green

Note - Values in BLUE denote water above level of response zone (flooded)

Preliminary ground gas monitoring suggests that the site can be classified as CS1/Green, although this classification is subject to the completion of the overall monitoring programme.

Made Ground has been encountered across the site to a recorded depth of 5.80 m bgl. Drift deposits comprising glacial till of SAND and CLAY have been encountered across the site at depths ranging between 0.10 m and 15.00 m bgl.

The historical landfill in the eastern section of the Tack Lea Works area has had limited investigation with regard to potential ground gas risk. As such, it is recommended that precautionary allowances for CS2 protection measures should be implemented across the site until further monitoring and assessment have been undertaken.

It is noted that elevated concentrations of volatile contaminants (naphthalene, TPHs, VOCs, SVOCs, and mercury) have been identified within the Made Ground on-site, which present a potential volatilisation to indoor air risk.

Elevated concentrations of volatile contaminants in the Tack Lea Works area are considered to be localised occurrences and therefore these locations can be treated as hotspots. However, elevated concentrations of volatile contaminants have been identified throughout the Shepherd Mill area and these do not appear to be localised hotspots.

Further assessment, in the form of a Tier II vapour risk assessment is required across the site to assess the level of risk to the future site users by volatilisation to indoor air. Subject to the findings of the vapour risk assessment, vapour resistant membranes may be required.



It is recommended that the full ground gas assessment and recommended protection measures (if applicable) are agreed upon with the local authority prior to their adoption on-site. Furthermore, all protection measures adopted should be validated by a suitably qualified engineer.

4.7. RADON

As of February 2023, the UK Health Security agency (UKHSA) and the British Geological Society (BGS) have published an updated radon potential map for Great Britain.

The latest update to the radon map has the potential to reclassify areas that have previously been assured as low risk to be potentially be affected by radon.

A BGS Radon Report was purchased for the site, which indicated that the northeast and northwest of the site is situated in an area where 1–3% of homes are above the "Action Level" and the rest of the site is situated in an area where 0–1% of homes are above the "Action Level". Therefore, full radon protective measures are not necessary for the construction of new dwellings or extensions.

A full site-specific radon report is presented in Appendix XI.

4.8. POTABLE WATER SUPPLY

This section provides a summary of the ground investigation data with reference to the selection of potable water supply pipework. The assessment is made with reference to the UK Water Industry Research (UKWIR) publication "Guidance on the selection of Water Supply Pipes to be used in Brownfield Sites"

TABLE 4.10 PIPELINE SELECTION PE THRESHOLD CONCENTRATIONS

Contaminant Group	PE-threshold (mg/kg)	Concentrations at <u>Current</u> pipeline depth (mg/kg)
Total VOC	0.5	130
Total BTEX And MTBE	0.1	<1.0
Total SVOCs (Excluding PAH and those substances marked with an *)	2	110
EC5-EC10 Aliphatic and Aromatic Hydrocarbons	2	<1.0
EC10-EC16- Aliphatic and Aromatic Hydrocarbons	10	150
EC16-EC40 Aliphatic and Aromatic Hydrocarbons	500	460
Phenols (From SVOC Analysis)*	2	1.3
Cresols and Chlorinated Phenols (From SVOC Analysis)	2	N/A
Ethers*	0.5	N/A
Nitrobenzene*	0.5	N/A
Ketones*	0.5	N/A
Aldehydes*	0.5	N/A
Amines	Fail	N/A
Other Consideration		



Are there any exceedances of the PE threshold outside of the pipeline depth?	Yes
Is free product present in soil and groundwater?	None
Could hydrocarbon impact at greater depth than current pipeline depth be mobilised by rising groundwater levels?	Groundwater has been identified at depths deeper than 1.30 m bgl to date.
Will soils impacted with the above determinands likely be utilised elsewhere on-site?	Currently unknown
Will soils be imported to the site as part of any future earthworks	Currently unknown

Notes - Pipeline depth is normally between 0.75m–1.35m

Based on the assessment of current site conditions, it is likely that barrier pipe will be required at the proposed development.

This will need to be confirmed with a UKWIR risk assessment post-remediation. Post-remediation and enabling works ground conditions may be different from those identified during this ground investigation.



4.9. CONCEPTUAL SITE MODEL

Following the completion of the intrusive ground investigation, chemical analysis and risk assessment, the conceptual model shown in Table 4.11 has been prepared for the site.

TABLE 4.11 CONCEPTUAL MODEL

POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
PL1	Heavy metals, non-volatile PAH (Made Ground, historical mills, and industrial works.)	Dermal contact.	Future site users.	Likely	High	LOW
PL2		Dermal contact and ingestion.	Off-site receptors.			

Assessment:

Heavy metals (arsenic, lead and mercury), and non-volatile PAHs (phenanthrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(a)pyrene and dibenzo(a,h)anthracene) have been identified within Made Ground soils in the Tack Lea Works area (WS110, WS111, TP113, TP115, TP116, WS5, WS9 and WS10) and Sheppard Mill area (HP7, TP122, TP126 and WS25).

Elevated concentrations of lead and PAHs have also been identified within material sampled from the earthen bund in the centre of the Tack Lea Works area.

Recommendation:

A 600 mm reduced level garden cover system to garden and landscaped areas will prevent exposure to future site users.

Construction works to be completed with PPE and the provision of welfare.

During remediation and enabling works, speciated mercury analysis should be completed at the locations WS111, WS9 and WS25 to assess whether elemental mercury is present which may pose a risk to future site users through vapour inhalation. If elemental mercury is identified, it may be necessary to delineate and excavate the soils as a hotspot and place them in an area of low sensitivity such as beneath areas of public open space or removed from site. Alternatively, if it is proven that there is no elemental mercury, a clean cover system will be sufficient.



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POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
PL3	ACM in Made Ground	Inhalation of dust.	Future site users. Off-site land users.	Likely	High	LOW
Assessment: Asbestos in the form of chrysotile and amosite has been identified within localised areas in Made Ground deposits in the southern part of Sheppard Mill area (WS124 and WS18), the historical landfill in the eastern section of Tack Lea Works area (HP05) and the central section of Tack Lea Works (TP114 and TP116). Asbestos bulk fragments, in the form of hard cement were also identified in WS124, HP05 and WS10; and asbestos sheeting/board debris within HP05. Visual signs of ACM were encountered during the ground investigations in HP05. Quantification testing was undertaken with the highest concentration recorded in WS124 at 0.705%. The remaining samples had concentrations of 0.002% (TP116), 0.011% (TP114) and 0.036% (HP05). Recommendation: Impacted soils will require placement in accordance with the asbestos CSM. Construction works completed with PPE/RPE and provision of welfare. Asbestos bulk fragments will require removal via hand picking techniques prior to the commencement of any earthworks.						
PL4	Volatile Contaminants such as hydrocarbons and solvents (Made Ground, historical mills and industrial works)	Inhalation of vapours. Migration through permeable strata and preferential pathways.	Future site users. Off-site receptors.	Likely	High	To be determined
Assessment: Elevated concentrations of naphthalene, TPH, and trichloroethene (TCE) have been identified within the Tack Lea Works area (TP116 and WS12); these are considered to be localised occurrences and therefore can be treated as a localised hotspot. SVOCs identified in WS107 and TP116 within the Tack Lea Works area are not considered to pose a risk to future site users given the marginal concentrations. However, elevated concentrations of naphthalene, TPH, VOCs and SVOCs have been identified throughout the Shepherd Mill area and these do not appear to be localised hotspots.						



POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
Recommendation: During a process of cut/fill enabling works, a hotspot removal should be undertaken in the Tack Lea Works area where these soils may be chemically validated to assess chemical suitability for retention on-site in an area of no future sensitivity. A Tier II vapour risk assessment is required in the Sheppard Mill area to assess the level of risk to the future site users by volatilisation to indoor air. Visual and olfactory evidence of contamination has been identified in a number of locations; therefore, a watching brief should be completed during remediation works to monitor the locations where visual or olfactory hydrocarbon impact has been identified during all phases of investigation completed to date.						
PL4	Methane, carbon dioxide (Made Ground and potentially infilled features on and within 250 m of the site)	Inhalation of gas. Migration through permeable strata and preferential pathways. Explosion in confined spaces.	Future site users. Buildings. Off-site land users.	Low likelihood	Low	LOW
Assessment: Deep Made Ground and organic deposits have been identified as potential sources of hazardous ground gas. Preliminary ground gas monitoring data suggests the site can be classified as CS1. It is noted that elevated concentrations of volatile contaminants (naphthalene, TPHs, VOCs, SVOCs, and mercury) have been identified within the Made Ground on-site, which present a potential volatilisation to indoor air risk. Elevated concentrations of volatile contaminants in the Tack Lea Works area are considered to be localised occurrences and therefore these locations can be treated as hotspots. However, elevated concentrations of volatile contaminants have been identified throughout the Shepherd Mill area and these do not appear to be localised hotspots.						
Recommendation: Completion of gas monitoring is required to confirm this. Due to the presence of the historical landfill in the eastern section of the Tack Lea Works area, allowances for CS2 protection measures should be implemented across the site until further monitoring and assessment have been undertaken. Further assessment, in the form of a Tier II vapour risk assessment is required across the site to assess the level of risk to the future site users by volatilisation to indoor air. Subject to the findings of the vapour risk assessment, vapour resistant membranes may be required.						



POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
PL5	Mobile contaminants such as metals, PAHs, hydrocarbons, volatile compounds (Made Ground, historical mills and works)	Surface runoff. Migration through permeable strata and preferential pathways. Perched waters migration.	Groundwater (Secondary A bedrock aquifer). Surface water (Woodhouse Lane Brook and Naden Brook).	Likely	High	To be determined

Assessment:

Historically, the site has been subjected to extensive infilling and a number of industrial uses including a mill and filter beds/tanks. Chemical by-products of manufacturing processes and compounds within the Made Ground may have subsequently leached down into the underlying ground and contaminated groundwater both within Made Ground and natural drift deposits.

The Tier I controlled waters risk assessment identified exceedances of the EQS for heavy metals (chromium (III), copper, and zinc), non-volatile PAHs (anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(123cd)pyrene, and fluoranthene) and naphthalene in both the leachate and dissolved phases. Exceedances of the EQS for chromium (VI), cyanide, lead, nickel and pH were also identified in the leachate phase only. Exceedances of the EQS for TPHs (m&p-xylene, o-xylene, TPH Aromatic C8-C35 and Aliphatic C8-C16) were also identified in the dissolved phase only, within groundwater samples taken by Encia in the Sheppard Mill area (BH12 and WS19).

The underlying Secondary A Aquifer is deemed to be at a low risk from on-site contamination given the presence of cohesive deposits in excess of 5.00 m; the proposed development will create new hardstanding which will reduce infiltration and the number of contaminants present in leachate migrating off-site; and the fact that the site is not located within a groundwater source protection zone and that no active groundwater abstraction points are located within a 1 km radius of the site.

Concentrations of chromium (III) were found to be in exceedance of the EQS within leachate samples taken by E3P and leachate, groundwater and surface water samples taken by Encia. Non-volatile PAHs were also identified within the chemical testing in surface water samples taken downstream of Woodhouse Lane Brook (E3P, Woodhouse Lane Downstream) and Naden Brook (Encia, W4). This shows lateral migration of contaminants identified within soils and groundwater is occurring at the site and causing a detrimental impact on the surface water receptors.



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POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
It is noted that mobile contaminants identified within the soils and groundwater (non-volatile PAHs, naphthalene and TPHs) have the potential to migrate laterally towards the surface water receptors as a result of the high permeability strata present beneath the site. The cohesive strata that is present beneath the site may also act as an impermeable barrier and channel mobile contaminants towards the surface water receptors. As such, the surface water receptors are deemed to be at a high risk from on-site contamination. It is noted that limited groundwater sampling was undertaken during the monitoring programme. This was due to the majority of monitoring wells either having insufficient or no groundwater within them. As such, it has not been possible to determine a groundwater flow direction. During the remediation and enabling works phase, the removal of the hardstanding currently present across the site may induce infiltration and potential mobilisation of contaminants present within the soils and groundwater directly into the surface water receptors. Recommendation: Further investigation, in the form of deep boreholes and monitoring well installations, with further groundwater and surface water monitoring and sampling is recommended in order to develop a robust groundwater conceptual site model and controlled waters risk assessment for the site.						
POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
PL6	Sulphate (potential ash within Made Ground)	Sulphate attack on concrete.	Building structure.	Likely	Low	LOW
Assessment: The Made Ground and natural soils at the site meet class DS-1, AC-1s. In the LK Consult 2020 Report, concentrations of soluble sulphate in the soil when contrasted to BRE Digest 200535 categorised the concrete requirement as DS-2 AC-3z in the Made Ground and DS-1 AC1 in the natural strata. Recommendation: Concrete should be designed in accordance with the chemical testing results.						



POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
PL7	Organic contaminants such as hydrocarbons, solvents (Made Ground, scrap yards, mills and works)	Ingestion of tainted water supply.	Future site users. Water pipes.	Likely	Moderate	LOW
Assessment: Elevated concentrations of TPH have been identified at the proposed pipeline depth (0.75 m – 1.35 m).						
Recommendation: Based on the assessment of current site conditions, it is likely that barrier pipe will be required. This will need to be confirmed with a UKWIR risk assessment post-remediation. Post-remediation and enabling works ground conditions may be different from those identified during this ground investigation.						
POLLUTANT LINKAGE	CONTAMINANT (SOURCE)	PATHWAY	RECEPTOR	PROBABILITY	CURRENT RISK	RESIDUAL RISK AFTER MITIGATION
PL8	Phytotoxic contaminants (Made Ground)	Direct Contact (plant uptake).	Flora.	Likely	Low	LOW
Assessment: Contamination has been encountered within shallow Made Ground across the site which may be taken up by flora in soft landscaping. Copper and zinc are present within groundwater and leachate.						
Recommendation: Installation of a clean cover system within any areas of soft landscaping to prevent plant uptake of contaminants.						

Main exposure pathways:

PL1 = soil ingestion, PL2 = dermal contact and ingestion, PL3 = dust inhalation; PL4 = Vapour/Gas Inhalation; PL5 = Vertical / Lateral Migration; PL6 = Corrosion of concrete; PL7=Tainting of water supply; PL8 = Uptake by plants;



5. GEOTECHNICAL ASSESSMENT

5.1. PROPOSED DEVELOPMENT

Stonebond Properties Ltd intends to construct a low-rise residential development comprising 49 residential dwellings with associated gardens, estate roads, and infrastructure, including a connecting bridge. Drawing 16-465-002 (Appendix III) identifies the proposed development layout.

5.2. SUMMARY OF GROUND CONDITIONS

Made Ground

Made Ground deposits were encountered within all exploratory hole locations to depths ranging between 0.00 m and 5.80 m bgl. However, in 34 locations, the full thickness of Made Ground could not be proven due to significant concrete and brick obstructions and basement features, which are indicative of relict foundations from the former buildings. The five hand pit locations within the eastern section of the Tack Lea Works area were all terminated within Made Ground.

In all locations except WS101 and WS103 (central section of the Tack Lea Works area), concrete was encountered to a maximum proven depth of 0.68 m bgl (WS104). The concrete often contained rebar. In WS101 and WS103, a dark brown clay with occasional rootlets (reworked topsoil) was encountered.

In the majority of locations, the concrete was underlain by brown sandy gravel with gravels of sandstone, mudstone, limestone, concrete, and brick.

In two locations in the Tack Lea Works area (TP118, and TP120) and one location in Sheppard Mill area (TP121) a brown gravelly sand was encountered.

In five locations in the Tack Lea Works area (WS101, WS102, WS103, WS107 and WSS14) and three locations in Sheppard Mill area (WS119, WS122 and WS124) a brown gravelly clay was encountered underneath the sandy gravel.

In one location within the Tack Lea Works area (TP113), a dark brown blackish slightly clayey slightly gravelly silt and a white sandy silt were encountered.

Frequent fragments of ceramic, glass, wood, and metal were encountered within the Made Ground. Ash was also encountered in one location within the Tack Lea Works area (WS115) and one location in the Sheppard Mill area (WS123).

Drift

Drift deposits were encountered within twenty-four exploratory hole locations between depths of 0.50 m and 15.00 m bgl. The drift deposits varied, with the majority comprising a brown gravelly CLAY with gravels of mudstone and sandstone. The strength of CLAY varied from soft to very stiff.

In seven locations across the Tack Lea Works area (TP130, WS102, WS103, WS105, WS107, WS111 and WS114) and in two locations within Sheppard Mill area (WS119 and WS120) a brown clayey GRAVEL was encountered with gravels of sandstone and mudstone.

In TP103 (south-western boundary of Tack Lea Works Area), a brown gravelly SAND was encountered with gravels of sandstone and mudstone.



Solid

The solid bedrock geology was not encountered during this phase of the investigation. There are no BGS boreholes within close proximity to the site.

In the Encia Consulting 2006 Report, shallow bedrock of sandstone was encountered in the central and western sections of the Tack Lea Works area at depths typically <2.00 m bgl. To the north of the Tack Lea Works area, bedrock can be seen outcropping in the valley and hillside. To the east of the Tack Lea Mill Buildings and in the Sheppard Mill area, bedrock was found to be deeper and was encountered at depths ranging between 4.30 m and 5.00 m bgl.

Groundwater

Groundwater was encountered as seepages in five locations between 1.40 m – 2.50 m bgl.

5.3. SITE PREPARATION

The site should be cleared and any vegetation below areas of proposed development stripped in accordance with Series 200 of the *Manual of Contract Documents for Highway Works (MCHW)*. This should include the following:

- ✚ As parts of the proposed development works (i.e., demolition and construction) will be completed within 8 m of a main river, a Flood Risk Activity Permit (FRAP) will be required.
- ✚ Roots present below the footprint of proposed structures and infrastructure should be grubbed out and the resulting void infilled with suitable compacted engineered fill.
- ✚ Demolition of all existing buildings and removal of all concrete hardstanding.
- ✚ Redundant services should be sealed off and grubbed out and replaced with suitable compacted engineered fill.
- ✚ Buried structures and old foundations have been encountered on-site. These should be excavated from below the proposed development footprint with the resulting void backfilled.

5.4. FOUNDATION CONDITIONS AND ASSESSMENT OF POTENTIAL BEARING CAPACITIES

In due consideration of the identified ground conditions, in-situ and laboratory geotechnical testing, E3P has undertaken an assessment of the net safe allowable bearing pressure (ABP) within the underlying natural stratum to assist in the detailed design of foundations and infrastructure and determine the target founding stratum. The results of this assessment are summarised in Table 5.1.



TABLE 5.1 SUMMARY OF ABP

GRANULAR SOILS			
Description	Depth (Range m bgl)	Relative Density	Allowable Bearing Pressure (kN/m ²)
Clayey GRAVEL	1.00 – 2.00	Loose	60 - 73
Sandy GRAVEL (1 location – CP103)	3.00	Loose	70
Sandy GRAVEL	1.00 – 5.00	Medium Dense	155 - 278
Clayey GRAVEL	1.00 – 7.00	Dense	322 - 457
COHESIVE SOILS			
Description	Depth (range m bgl)	Undrained Shear Strength (Cu) (kN/m ²)	Allowable Bearing Pressure (kN/m ²)
Soft Gravelly CLAY (1 Location – WS102)	1.00	15	31
Firm Gravelly CLAY	2.00 – 3.00	27 - 39	56 - 80
Stiff Silty CLAY	1.00 – 9.50	40 - 74	83 - 154
Very Stiff Gravelly CLAY	2.70 – 4.00	76 - 220	156 - 452

Based on the assessment of the relative undrained shear strength, relative in-situ densities and corresponding safe net allowable bearing pressure, the suitable target founding stratum has been identified as the underlying stiff to very stiff glacial clay and localised areas of medium-dense to dense gravel.

Medium dense gravels identified between 1.00–4.00 m bgl has been assessed as having an ABP of 152 –278 kN/m². Dense gravel identified between 2.50–7.00 m bgl has been assessed as having an ABP of 322–456 kN/m².

Loose gravels have also been identified between 1.00–2.00 m bgl in the central section of the Tack Lea Works area (WS102, WS103, and WS105) and at 3.00 m bgl in the central section of the Sheppard Mill area (CP103) has been assessed as having an ABP of 52–80 kN/m².

Firm gravelly CLAY has been identified between 2.00–3.00 m bgl with a net ABP of 56–80 kN/m². Stiff silty CLAY identified at 1.00–9.50 m bgl has been assessed as having a net ABP of 83–154 kN/m². Very stiff gravelly CLAY has been identified at 2.70–15.00 m bgl and has a net ABP of 156–452 kN/m².

Soft gravelly CLAY was also identified at 1.00 m bgl in the central section of the Tack Lea Works area (WS102) and has been assessed as having a net ABP of 31 kN/m².

Given the significant topographical variances on the site, prior to the detailed design of a suitable foundation solutions, a programme of remediation and enabling works will be required to remove the extensive buried obstructions and cut/fill the site in order to create proposed development platform levels suitable for residential development.



Following the removal of obstructions and subsequent engineering of soils to a specific performance specification, proposed plots could be constructed utilising vibro stone columns to support a suitably reinforced spread footing. Where tree influence is present and clays prone to volumetric instability, an alternative foundation solution may need to be adopted to deepen the foundation or the cohesive stratum may be removed and replaced with a granular material. The depth of the granular infill will be plot specific and require calculation on receipt of development levels. The use of vibro stone columns will also be dependent on the removal of clays that have a shear strength of $<30\text{kN/m}^2$.

Where plots are in close proximity to slopes or the existing retaining walls, the proposed loadings may need to be transferred beneath the influencing depth of the retainer or slope to ensure no unacceptable loading is induced that would cause a geotechnical failure.

Consideration should also be given to the historical landfill located in the eastern section of Tack Lea Works, as well as the potential presence of a quarry high wall associated with the historical sandstone quarry in the north of Tack Lea Works area. Where plots span such a feature, socketed piles into the bedrock will be required to reduce the risk of differential settlement.

Therefore, upon completion of these enabling works, it is anticipated that the final foundation solution will be a combination of:

- ✳ Vibro Stone Columns (VSC) that will ensure a uniform ABP in the order of 100kN/m^2 for the construction of a doubly reinforced strip footing at $\sim 600\text{mm}$ below remediated ground level (1050mm below FFL);
- ✳ Shallow strip foundations, where viable, bearing on localised areas of firm to very stiff clays, medium dense sands and shallow bedrock;
- ✳ Mass trench fill bearing on localised areas of firm to very stiff clays, medium dense sands and shallow bedrock;
- ✳ Piled foundations may be required where deep Made Ground and soft clays have been encountered; and for plots which span the historical sandstone quarry and associated high wall in the north-western section of the Tack Lea Works area; and
- ✳ Raft foundations may be required where obstructions cannot be removed.

Foundation depths within the conjectured influence of former, existing or proposed trees will need to be deepened to ensure that structural loading bears within the underlying target founding stratum, which cannot be subject to volumetric instability associated with fluctuation in moisture content.

It is recommended that, at working drawing stage, a foundation schedule is prepared for the development taking account of the physical change of natural clay soils and the current/proposed locations of trees.

To determine if VSC is viable at the subject site, E3P has completed a Ground Improvement Design Risk Matrix that is summarised in Table 5.2.



TABLE 5.2 GROUND IMPROVEMENT DESIGN RISK MATRIX

RISK ITEM	COMMENT	PASS/FAIL
Soft clays with an undrained shear strength of less than 30 kN/m ²	CLAY soils are generally firm to stiff with Cu > 80 kN. Isolated areas of softer clay soils were encountered with Cu > 30 kN/m ² ; however, it is considered that these will either be piled, or soft material excavated to remove the organic deposits.	PASS
Ground with peat layers close to foundation level or the base of the stone column, or where intermediate layers of peat are thicker than 200 mm, either as a single layer or the sum of the thicknesses of individual layers throughout the length of the stone column	None identified.	PASS
Voided filled ground, e.g., old water tanks, pottery, glass bottles, concrete rubble or brick fill of unsuitable grading	Made Ground beneath the site will require removal and processing to render the site suitable for VSC. The existing buildings substructure will also require excavation and processing into a graded aggregate suitable for Vibro treatment.	PASS – on completion of enabling works
Loose or non-engineered fill not previously subject to rising or fluctuating water levels saturation	None Identified	PASS
Filled ground still settling or expected to settle under its own weight or due to the effects of surcharging/upfilling where there is a high organic content or where decay is continuing	None Identified	PASS
Fill, containing degradable material where organic material forms more than 15% of fill by volume	None identified.	PASS
Clays with a plasticity index greater than 40%	None identified.	PASS
Highly sensitive soils liable to collapse or remoulding	None identified.	PASS
Cohesive soils with trees in influencing distance	Plots where tree influence has been modelled and will either be subject to a piled or mass trench-fill solution.	PASS
Overall Risk Rating and Suitability for Vibratory Ground Improvement		PASS

A summary of anticipated foundations is presented in Table 5.3



TABLE 5.3 ANTICIPATED FOUNDATIONS

LOCATION	ANTICIPATED FOUNDING STRATA DEPTH (m bgl)	GROUNDWATER (m bgl)	TARGET STRATUM	TREES	FOUNDATION TYPE	TYPE OF CONCRETE
TP101	1.25	N/A	Stiff CLAY	Y	Shallow Strip	DS-1 AC-1s
TP102*	>2.00	N/A	TBC	Y	Engineered - VSC	-
TP103	>2.25	N/A	TBC	Y	Engineered - VSC	-
TP104*	>0.80	N/A	TBC	Y	Engineered - VSC	-
TP105*	>1.20	N/A	TBC	Y	Engineered - VSC	-
TP106*	>1.80	N/A	TBC	Y	Engineered - VSC	-
TP107*	>1.10	N/A	TBC	Y	Engineered - VSC	-
TP108*	>1.20	N/A	TBC	Y	Engineered - VSC	DS-1 AC-1s
TP109*	>0.70	N/A	TBC	Y	Engineered - VSC	-
TP110	1.95	N/A	Firm CLAY	Y	Mass Trench	DS-1 AC-1s
TP111*	>0.50	N/A	TBC	Y	Engineered - VSC	-
TP112*	>0.40	N/A	TBC	Y	Engineered - VSC	-
TP113*	>1.10	N/A	TBC	Y	Engineered - VSC	DS-1 AC-1s
TP114*	>1.50	1.50	TBC	Y	Engineered - VSC	DS-1 AC-1s
TP115	>2.20	N/A	TBC	Y	Engineered - VSC	DS-1 AC-1s
TP116*	>1.40	N/A	TBC	Y	Engineered - VSC	DS-1 AC-1s
TP117	1.45	N/A	Firm CLAY	Y	Mass Trench	-
TP118*	>0.80	N/A	TBC	Y	Engineered - VSC	-
TP119	>1.60	1.50	TBC	Y	Engineered - VSC	-



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LOCATION	ANTICIPATED FOUNDING STRATA DEPTH (m bgl)	GROUNDWATER (m bgl)	TARGET STRATUM	TREES	FOUNDATION TYPE	TYPE OF CONCRETE
TP120*	>0.90	N/A	TBC	Y	Engineered - VSC	DS-1 AC-1s
TP121*	>0.60	N/A	TBC	Y	Engineered - VSC	-
TP122	>2.20	N/A	TBC	Y	Engineered - VSC	DS-1 AC-1s
TP123*	>2.20	N/A	TBC	Y	Engineered - VSC	DS-1 AC-1s
TP124	1.60	N/A	TBC	Y	Engineered - VSC	DS-1 AC-1s
TP125	1.45	N/A	Firm CLAY	Y	Mass Trench	DS-1 AC-1s
TP126*	>1.60	N/A	TBC	Y	Engineered - VSC	DS-1 AC-1s
TP127*	>1.90	N/A	TBC	Y	Engineered - VSC	-
TP128*	>1.80	N/A	TBC	Y	Engineered - VSC	-
TP129*	>1.90	N/A	TBC	Y	Engineered - VSC	-
TP130	>1.55	N/A	TBC	Y	Engineered - VSC	-
WS101	4.45	N/A	Stiff CLAY	Y	Engineered - VSC	-
WS102	3.35	N/A	Dense GRAVEL	Y	Engineered - VSC	-
WS103	2.35	N/A	Dense GRAVEL	Y	Engineered - VSC	-
WS104*	>0.60	N/A	TBC	Y	Engineered - VSC	-
WS105	2.35	N/A	MD GRAVEL	Y	Engineered - VSC	DS-1 AC-1s
WS106*	>0.30	N/A	TBC	Y	Engineered - VSC	-
WS106a*	>0.60	N/A	TBC	Y	Engineered - VSC	-
WS107	3.35	N/A	Dense GRAVEL	Y	Engineered - VSC	DS-1 AC-1s
WS108*	>1.25	N/A	TBC	Y	Engineered - VSC	-



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LOCATION	ANTICIPATED FOUNDING STRATA DEPTH (m bgl)	GROUNDWATER (m bgl)	TARGET STRATUM	TREES	FOUNDATION TYPE	TYPE OF CONCRETE
WS109*	>0.60	N/A	TBC	Y	Engineered - VSC	-
WS109a*	>0.50	N/A	TBC	Y	Engineered - VSC	-
WS110*	>0.60	N/A	TBC	Y	Engineered - VSC	DS-1 AC-1s
WS110a*	>0.60	N/A	TBC	Y	Engineered - VSC	-
WS111	1.45	N/A	Stiff CLAY	Y	Shallow Strip	DS-1 AC-1s
WS112	1.65	N/A	Stiff CLAY	Y	Mass Trench	-
WS113*	>0.40	N/A	TBC	Y	Engineered - VSC	-
WS114	1.35	N/A	Medium Dense GRAVEL	Y	Mass Trench	-
WS115*	>3.45	N/A	TBC	Y	Engineered - VSC	-
WS116	>0.78	N/A	TBC	Y	Engineered - VSC	DS-1 AC-1s
WS117	3.45	N/A	Stiff CLAY	Y	Engineered - VSC	DS-1 AC-1s
WS118*	>0.40	N/A	TBC	Y	Engineered - VSC	-
WS118a*	>0.40	N/A	TBC	Y	Engineered - VSC	-
WS119	1.35	N/A	Dense GRAVEL	Y	Mass Trench	-
WS120	>1.45	N/A	Dense GRAVEL	Y	Engineered - VSC	-
WS121*	>0.50	N/A	TBC	Y	Engineered - VSC	-
WS122	2.45	N/A	Firm CLAY	Y	Engineered - VSC	DS-1 AC-1s
WS123*	>1.65	N/A	TBC	Y	Engineered - VSC	-
WS124*	>3.45	N/A	TBC	Y	Engineered - VSC	DS-1 AC-1s



LOCATION	ANTICIPATED FOUNDING STRATA DEPTH (m bgl)	GROUNDWATER (m bgl)	TARGET STRATUM	TREES	FOUNDATION TYPE	TYPE OF CONCRETE
CP101	3.70	3.70	Dense GRAVEL	Y	Piled	-
CP102	6.00	N/A	Dense GRAVEL	Y	Piled	-
CP103	4.80	3.00	Firm CLAY	Y	Piled	-

Notes: * = Ground conditions not proven due to obstructions within Made Ground.

5.5. GROUND FLOOR SLABS

Current building control regulations require that where the infilled ground is present to depths in excess of 600 mm, or where the substratum is variable in terms of the structure and settlement potential, or where clay soils are present within the influence of existing or proposed trees, a suspended floor slab is required.

In this instance, it is considered that for the majority of substructures, the underlying stratum would have in excess of 600 mm of infill and, as such, a suspended floor slab will be required.

Where a cast in-situ suspended slab is utilised with no subfloor void, appropriate compressible material (heave precautions) will be required in the construction of the substructure.

5.6. HEAVE PRECAUTIONS

The site has been proven to be underlain by clay soils, which are susceptible to volumetric instability due to fluctuations in moisture content, particularly within the influencing distance of trees as per the NHBC/LABC conjectured zones of influence.

As the clay is deemed to be low plasticity, heave precautions are not required to the internal face of the external load-bearing walls (outside or within tree influence).

If a ground beam is to be constructed within the zone of tree influence, heave precautions are required to the underside of this and edge beams.

If the ground floor slab is to be constructed with a beam and block floor, a minimum subfloor void of 200 mm is required within any structures located in the zone of conjectured tree influence.

If the ground floor slab is constructed with a cast in-situ suspended floor slab, then heave precautions that can tolerate 50 mm of clay swelling are required within any part of the floor slab to be located within the zone of influence of a tree.

A summary of heave precautions is presented in Table 5.4.



TABLE 5.4 SUMMARY OF HEAVE PRECAUTIONS

		MINIMUM VOID DIMENSION FOR FOUNDATIONS, GROUND BEAMS AND SUSPENDED IN-SITU CONCRETE GROUND FLOORS		MINIMUM VOID DIMENSIONS UNDER PRECAST CONCRETE AND SUSPENDED TIMBER FLOORS
Plasticity Index of Soil	Required Foundation Depth (m)	Thickness of Void Former Against Side of Foundation or Ground Beam (mm)	Thickness of Void Former on Underside of Edge Beam and Floor Slab (mm)	Void Dimension (mm)
High Plasticity (> 40)	> 2.5	Engineer Design		Engineer Design
	2.0–2.5	35	150	300
	1.5–2.0	25	75	
Moderate Plasticity (20–40)	> 2.5	Engineer Design		Engineer Design
	2.0–2.5	25	100	250
	1.5–2.0	25	50	
Low Plasticity (< 20)	2.0–2.5	N/A	50	200
	> 2.0	No Special Precautions		

5.7. HIGHWAYS CONSTRUCTION

A programme of remediation and enabling works will be required to remediate the proposed road subgrade in accordance with the requirements of the Manual of Contract Documents for Highway Works Volume 1 Specification for Highway Works (Series 600-Earthworks) for method compaction.

It is considered that the material can be re-engineered using method compaction to achieve a CBR in excess of 5% if works are completed in favourable climatic conditions.

The proposed development includes the construction of a connecting bridge linking the Tack Lea Works area and Sheppard Mill area. However, no investigation was undertaken in this area due to limited access. Therefore, further investigation is recommended in this area.

5.8. DRAINAGE

The presence of substantial depths of Made Ground across some areas of the site may result in settlement. It is therefore recommended that drain runs are designed using steeper gradients and flexible joints to allow for some differential settlement.

Due to significant variability in the characteristics of the Made Ground across the site, the lateral continuity cannot be assured, therefore it is not recommended that soakaways are utilised on-site.



5.9. CONCRETE DURABILITY

Based upon the results of the chemical analyses it is considered that subsurface concrete can be designed in accordance with Design Sulphate Class DS-1, Aggressive Chemical Environment for Concrete Classification (ACEC) AC-1s in accordance with the recommendations provided in BRE *Special Digest 1* (2005).

In the LK Consultant 2020 Report, concentrations of soluble sulphate in the soil when contrasted to BRE Digest 200535 categorised the concrete requirements as DS-2 AC-3z in the Made Ground and DS-1 AC-1 in the natural strata.

5.10. EXCAVATIONS

Trial pits were generally stable in natural strata; as such, it is considered that near-surface excavations will be feasible. In areas where Made Ground exceeded 2 m, excavations were generally less stable.

Site observations indicated that excavations should be feasible in the near-surface with normal plants; however, obstructions were identified in the near-surface, including former foundations, former floor slabs and basement features. It is anticipated that any obstructions will be grubbed out during the reduced-level dig for the substructure works.

Due to the depth and variability of the Made Ground and the likelihood of trench collapse, it is considered that all excavations are supported or battered back in accordance with the guidance contained in CIRIA R97.

If local pumping of groundwater is required during the advancement of excavations for the proposed foundations, then consideration should be given to the potential for dewatering gravels in the surrounding areas that may cause structural damage to building substructures in close proximity to the site.

TABLE 5.5 CIVIL ENGINEERING EXCAVATION RISK MATRIX

RISK ITEM	PRESENT	COMMENT
Running Sands	No	No running sand has been identified.
Minor Water Ingress	Yes	Minor water ingress will require localised dewatering/sump pumping during the construction of the site drainage infrastructure. Ingress of water into foundation excavation will potentially flood foundation excavations, limiting the viability of spread foundations to be constructed.
Shallow Bedrock	Yes	Previous investigations identified shallow bedrock of sandstone in the central and western sections of the Tack Lea Works area at depths typically <2.00 m bgl. To the north of the Tack Lea Works area, bedrock can be seen outcropping in the valley and hillside. To the east of the former Tack Lea Mill Buildings and in the Sheppard Mill area, bedrock was found to be deeper and was encountered at depths ranging between 4.30 m and 5.00 m bgl.



5.11. SLOPE STABILITY

The site has significant topographical changes. As and when detailed topographic information is available and in due consideration of the proposed development design, structural and infrastructure loading, a detailed slope stability model will be required. This model will seek to determine the potential for newly imposed loadings to generate a risk of instability or failure within the off-site embankment and the need for any mitigation measures such as piled foundations to transfer loadings below the base of the slope.

5.12. CONSTRUCTION ACTIVITY AND INSPECTION

The following activities and inspections should be incorporated into the site works:

- ✳ Due to the variability of the soils at the site, it is recommended that sufficient allowance is made for the inspection of formations and sub-formations to foundations and pavement construction.
- ✳ Excavations, where access is required, should be subject to a risk assessment from a competent person and, where appropriate, mitigation measures such as benching back the sides or use of support systems in accordance with CIRIA R97 should be utilised.
- ✳ It is considered that dewatering may be required, especially following periods of heavy rainfall. Removal of surface water and water within trenches should be possible with conventional sump pumping. Discharge of any water should be agreed upon with the relevant regulatory body and be undertaken under a trade effluent discharge, where required. Measures to remove silt and suspended solids may be required and consideration should be given to the provision of space for settling tanks or an attenuation pond.
- ✳ Where access to confined spaces is required, appropriate mitigation measures should be addressed within the construction stage health and safety plan. Particular account should be taken of the gas results.
- ✳ The presence of potential contamination and mitigation measures should be addressed as part of the construction stage health and safety plan and should include measures to design out the risks, reduce their impact and, finally, to include the use of personnel protective equipment (PPE).

5.13. WASTE MANAGEMENT

The eastern section of the Tack Lea Works area is occupied by a historical landfill where the material was deposited under a Waste Management License.

Materials originating from licensed landfills are regulated under the Waste Framework Directive (WFD). Furthermore, materials originating from future excavations (both during remediation or construction) cannot be recovered for re-use using the normal processes and protocols such as the CL:AIRE DoW CoP.

It is understood that this area will remain undeveloped with the exception of an access road, therefore the material should be retained in-situ where possible.

Remediation options for this sector of the site warrant robust consideration given that options for re-use would either be an application for a new Environmental Permit (Deposit for Recovery – DFR) or alternatively the on-site processing of material to recover the fractions that would no longer cease to be a waste with the off-site disposal of all non-recoverable portions.



E3P would recommend that a waste management and recovery strategy be defined to facilitate the safe and economic re-use of material from landfill. A volume of 'waste' will require removal from site, this should be considered as part of a site viability assessment.

It is also noted that potential waste material may be present within former drains, the current and historical filter beds and tanks and at the base of the current and historical reservoirs located on-site. Further chemical analysis of these materials will be required to assess their chemical suitability for retention on-site in an area of no future sensitivity or off-site disposal.



5.14. GEOTECHNICAL RISK REGISTER

POTENTIAL CONSTRAINT	ABNORMAL	LOCATION ON-SITE	ESTIMATED AREA OF SITE AT RISK (%)	ASSESSMENT AND MITIGATION
Remediation of contaminated soils		All	100	The site will likely require remediation in the form of the removal of deleterious material and potential groundwater remediation.
Bedrock		All	25	Previous investigations identified shallow bedrock of sandstone in the central and western sections of the Tack Lea Works area at depths typically <2.00 m bgl. To the north of the Tack Lea Works area, bedrock can be seen outcropping in the valley and hillside. To the east of the former Tack Lea Mill Buildings and in the Sheppard Mill area, bedrock was found to be deeper and was encountered at depths ranging between 4.30 m and 5.00 m bgl. This represents a significant risk in terms of the viability for excavations to install infrastructure using standard construction equipment.
Obstructions		All	100	The site has been subject to significant historical development and, above-ground structures remain, potential subsurface obstruction from relict foundations, basements and slabs remain.
Artificially levelled and filled platforms		All	100	The site appears to have been levelled and artificially backfilled.
Retaining walls		Across the site	10	Several retaining walls are present on-site. These will need to be assessed by a structural engineer before development.
Trench collapse		All	100	Made Ground present beneath the site is likely to be loosely compacted and possibly prone to collapse.
Infilled Ponds and Reservoirs		NW, Centre and South	20	The former infilled reservoirs and ponds will need to be identified and investigated to assess the nature of materials and the extent of any organic or deleterious elements.



POTENTIAL CONSTRAINT	ABNORMAL	LOCATION ON-SITE	ESTIMATED AREA OF SITE AT RISK (%)	ASSESSMENT AND MITIGATION
Mature trees		All	75	An arboriculture survey is required to determine areas of potential tree influence (undertaken by E3P, Report Ref: 80-742-R3-2, dated June 2022).
Volume change potential clay		All	TBC	The clay soils are classified as having low volume change potential.
Running sands		N/A	N/A	Data searches indicate low risk.
Ground dissolution		N/A	N/A	Data searches indicate no hazard.
Concrete design		All	100	E3P categorised the concrete requirements as DS-1 AC-1s. The LK Consult 2020 Report categorised the concrete requirement as DS-2 AC-3z in the Made Ground and DS-1 AC1 in the natural strata.
Low-permeability ground		All	100	Soakaways are not considered to be suitable due to deep Made Ground and underlying cohesive drift deposits.
Services/sensitive structures		All	100	A review of online services has identified several services within the site boundary. Piling may not be possible within proximity to any sensitive infrastructure.
Abnormal foundation solutions		All	100	Due to significant Made Ground and some soft clays, an engineered foundation solution will be required.
Surface water features		ALL	10	Woodhouse Lane Brook runs through the centre of the site. Naden Brook borders the site's western and southern boundaries. Culverted water courses and springs associated with the former mill buildings are also believed to be present on-site, though these were not identified during the ground investigation. During the site walkover, a spring was identified in the far northwest part of the Tack Lea works area within an area of outcropping bedrock.
Flood Risk Activity Permit		Within 8 m of Main River	20	As parts of the proposed development works will be completed within 8 m of a main river, a Flood Risk Activity Permit (FRAP) will be required.



POTENTIAL CONSTRAINT	ABNORMAL	LOCATION ON-SITE	ESTIMATED AREA OF SITE AT RISK (%)	ASSESSMENT AND MITIGATION
Slope		All	100	The site has significant topographical change, detailed assessment and modelling are required to assess the long-term stability in both the temporary and permanent state associated with current, temporary and permanent loading



5.15. FURTHER WORKS

Based on the findings of the intrusive ground investigation, the following additional works are recommended to be completed in due course:

- ✳ Further investigation to confirm depth of Made Ground across the site;
- ✳ Further investigation (deep boreholes and monitoring well installations) with further groundwater and surface water monitoring and sampling to develop a robust groundwater conceptual site model and controlled waters risk assessment;
- ✳ Further investigation of inaccessible areas - central section of the Tack Lea Works area (current buildings); and eastern section of Tack Lea Works area (historical landfill area - for the estate road and connecting bridge construction);
- ✳ Tier II Vapour Risk Assessment for the Sheppard Mill area;
- ✳ Plot-specific foundation schedule (upon receipt of the final development levels);
- ✳ Application for a Flood Risk Activity Permit (FRAP);
- ✳ Arboricultural survey (undertaken by E3P, Report Ref: 80-742-R3-2, dated June 2022);
- ✳ Settlement Analysis for earthworks design;
- ✳ Slope stability assessment;
- ✳ A structural survey of Retaining Walls;
- ✳ Geotechnical earthworks strategy (infrastructure);
- ✳ Remediation and enabling works strategy;
- ✳ Construction phase Surface Water Management Plan; and,
- ✳ Waste management plan for any works in the area of the former historical landfill.



6. CONCLUSIONS AND RECOMMENDATIONS

6.1. CONTAMINATED LAND ASSESSMENT

Human Health	The Tier 1 human health risk assessment identified site-wide concentrations of heavy metals, asbestos, non-volatile PAHs, naphthalene, petroleum hydrocarbons, VOCs and SVOCs that would present unacceptable degrees of theoretical risk to the identified receptors associated with direct exposure pathways. The majority of the identified elevated concentrations have primary exposure pathways related to dermal contact and ingestion of soils, inhalation of particulate and consumption of homegrown vegetables; with naphthalene, petroleum hydrocarbons, VOCs and SVOCs having a primary exposure pathway related to volatilisation to indoor air risk. The risk to chronic human health associated with the elevated concentrations of inorganic heavy metals and non-volatile PAH compounds can be mitigated through the installation of a suitable cover system in all proposed private gardens, landscaping and public open space to remove any potential for direct exposure to impacted soils. The specific design and installation process for the appropriate cover systems will be clearly defined within the site remediation and enabling works strategy; however, industry best practice will require the following minimum depths of certified clean cover: - Private gardens – 600 mm - Landscaped areas– 300 mm - Public open space (POS) – 300 mm Asbestos in the form of chrysotile and amosite has been identified within localised areas in Made Ground deposits in WS124 (south of Sheppard Mill area), HP05 (historical landfill in the eastern section of Tack Lea Works area), TP114 and TP116 (central section of Tack Lea Works). Asbestos in the form of chrysotile and amosite has been identified within localised areas in Made Ground deposits in the southern part of Sheppard Mill area (WS124 and WS18), the historical landfill in the eastern section of Tack Lea Works area (HP05) and the central section of Tack Lea Works (TP114 and TP116). Asbestos bulk fragments, in the form of hard cement were also identified in WS124, HP05 and WS10; and asbestos sheeting/board debris within HP05. Visual signs of ACM were encountered during the ground investigations in HP05.
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Human Health
Continued...

It is noted that the presence of asbestos sheeting and boarding will require a different remedial approach to those proposed within the asbestos risk mitigation conceptual site model (i.e., hand picking of visible bulk asbestos fragments). Where asbestos sheeting and boarding has previously been identified, any proposed earthworks within those areas may be required to be undertaken under license. In addition, any off-site disposal of materials from these areas would be considered hazardous unless the asbestos bulk fragments are pre-removed via hand picking techniques.

Elevated concentrations of mercury have been identified within two locations within the Tack Lea Works area (WS111 at 0.60 m bgl and WS9 at 0.50 m bgl); and one location within the Sheppard Mill area (WS25 at 0.70 m bgl). Mercury occurs in three different forms; elemental mercury, inorganic mercury and methyl mercury. Inorganic and methyl mercury have an exposure pathway of dermal contact and ingestion, whereas elemental mercury could present a potential volatilisation to indoor air risk.

During remediation and enabling works, speciated mercury analysis should be completed at the locations WS111, WS9 and WS25 to assess whether elemental mercury is present which may pose a risk to future site users through vapour inhalation. If elemental mercury is identified, it may be necessary to delineate and excavate the soils as a hotspot and place them in an area of low sensitivity such as beneath areas of public open space or removed from site. Alternatively, if it is proven that there is no elemental mercury, a clean cover system will be sufficient.

The elevated concentrations of naphthalene, TPH and trichloroethene (TCE) identified within the Tack Lea Works area (TP116 and WS12) are considered to be localised occurrences and therefore this location can be treated as a localised hotspot. During a process of cut/fill enabling works, a hotspot removal should be undertaken where these soils may be chemically validated to assess chemical suitability for retention on-site in an area of no future sensitivity.

However, elevated concentrations of naphthalene, TPH, VOCs and SVOCs have been identified throughout the Shepherd Mill area and these do not appear to be localised hotspots. A Tier II vapour risk assessment is required in this sector of the site to assess the level of risk to the future site users by volatilisation to indoor air.

The SVOCs identified in WS107 and TP116 within the Tack Lea Works area are not considered to pose a risk to future site users given the marginal concentrations.

Furthermore, with regards to the elevated volatile contaminants (naphthalene, TPH, VOCs and SVOCs) identified in the Tack Lea Works area and the Sheppard Mill area, vapour resistant membranes may be required to be installed during the build phase for any proposed buildings situated within the immediate vicinity of the contamination hotspot / impacted soils. A Detailed Quantitative Risk Assessment (DQRA) may also be required to determine if any risks to human health and controlled water receptors remains following the hotspot removal.



Human Health <i>Continued...</i>	Chemical analysis of the natural subsoil deposits has indicated these soils to be acceptable for use within the proposed garden areas; however, further chemical validation samples will be required to confirm this. No suitable source of natural topsoil deposits has been identified on-site.
Controlled Waters	The ICSM developed within the context of the site setting has determined that the surface water features (Naden Brook, Woodhouse Lane Brook and the culverted water courses and springs) to be the critical receptors at risk from a viable pollutant pathway, which would be the lateral migration of potentially mobile phase-soluble contaminants. The presence of low permeability cohesive drift deposits across the site affords protection from vertical migration to the underlying Secondary A bedrock aquifer. As such, this receptor is considered to be at a low risk. A comparison of leachate and groundwater samples taken by E3P and Encia to the Tier 1 assessment Criteria (Table 4.5) has shown exceedances for heavy metals & inorganics, non-volatile PAHs and naphthalene within soils and groundwater. Exceedances for TPHs were also identified within groundwater in the Sheppard Mill area. The underlying Secondary A Aquifer is deemed to be at a low risk from on-site contamination given the presence of cohesive deposits in excess of 5.00 m; the proposed development will create new hardstanding which will reduce infiltration and the number of contaminants present in leachate migrating off-site; and the fact that the site is not located within a groundwater source protection zone and that no active groundwater abstraction points are located within a 1 km radius of the site. A comparison of surface water samples taken by E3P and Encia from Naden Brook and Woodhouse Lane Brook to the Tier 1 assessment criteria (Table 4.6) has shown exceedances for copper and zinc within all samples upstream and downstream of the site. As a result of this, it can be said that elevated levels of these determinants cannot be attributed to the site, due to their presence within upstream samples. The m-BAT assessment has also shown that within surface water samples taken by E3P, neither copper nor zinc are considered to be bioavailable. Concentrations of chromium (III) were found to be in exceedance of the EQS within leachate samples taken by E3P and leachate, groundwater and surface water samples taken by Encia. Non-volatile PAHs were also identified within the chemical testing in surface water samples taken downstream of Woodhouse Lane Brook (E3P, Woodhouse Lane Downstream) and Naden Brook (Encia, W4). This shows lateral migration of contaminants identified within soils and groundwater is occurring at the site and causing a detrimental impact on the surface water receptors.



Controlled Waters <i>Continued...</i>	It is noted that mobile contaminants identified within the soils and groundwater (non-volatile PAHs, naphthalene and TPHs) have the potential to migrate laterally towards the surface water receptors as a result of the high permeability strata present beneath the site. The cohesive strata that is present beneath the site may also act as an impermeable barrier and channel mobile contaminants towards the surface water receptors. As such, the surface water receptors are deemed to be at a high risk from on-site contamination. It is noted that limited groundwater sampling was undertaken during the monitoring programme. This was due to the majority of monitoring wells either having insufficient or no groundwater within them. As such, it has not been possible to determine a groundwater flow direction. During the remediation and enabling works phase, the removal of the hardstanding currently present across the site may induce infiltration and potential mobilisation of contaminants present within the soils and groundwater directly into the surface water receptors. As such, it is recommended that further investigation, in the form of deep boreholes and monitoring well installations, with further groundwater and surface water monitoring and sampling is undertaken in order to develop a robust groundwater conceptual site model and controlled waters risk assessment for the site.
Ground Gas	Characteristic Situation 1 (pending completion of gas monitoring). CS2 measure recommended for the whole site due to the presence of the historical landfill (eastern section of the Tack Lea Works area). Elevated concentrations of volatile contaminants (naphthalene, TPHs, VOCs, SVOCs, and mercury) have been identified within the Made Ground on-site, which present a potential volatilisation to indoor air risk. Elevated concentrations of volatile contaminants in the Tack Lea Works area are considered to be localised occurrences and therefore these locations can be treated as hotspots. However, elevated concentrations of volatile contaminants have been identified throughout the Shepherd Mill area and these do not appear to be localised hotspots. Further assessment, in the form of a Tier II vapour risk assessment is required across the site to assess the level of risk to the future site users by volatilisation to indoor air. Subject to the findings of the vapour risk assessment, vapour resistant membranes may be required.
Potable Water	Based on the assessment of current site conditions, it is likely that barrier pipe will be required at the proposed development. Post-remediation and enabling works ground conditions may be different from those identified during this ground investigation.



6.2. GEOTECHNICAL ASSESSMENT

Significant concrete and brick obstructions and basement features, which are indicative of relict foundations from former buildings have been encountered within the Made Ground. As such, the full thickness of the Made Ground could not be proven across the vast majority of the site. Further investigations will be required to prove the depth to Made Ground across the site.

During a phase of cut-and-fill enabling works to create a developable platform, all below-ground obstructions will require grubbing out to the base of the Made Ground to enable the construction of proposed plots.

Medium dense gravels identified between 1.00–4.00 m bgl has been assessed as having an ABP of 152–278 kN/m². Dense gravel identified between 2.50–7.00 m bgl has been assessed as having an ABP of 322–456 kN/m².

Loose gravels have also been identified between 1.00–2.00 m bgl in the central section of the Tack Lea Works area (WS102, WS103, and WS105) and at 3.00 m bgl in the central section of the Sheppard Mill area (CP103) has been assessed as having an ABP of 52–80 kN/m².

Firm gravelly CLAY has been identified between 2.00–3.00 m bgl with a net ABP of 56–80 kN/m². Stiff silty CLAY identified at 1.00–9.50 m bgl has been assessed as having a net ABP of 83–154 kN/m². Very stiff gravelly CLAY has been identified at 2.70–15.00 m bgl and has a net ABP of 156–452 kN/m².

Soft gravelly CLAY was also identified at 1.00 m bgl in the central section of the Tack Lea Works area (WS102) and has been assessed as having a net ABP of 31 kN/m².

Given the significant topographical variances on the site, prior to the detailed design of a suitable foundation solutions, a programme of remediation and enabling works will be required to remove the extensive buried obstructions and cut/fill the site in order to create proposed development platform levels suitable for residential development.

Following the removal of obstructions and subsequent engineering of soils to a specific performance specification, proposed plots could be constructed utilising vibro stone columns to support a suitably reinforced spread footing. Where tree influence is present and clays prone to volumetric instability, an alternative foundation solution may need to be adopted to deepen the foundation or the cohesive stratum may be removed and replaced with a granular material. The depth of the granular infill will be plot specific and require calculation on receipt of development levels. The use of vibro stone columns will also be dependent on the removal of clays that have a shear strength of <30kN/m².

Where plots are in close proximity to slopes or the existing retaining walls, the proposed loadings may need to be transferred beneath the influencing depth of the retainer or slope to ensure no unacceptable loading is induced that would cause a geotechnical failure.

Consideration should also be given to the historical landfill located in the eastern section of Tack Lea Works, as well as the potential presence of a quarry high wall associated with the historical sandstone quarry in the north of Tack Lea Works area. Where plots span such a feature, socketed piles into the bedrock will be required to reduce the risk of differential settlement.

Therefore, upon completion of these enabling works, it is anticipated that the final foundation solution will be a combination of:



- ✳ Vibro Stone Columns (VSC) that will ensure a uniform ABP in the order of 100kN/m² for the construction of a doubly reinforced strip footing at ~600mm below remediated ground level (1050mm below FFL);
- ✳ Shallow strip foundations, where viable, bearing on localised areas of firm to very stiff clays, medium dense sands and shallow bedrock;
- ✳ Mass trench fill bearing on localised areas of firm to very stiff clays, medium dense sands and shallow bedrock;
- ✳ Piled foundations may be required where deep Made Ground and soft clays have been encountered; and for plots which span the historical sandstone quarry and associated high wall in the north-western section of the Tack Lea Works area; and
- ✳ Raft foundations may be required where obstructions cannot be removed.

Foundation depths within the conjectured influence of former, existing or proposed trees will need to be deepened to ensure that structural loading bears within the underlying target founding stratum, which cannot be subject to volumetric instability associated with fluctuation in moisture content.

It is recommended that, at working drawing stage, a foundation schedule is prepared for the development taking account of the physical change of natural clay soils and the current/proposed locations of trees.

END OF REPORT



APPENDIX I LIMITATIONS

1. This report and its findings should be considered in relation to the terms of reference and objectives agreed between E3P and the client as indicated in Section 1.3.
2. For the work, reliance has been placed on publicly available data obtained from the sources identified. The information is not necessarily exhaustive and further information relevant to the site may be available from other sources. When using the information, it has been assumed it is correct. No attempt has been made to verify the information.
3. This report has been produced in accordance with current UK policy and legislative requirements for land and groundwater contamination which are enforced by the local authority and the Environment Agency. Liabilities associated with land contamination are complex and requires advice from legal professionals.
4. During the site walkover, reasonable effort has been made to obtain an overview of the site conditions. However, during the site walkover, no attempt has been made to enter areas of the site that are unsafe or present a risk to health and safety, are locked, barricaded, overgrown, or the location of the area has not been made known or accessible.
5. Access considerations, the presence of services and the activities being carried out on the site limited the locations where sampling locations could be installed and the techniques that could be used.
6. Site sensitivity assessments have been made based on available information at the time of writing and are ultimately for the decision of the regulatory authorities.
7. Where mention has been made to the identification of Japanese Knotweed and other invasive plant species and asbestos or asbestos-containing materials, this is for indicative purposes only and do not constitute or replace full and proper surveys.
8. The executive summary, conclusions and recommendations sections of the report provide an overview and guidance only and should not be specifically relied upon without considering the context of the report in full.
9. E3P cannot be held responsible for any use of the report or its contents for any purpose other than that for which it was prepared. The copyright in this report and other plans and documents prepared by E3P is owned by them and no such plans or documents may be reproduced, published or adapted without written consent. Complete copies of this may, however, be made and distributed by the client as is expected in dealing with matters related to its commission. Should the client pass copies of the report to other parties for information, the whole report should be copied, but no professional liability or warranties shall be extended to other parties by E3P in this connection without their explicit written agreement there to by E3P.
10. New information, revised practices or changes in legislation may necessitate the re-interpretation of the report, in whole or in part.



APPENDIX II

GLOSSARY

TERMS

ACM	Asbestos-containing material	MMP	Materials management plan
ADS	Acoustic design statement	ND	Not detected
AST	Above-ground storage tank	NDP	Nuclear density probe
BGS	British Geological Survey	NMP	Noise management plan
BSI	British Standards Institute	NPSE	Noise policy statement for England
BTEX	Benzene, toluene, ethylbenzene, xylenes	NR	Not recorded
CA	Coal Authority	PAH	Polycyclic aromatic hydrocarbon
CBR	California bearing ratio	PCB	Polychlorinated biphenyl
CIEH	Chartered Institute of Environmental Health	PI	Plasticity index
CIRIA	Construction Industry Research Association	PID	Photo ionisation detector
CLEA	Contaminated land exposure assessment	POS	Public open space
CML	Council of Mortgage Lenders	PPE	Personnel protective equipment
CoC	Contaminants of concern	ProPG	Professional practice guidance
CSM	Conceptual site model	QA	Quality assurance
DNAPL	Dense non-aqueous phase liquid (chlorinated solvents, PCB)	SGV	Soil guideline value
DWS	Drinking water standard	SPH	Separate-phase hydrocarbon
EA	Environment Agency	SPT	Standard penetration test
EQS	Environmental quality standard	SVOC	Semi-volatile organic compound
FFL	Finished floor level	TPH	Total and speciated petroleum hydrocarbon
GAC	General assessment criteria	TPH CWG	Total Petroleum Hydrocarbon (Criteria Working Group)
GL	Ground level	UKWIR	United Kingdom Water Infrastructure Risk
GSV	Gas screening value	UST	Underground storage tank
HCV	Health criteria value	VCC	Vibro-concrete column
ICSM	Initial conceptual site model	VOC	Volatile organic compound
LEL	Lower explosive limit	VRSC	Vibro-replacement stone columns
LMRL	Lower method reporting limit	VSC	Vibro-stone columns
LNAPL	Light non-aqueous phase liquid (petrol, diesel, kerosene)	WHO	World Health Organisation
MCV	Moisture condition value	WRAP	Waste and Resources Action Programme



Land at Greenbooth Road and Edenfield Road, Norden

Phase II Geoenvironmental Site Assessment

June 2023

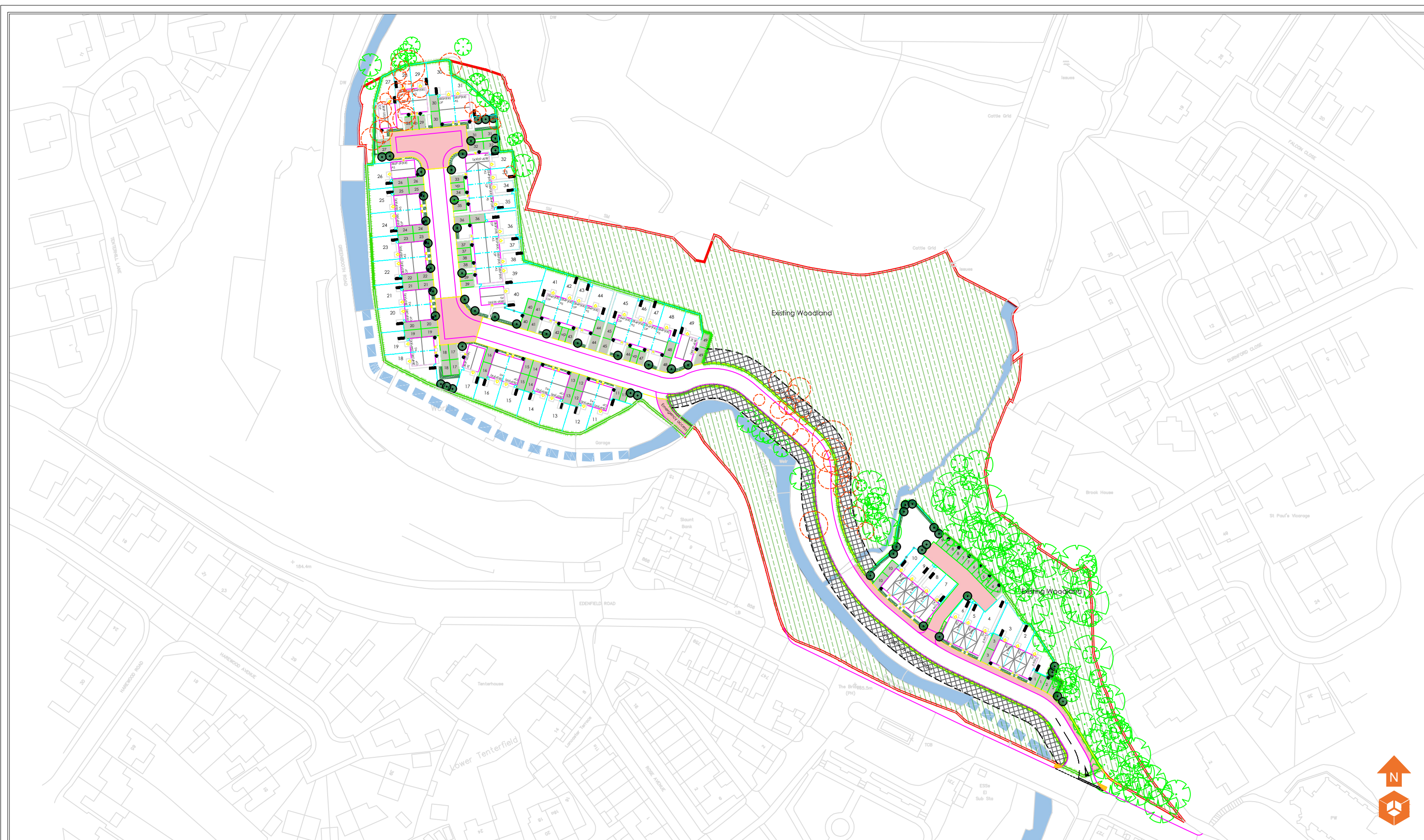
MIBK	Methyl isobutyl ketone	WTE	Water table elevation
m	Metres	ppm	Parts per million
km	Kilometres	mg/m³	Milligram per metre cubed
% v/v	Percent volume in air	m bgl	Metres below ground level
mb	Millibars (atmospheric pressure)	m bcl	Metre below cover level
l/hr	Litres per hour	mAOD	Metres above ordnance datum (sea level)
µg/l	Micrograms per litre (parts per billion)	kN/m²	Kilonewtons per metre squared
ppb	Parts per billion	µm	Micrometre
mg/kg	Milligrams per kilogram (parts per million)	SSRT	Site Specific Remediation Target
PSD	Particle Size Distribution	DD	Dry Density
CL:AIRE	Contaminated Land: Applications in Real Environments	Mc	Moisture Content
ρ	Bulk Density	GPR	Ground Penetrating Radar
NDP	Nuclear Density Probe	FFL	Finished Floor Level
LEL	Lower Explosive Limit	UKWIR	UK Water Industry Research
CIRIA	Construction Industry Research and Information Association	LOD	Limit of Detection



APPENDIX III DRAWINGS

DRAWING 16-465-001 – SITE LOCATION PLAN





Notes:				
P1	REVC	16.06.2023	OW	MW
P1	REVB	20.03.2023	EB	RJW
P1	REVA	17.11.2022	OW	MD
Phase	Issue	Date	Drawn	Checked

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Stonebond Properties Ltd
Job Title:
Land at Greenbooth Road and Edenfield Road, Norden

Job No:
16-465
Drawing No:
002

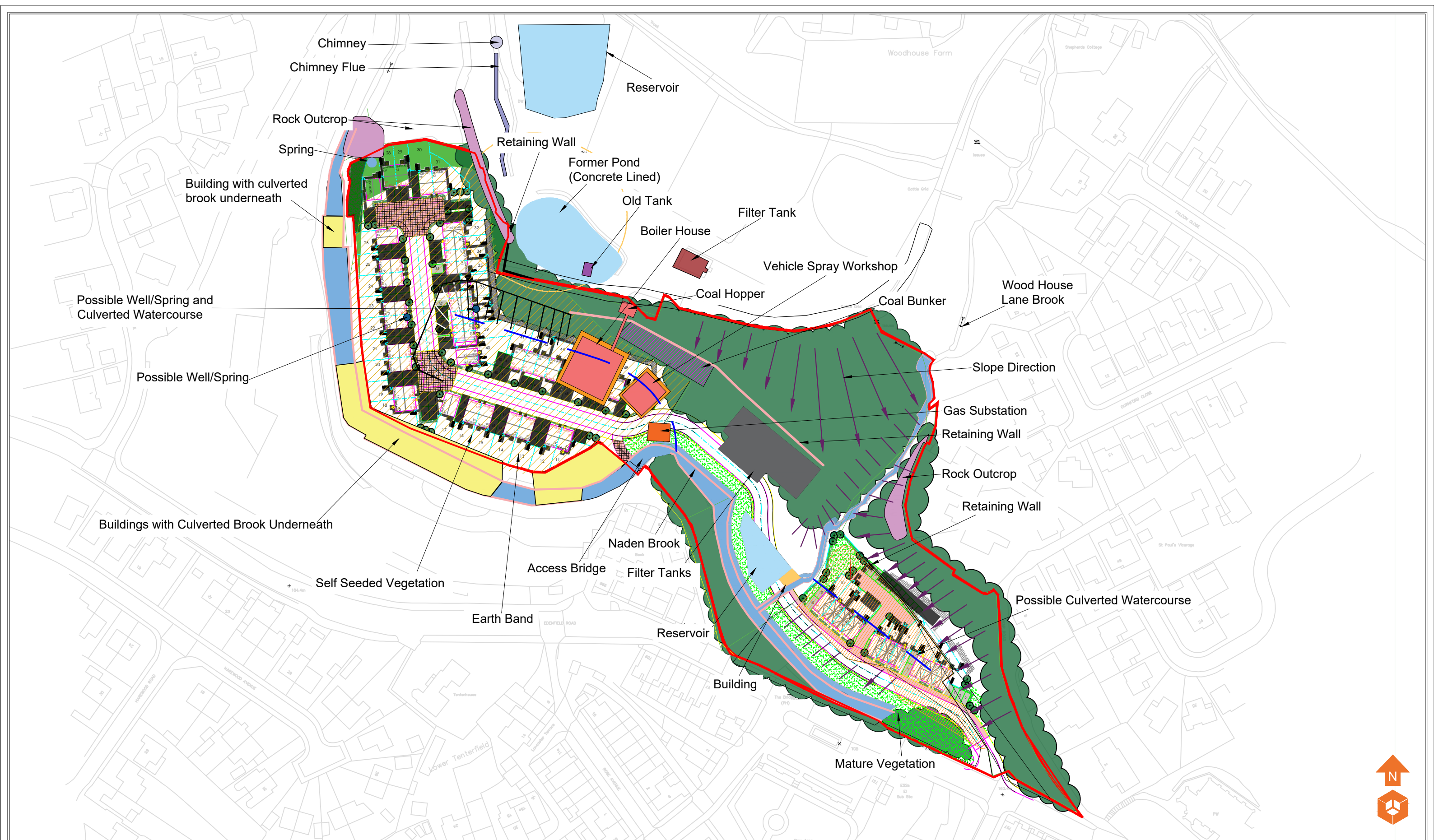
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16.06.2023
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Drawing Title:
Proposed Development Plan

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Site Features	
	Access Points
	Hard Standing
	Structures
	Surface Water Features
	Site Boundary
	Slope Direction
	Retaining Walls
	Access Bridge
	Filter Tanks
	Gas Substation
	Vegetation
	Earth Bank
	Rock Outcrop
	Filter Tank
	Chimney Flue
	Chimney

Notes:					
P1	REVG	06.06.2023	OW	MW	
P1	REVE	15.05.2023	OW	MW	
P1	REVE	17.04.2023	LM	MW	
P1	REVD	11.04.2023	LM	MW	
P1	REVC	14.12.2022	OW	MW	
P1	REVB	17.11.2022	OW	MD	
P1	REVA	28.10.2022	OW	MD	
Phase	Issue	Date	Drawn	Checked	

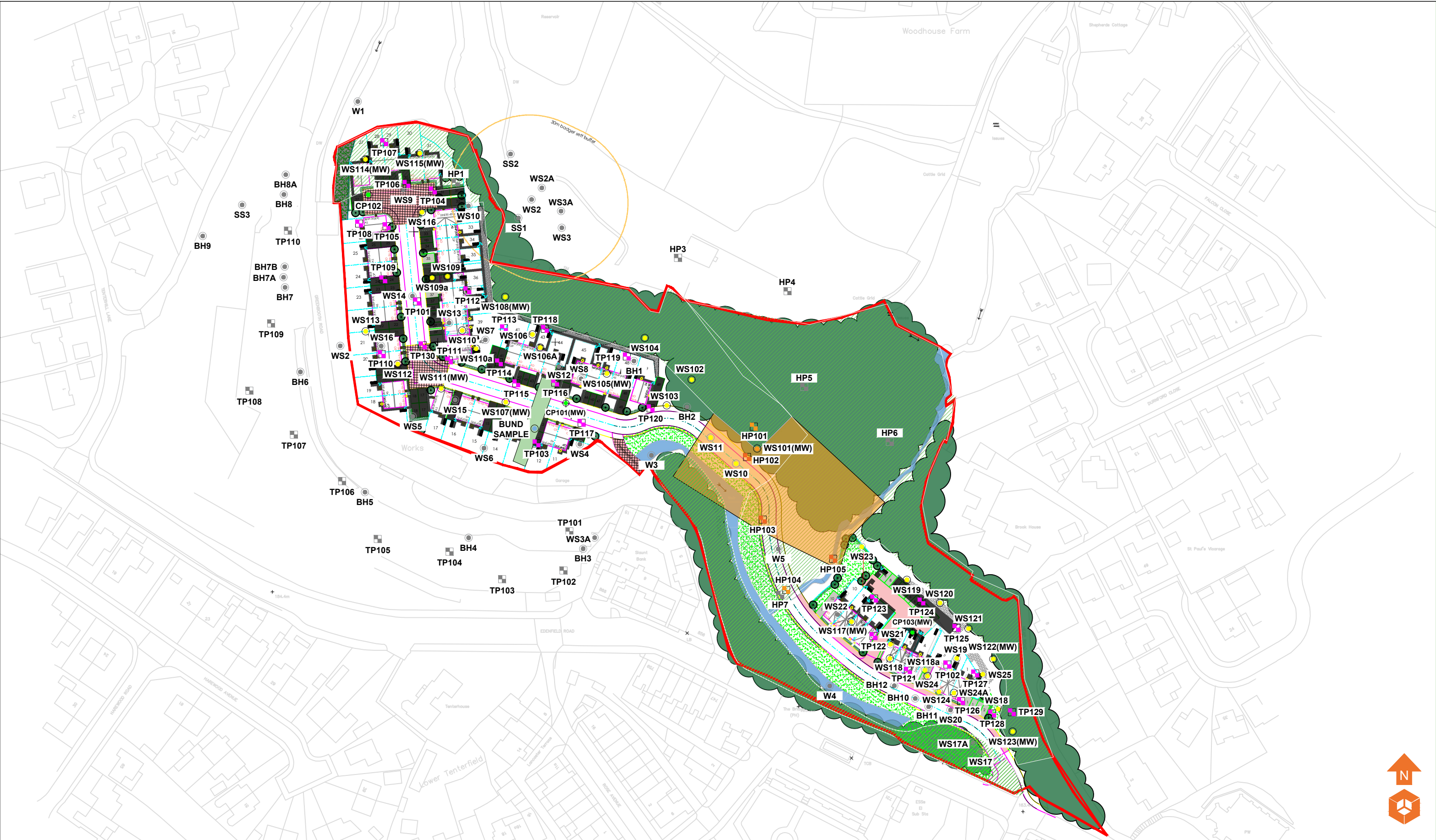
Client:	
Stonebond Properties Ltd	
Job Title:	
Land at Greenbooth Road and Edenfield Road, Norden	

Job No:	
16-465	
Drawing No:	
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Date:	
06.06.2023	
Scale:	
1:1000 @ A3	
Drawing Title:	
Site Features Plan	



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Location Symbols

	Approximate Window Sample Probehole Location		Inaccessible Area
	Approximate Trial Pit Location		Bund
	Approximate Cable Percussive Borehole Location		Historic Landfill
	Approximate Hand Dug Pit Location		
	Bund Sample Location		
	Approximate Hand Dug Pit Location (Enica - April 2006)		
	Approximate Trial Pit Location (Enica - April 2006)		
	Approximate Window Sample Probehole Location (Enica - April 2006)		
	Approximate Borehole Location (Enica - April 2006)		

Notes:

P1	REVJ	06.06.2023	OW	MW
P1	REVI	26.04.2023	OW	MW
P1	REVI	25.04.2023	EB	MW
P1	REVG	17.04.2023	LM	MW
P1	REVF	12.04.2023	LM	MW
P1	REVE	16.03.2023	NS	NS
P1	REVD	16.01.2023	EB	HM
P1	REVC	15.12.2022	LM	HM
P1	REVB	23.11.2022	OW	MW
P1	REVA	08.11.2022	OW	MW
Phase	Issue	Date	Drawn	Checked

Client:

Stonebond Properties Ltd

Job Title:

Land at Greenbooth Road and
Edenfield Road, Norden

Job No:

16-465

Drawing No:

005

Date:

06.06.2023

Scale:

NTS@ A3

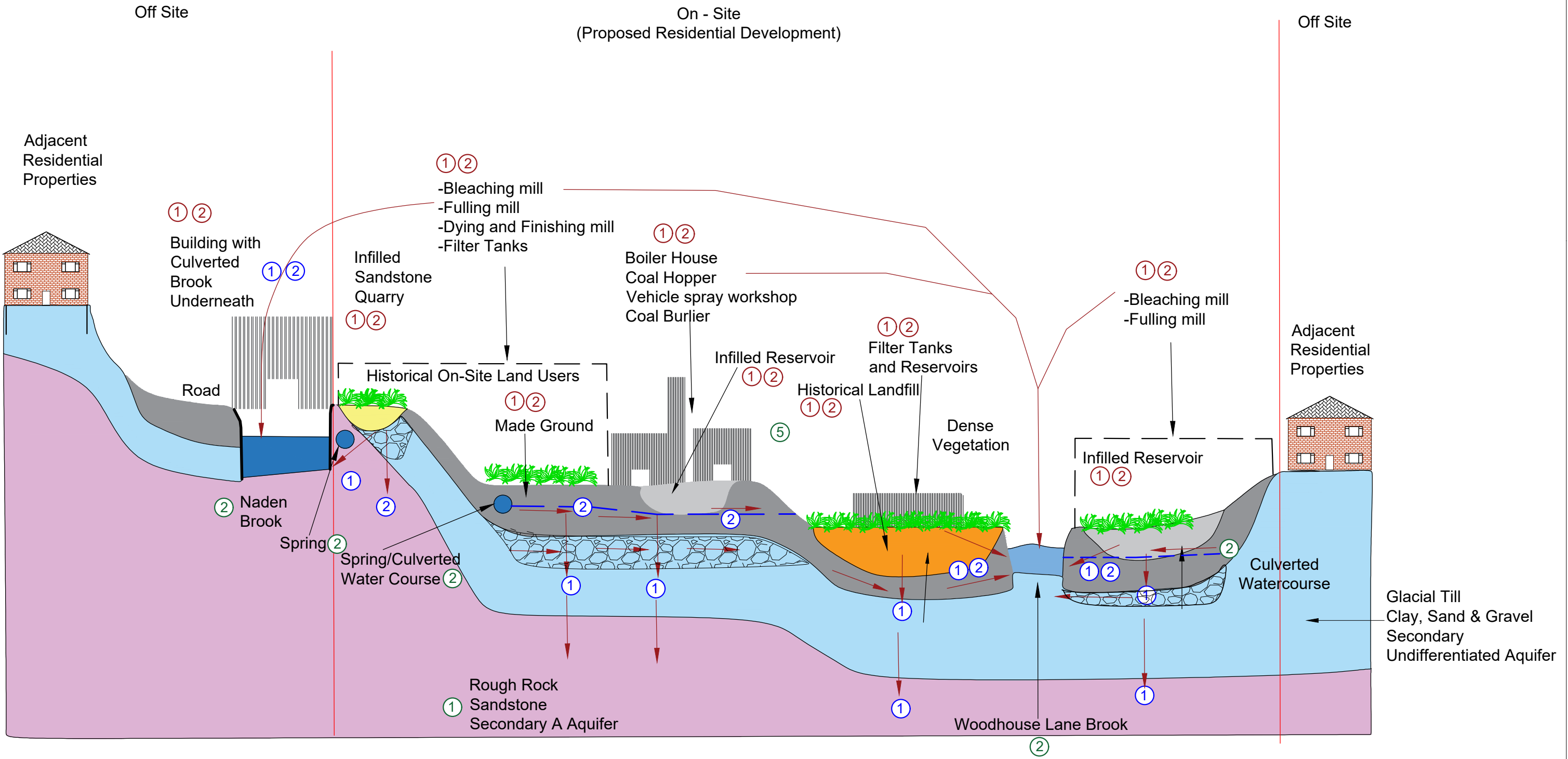
Drawing Title:

Exploratory Hole
Location Plan



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Geology Key

- Made Ground
- Glacial Till (Clay, Sand & Gravel)
- Rough Rock (Sandstone)
- Brook / Stream
- Historical Landfill
- Spring / Culverted Watercourse
- Infilled Reservoir

Sources

- ① Heavy metals, heavy end hydrocarbons and non volatile polycyclic hydrocarbons (PAHs)
- ② Volatile Organic Compounds (VOCs) and TPHs
- ③ Asbestos Containing Materials (ACMs)
- ④ Hazardous Ground Gases (CO2/CH4)
- ⑤ pH and Sulphate

Receptors

- ① Secondary A Aquifer
- ② Surface Water Courses
- ③ Foundation/Concrete
- ④ Residential End Users
- ⑤ Flora and Fauna

Pathways

- ① Vertical Migration
- ② Lateral Migration
- ③ Inhalation of Gas/Vapor/Dust
- ④ Dermal Contact/Soil Ingestion

Pathways arrows

Notes:

Phase	Issue	Date	Drawn	Checked
P1	REVB	17.04.2023	LM	MW
P1	REVA	12.04.2023	OW	MW

Client:

Stonebond Properties Ltd

Job Title:

Land at Greenbooth Road and Edenfield Road, Norden

Job No:

16-465

Drawing No:

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Date:

17.04.2023

Scale:

1:1000 @ A3

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