

## REVIEW OF GROUND ISSUES

<b>Job No.</b>	3435	<b>Site area/ha</b>	8.3	
<b>Client:</b>	Harron Homes	<b>NGR:</b>	SE 174 173	
<b>Site:</b>	Crossley Lane, Dalton	<b>Nearest postcode:</b>	HD5 0QP	

**Introduction.** It is understood that Harron Homes are considering acquisition of land at Crossley Lane, Dalton with a view to redevelopment with housing. Harron have provided Lithos with copies of the following:

1. 'Combined Stage 1 & 2 Desk Study & Geo-environmental Report – Land at Crossley Lane, Dalton, Huddersfield' (Ref MWD/01r1) issued by ARP in August 2016 to Minerva Works Developments Ltd.
2. 'Combined Stage 1 & 2 Desk Study & Geo-environmental Report – Sites Four and Five, Land at Crossley Lane, Dalton, Huddersfield' (Ref MWD/01r2) issued by ARP in March 2017 to Minerva Works Developments Ltd.

The two reports relate to Harron's proposed development site, which totals 8.3ha. ARP (and prior to them, Sirius) split the site into 5 parcels, named Sites 1 to 5. Report 1 relates to Sites 1, 2 & 3; Report 2 relates to Sites 4 & 5.

The boundaries of Sites 1 to 5 are shown on Lithos Drawing 3435/6 appended to this report.

**The Site.** The site can be better considered (based on past use & ground conditions) as 3 parcels of land (Areas A, B & C), intersected by Cold Royd Lane running north-south and Crossley Lane running east-west. Area B is further sub-divided into Areas B1 (north of Crossley Lane) and B2 (south).

The site is bounded to the south by Lees Hall Beck (named Ox Field Beck in the east), and to the north by steeply sloping land associated with a railway embankment. Previous site uses include a gas works (Area B2), dye & bleach works (Areas B1 & B2) and later, industrial development (warehouses/workshops) across Area B1 and Area C. The south-west (Area A) is essentially greenfield.

Key features are shown on Drawing 3435/3.

**Proposed Development & Levels.** Harron have provided a topographical survey and proposed layout (in CAD format), copied here as Drawing 3435/2.

**Environmental Setting.** Lithos have reviewed the above reports and our own geological maps, and data available on the Environment Agency's website. A summary is provided in the Table below.

Issue	Remarks
The Site	<p>Comprises three parcels of land split by Crossley Lane (running east-west) and Cold Royd Lane (running north-south).</p> <p>Concrete hardstand (former floor slabs of industrial buildings) are present across the south-east and north. A retaining wall runs along the north-east boundary at the base of a slope which is approximately 5m tall (former railway embankment) and heavily covered in vegetation.</p> <p>Stockpiles of demolition waste in the central north and south.</p> <p>Two cylindrical tanks in south-west of Area B1 (labelled ferric chloride).</p> <p>In the east of Area B2, above-ground gas tanks are present, along with a filling pump, likely associated with a UST. Concrete base of a (probable) former gas holder is seen in the south-east.</p> <p>Underground services include a high pressure gas main and underground sewer; overhead powerlines run along the southern boundary.</p> <p>The south-west is covered by rough grassland, with trodden footpaths evident.</p>
Site History	<p><b>Area A</b></p> <p>Essentially greenfield, with the exception of a bowling green that formerly encroached in the west and former allotments in the north. Lees Head Beck encroached into the south-west, then re-routed prior to 1958.</p> <p><b>Area C</b></p> <p>First developed in 1950s, but more significant development by 1980s with industrial building. Now demolished to slab level.</p> <p><b>Areas B1 &amp; B2</b></p> <p>Shows as 'Coal Tar Colour Works' from late 1890s, later renamed Minerva Works (Dyeing and Bleaching), expanding through to 1950s before redevelopment with a two large industrial buildings (one spanning Sites 3 &amp; 4, one on Site 5), including tanks in the north and east.</p>

Issue	Remarks
	<p>Now demolished to slab level.</p> <p>A former substation (recently demolished) was present in the north-west of Site 5.</p> <p>In addition to the above, a railway embankment runs along the north-east boundary of (Sites 2, 3 &amp; 4) from the late 1890s, resulting in a steep bank along the north-east boundary. This encroaches into Site 3. Railway shown as dismantled from the late 1960s.</p>
Environmental Setting	<p><b>Geology:</b> Made Ground: Shown in north-east (associated with railway embankment).            Drift: Alluvium across Sites 1 and 5 (south of Crossley Lane) and in the south of Site 2, 3 &amp; 4 (north of Crossley Lane).            Solid: Elland Flags in the north &amp; west of Site 1, elsewhere Lower Coal Measures.            Strata Dip: 2° to the south-east.</p> <p><b>Faults:</b> One fault running north-west to south-east runs through Site 5, downthrow to north-east.</p> <p><b>Hydrogeology:</b> The site does not lie within a groundwater Source Protection Zone. The bedrock aquifer is designated as Secondary A Aquifer. Groundwater abstraction in Site 3.</p> <p><b>Hydrology:</b> Lees Head Beck/Ox Field Beck immediately south, flowing to the west. Surface water abstraction in Site 3.</p> <p><b>Landfills:</b> Two within 250m. One immediately south (inert &amp; commercial material as well as 'excavation waste from Fenay Beck') and one accepting inert waste 180m south-east.</p> <p><b>Radon:</b> The site lies in an area where 1-3% of homes are estimated to be above the action level; no measures required.</p> <p><b>Flooding:</b>            Site 1 – majority is Flood Zone 3 but benefitting from flood defences, the north-east is Flood Zone 2.            Sites 2, 3, &amp; 4 – Flood Zone 1            Site 5 – majority in Flood Zone 1, east lies in Flood Zones 2 and 3.</p>
Mining & Quarrying	<p><b>Coal:</b> Shallowest coal c. 100m (Hard Bed). No significant risks identified.</p> <p><b>Elland Flags:</b> Risks of Elland Flags mining are not mentioned by ARP. The west of the site (Site 1) is underlain by Elland Flags Sandstone. However, no quarries are shown on historical plans on site, nor within the local area. The nearest known former Elland Flags mine is at Fixby, some 6km north-west, and the Elland Flags are overlain by alluvium (according to BGS plans). Therefore, risks of workings beneath the site are considered very low and do no warrant further assessment.</p> <p><b>Quarries:</b> None within the vicinity of the site.</p>
Ground Investigations	<p>Have been undertaken by:</p> <p><b>Sirius</b> (2006). This included boreholes, trial pits and WSs across the site. ARP's Report 1 (for Sites 1 to 3) includes Sirius' lab testing results and comments are made regarding ground conditions encountered by Sirius. However, Sirius' logs are not included in ARP's report and Lithos do not have a copy of Sirius' report. In Report 2 (for Sites 4 and 5), ARP do not appear to use any of Sirius' lab testing results.</p> <p><b>ARP</b> (2016): This GI included: 48 trial pits and 48 window-sample boreholes. All exploratory hole locations are shown on Drawing 3435/6. Further comments below.</p>
Made Ground	<p><b>Site 1 (Area A)</b>            Made Ground Topsoil only (to 0.3m depth), with "possible" deeper made ground (loose sand and very soft clay) to 2.7m in WS46 (south-west). Looking at the log for WS46, this is more likely to be alluvium than made ground, but could be fill material associated with the diversion of the beck.</p> <p><b>Sites 2 to 5 (Areas B1, B2 &amp; C)</b>            Reinforced <b>concrete</b> covers the majority of these sites, between 0.1-0.3m thick. The reinforcement across Site 5 (south-east) was noted as stronger and more difficult to penetrate with a coring barrel on the window sampling rig.</p> <p><b>Macadam</b> Hardstand (0.1m thick) was encountered in the north-west of Site 5.            In the west of Site 5 (grassed areas), <b>Made Ground Topsoil</b> was encountered.</p> <p>Made ground encountered by ARP typically comprised <b>Granular Made Ground</b> (sandy gravel of limestone, brick, concrete, clinker, with some 'ash' noted), occasionally interbedded with <b>Cohesive Made Ground</b> (soft clay with gravel of brick, sandstone, mudstone, coal) and occasionally re-worked natural soils.</p> <p>Depths of made ground range from 0.2m to &gt;3.45m. Typically, made ground is less than 2m thick, but sporadic areas of deeper made ground (&gt;2.5m thick) are present in Site 3 (WS22), Site 4 (WS31, TP39) and Site 5 (TPs 10 to 14 and WSs 6, 7 &amp; 12) roughly in the centre.</p> <p>Locally, made ground topsoil is present in former soft landscaped areas of the works buildings.</p>
Natural Ground	<p>Natural ground encountered by ARP typically comprises <b>firm to stiff gravelly clay</b>, often interbedded with sands and gravel. This material is classified by ARP as 'Alluvium' in the majority of exploratory holes, although occasionally it is referred to as 'Possible Head' deposits.</p> <p>Dynamic probing by ARP across the site achieved depths of between 8m and 10m before refusal on suspected bedrock.</p>

Issue	Remarks
	<p>Some loose sands/soft clays were encountered, usually within the upper 1m or so, but occasionally extending to &gt;2.5m depth (south of Site 4 and south of Sites 1 &amp; 5). In the far south, <b>peat</b> was encountered close to Lees Hall Beck in WS12 on the southern boundary.</p> <p>The material encountered in the far north (at the base of the railway embankment) is almost certainly weathered Coal Measures (residual soils) and not 'Head' deposits as described by ARP. Further comments below.</p>
Groundwater	<p>Groundwater was encountered by ARP at depths of between 1m and 3m in various exploratory holes across the site as seepages/inflows. Groundwater inflows/seepages were more common in the lower-lying Sites 1 and 5, closer to Lees Hall Beck to the south.</p>
Contamination	<p>During fieldwork a potential 'hotspot' of hydrocarbon contamination (visual &amp; olfactory evidence) was encountered by ARP within cohesive made ground up to 2m thick in the central-west (see Drawing 3435/3). In addition, 'possible methylated spirits' were identified in TP13.</p> <p>Across both Sirius' and ARP's investigations, the following were tested (according to ARP's report)</p> <ul style="list-style-type: none"> <li>• 38 samples of topsoil/ MG topsoil</li> <li>• 102 samples of made ground</li> </ul> <p>It is likely that more testing was carried out by Sirius in Sites 4 and 5, but only Sirius' results for Sites 1 to 3 are used by ARP (as well as their own tests results).</p> <p>In summary, ARP conclude:</p> <p><b>Site 1</b></p> <p>No contamination with the exception of topsoil in TP4, which ARP state requires further sampling to delineate the extent of lead and PAH contamination. TP4 actually lies in Site 5, so Site 1 (greenfield) is considered 'clean' based on ARP's report, and should be suitable for re-use.</p> <p><b>Site 2</b></p> <p>Arsenic and PAH contamination encountered within the made ground. Will require 600mm clean soil cover in gardens underlain by made ground.</p> <p><b>Sites 3, 4 &amp; 5</b></p> <p>Made ground across the former Minerva Works was found to contain elevated concentrations of various heavy metals, asbestos (especially within Site 5) and PAHs. Elevated concentrations of VOCs were also encountered sporadically across Sites 4 and 5. A 600mm clean soil cover system is recommended in garden areas, with an underlying hard-dig layer (100mm thick) due to the presence of asbestos contamination.</p> <p>Not all of the samples which yielded positive asbestos IDs were scheduled for quantifications. Of those that were, results ranged from &lt;0.001% to 0.009%.</p> <p>Sirius' BH 3 on Site 3 identified elevated concentrations of DRO and MRO in groundwater. ARP state that they installed a well adjacent to this to re-test the groundwater in this location. This was done after the report was issued so the results are not included.</p> <p>ARP conclude that risks to surface waters from VOCs could be mitigated by removal of the contamination (by excavation). Further comments provided below.</p>
Hazardous Gas	<p>14 no. wells installed and monitored by ARP. In addition, monitoring was undertaken by Sirius in 2006.</p> <p>They zone the site by calculating worst-case GSVs for each individual wells, concluding that the west and north-east can be characterised as CS1, with the centre and south-west requiring CS2 protection measures. This assessment is not considered appropriate. Further comments given below.</p> <p>No radon measures are required.</p>
Site preparatory works	<p>These are not discussed in great detail by ARP, but are likely to include:</p> <ul style="list-style-type: none"> <li>• General clearance and grubbing up of hardstand</li> <li>• Turnover of made ground</li> <li>• Excavation and treatment/disposal of contamination hotspots</li> <li>• Provision of 100mm hard-dig layer in Sites 3, 4 &amp; 5</li> <li>• Provision of 600mm clean soil cover in Sites 2, 3, 4 &amp; 5</li> </ul> <p>Further comments given below.</p>
Foundations	<p>Clay is of medium shrinkability, so a minimum founding depth of 0.9m is required in clay soils.</p> <p>ARP suggest a bearing capacity of 100kPa for the natural soils on Sites 1 to 3; with footings to be deepened through localised soft/loose deposits.</p> <p>ARP suggest a bearing capacity of 90kPa for the natural strata beneath Sites 4 and 5, again with footings to be deepened through any soft material, but shallow foundations are only practically possible in the north-east of Site 4 (according to ARP).</p> <p>Reinforcement is recommended given the variability of the natural soils.</p> <p>Piled foundations are recommended by ARP in the south of Site 1, the majority of Site 4 and all of Site 5 where competent strata are at significant depth (c. 4m) and/or where the nature of shallow natural strata is highly variable.</p> <p>Further comments are given below.</p>

Issue	Remarks
Excavations	Excavations by ARP in the natural soils generally showed good stability, with the exception of the south-west of Site 1. Elsewhere, some instability was common when excavating through the made ground, most notably where groundwater was also encountered. Although not discussed in great detail by ARP, some obstructions (former floor slabs, boulders up to 0.5m) were encountered in the made ground.
Drainage	ARP state that soakaways are “unlikely to be feasible” due to low permeability natural soils, watercourses and shallow groundwater. Lithos agree that soakaways are not suitable here.
Highways	ARP give an estimated CBR value of 2% for shallow natural soils, which seems reasonable, although slightly conservative.

## Lithos Comments

**Scope.** The ARP investigation appears reasonable in terms of scope; a good number of trial pits and boreholes have been advanced, and a good number of samples have been tested.

That said, VOC analysis was somewhat limited, and testing for hydrocarbons was done via a ‘total EPH’ test with speciation only carried out on 4 samples. This does not provide sufficient data for a robust risk assessment with regards to hydrocarbons, especially given the site’s previous use and the presence of grossly contaminated soils in Site 5. On the back of the 4 speciated TPH results, ARP dismiss risks of hydrocarbon contamination in relation to human health. The three-step approach for TPH contamination does not seem to have been followed here and their conclusions with regards to human health risks are considered highly questionable.

No samples were tested for cyanide, a known contaminant associated with gas works.

No cable percussion boreholes have been advanced in areas of deep made ground/alluvial soils (most notably in the south of the site, where piled foundations are anticipated). These will be required for pile design, along with more detailed geotechnical soils analysis (including triaxial strength tests and consolidation tests on undisturbed samples of clay where possible).

14 no. gas monitoring wells were installed and monitored by ARP; ideally around 30 would have been installed. In addition, the same response zone (1m to 3m) was installed in each borehole, regardless of the strata encountered. Response zones should never span the boundary between made ground and natural ground; a mixture of response zones should have been installed, some within made ground and some in natural ground in order to enable a more detailed assessment of gas risks, assessing the sources (made ground, natural strata and landfills) individually.

No access was available to very steep slopes in the north of Site 3 (former railway embankment) due to dense vegetation and topography.

**Reports.** ARP’s investigation has been split across two reports, and then split further into individual parcels (referred to as Sites 1 to 5). Presumably, this was something to do with proposed land sales at the time of writing. However, it makes reading the ARP reports somewhat confusing. Every aspect of the investigation (exploratory holes, ground conditions, laboratory testing results, remediation proposals) is split into sub-headings associated with each individual parcel. This is not always appropriate as the parcel boundaries (most notably between Sites 3 and 4) are somewhat arbitrary, and in terms of conceptualisation from a contamination risk point of view, findings from Parcels 3, 4 & 5 should be considered more holistically as they all former part of the former ‘Minerva Works’.

This sub-division also lends itself to clerical errors. For example, the log for TP31 is not included within either ARP report (likely due to deleting one too many from the appendices). In addition, numerous references are made to contamination encountered in TP04 within Site 1 in Report 1. Actually, TP04 lies in Site 5, within a grassed area associated with the former Minerva Works buildings. The topsoil in Site 1 (essentially greenfield) is therefore considered ‘clean’ based on ARP’s report.

**Ground conditions & logs.** The natural ground described by ARP varies, but in most locations includes firm to stiff gravelly clay, often interbedded with sands and gravel. Trial pits often '*terminate in hard strata*'. The clay is sometimes described as 'friable' and the gravel content varies significantly including subrounded to angular tabular sandstone. This material is classified by ARP as 'Alluvium' in the majority of exploratory holes, although occasionally it is referred to as 'Possible Head' deposits.

In some cases, descriptions in boreholes/trial pits are similar to each other but are given different geological classifications (stratum names) despite their similarities. This might be a case of simply assigning a strata type based on the BGS plan and the hole's location.

The classifications given by ARP are questionable given the descriptions within their logs. Typically, alluvial deposits would include soft clay/silt and loose sands, often organic-rich with some peat. Such material was rarely encountered, and where it was, it tended to be towards the southern boundary (close to Lees Hall Beck). Nonetheless, the majority of the soils encountered are called 'alluvium' by ARP.

Where soft material was encountered, it was typically within WS boreholes (not trial pits). It is possible that the disturbance caused by drilling has artificially softened the soils that the field engineer has described.

Most of the SPTs within the window sample boreholes, and hand vane readings yielded 'good' results within the upper most 2.5m, but results within the soft/loose range were recorded up to 4m depth in multiple locations, most notably on Site 5, and sporadically on Sites 3 & 4.

Cable percussion boreholes would allow a more robust description and assessment of natural soils beneath the site.

The firm/stiff gravelly clays encountered across the majority of the site could actually be weathered Coal Measures strata, although this too appears unlikely given the depths achieved by ARP in their dynamic probes (between 8m and 10m before refusal). That said, the material encountered in the far north (at the base of the railway embankment) is almost certainly weathered Coal Measures and not 'Head' deposits as described by ARP.

**Foundations.** ARP suggest an allowable bearing capacity of 100kPa for all natural soils in Report 1 (Sites 1, 2 and 3) but only 90kPa in Report 2 (Sites 4 and 5). It is not clear why, given that the natural ground conditions are similar across all parcels, with the exception of the northern edge of Site 4 where suspected weathered Coal Measures strata was encountered.

Reference is made by ARP to '*halving the bearing capacity due to shallow groundwater*' in their report. This is misleading. Whilst shallow groundwater can significantly affect the bearing capacity of granular soils, it requires site-specific assessment based on ground conditions and groundwater monitoring results. Groundwater has little effect on clay soils (the predominant soil type here).

A bearing capacity of at least 100kPa (possibly up to c. 150kPa) seems reasonable at this stage for natural ground (aside from soft/loose spots). If proven by supplementary investigation, a bearing capacity in excess of 130kPa would allow strip/trench fill foundations where competent strata lies within 2.5m depth. However, it should be noted that no compressibility testing (consolidation tests) has been undertaken by ARP. This is important within suspected alluvial soils (which are under-consolidated) in order to assess likely long-term settlements and therefore shallow foundation feasibility.

ARP rightly point out that, where deep made ground and/or soft/loose soils are encountered, foundations will need deepening through to competent strata below.

Piled foundations are recommended by ARP in the south of Site 1, the majority of Site 4 and all of Site 5 where competent strata are at significant depth (c. 4m) and/or where the nature of shallow natural strata is highly variable.

Additional assessment is needed before foundation recommendations can be given. Most notably:

- Trial pitting in order to:
  - Provide further assessment of the origin of natural soils beneath the site (i.e. alluvial, weathered Coal Measures etc)
  - Delineate areas of deep made ground/soft clays
- Cable percussion drilling in order to:
  - Obtain geotechnical data from depth (SPTs, undisturbed samples of clay where possible)
  - Ascertain the depth of soft/loose sands
  - Ascertain natural ground conditions beneath areas of deep made ground/soft & loose soils for pile design

That said, some preliminary recommendations can be given based on the data available from ARP's investigation. An approximate zoning plan showing areas likely to require piling has been produced by Lithos (see Drawing 3435/2) based on the ground conditions reported by ARP.

Based on Harron's current layout, Plots 65 to 68 will necessitate significant 'cut' into a steep railway embankment which runs along the northern boundary (c. 5m high). This may also be the case for Plots 26, 56 to 59 and 64, though the topo survey is not clear. Such works will require substantial retaining walls along the northern boundary of the plots and gardens.

**Highways.** Where made ground is present its full thickness (up to a maximum of 2m - from existing ground level or proposed highway formation, whichever is the lower) should be excavated and either: replaced with suitable aggregate; or screened, before being replaced in engineered layers. Some refinement of this advice might be possible after highways design (with consideration of the proposed formation level cf existing ground level), and via inspection (and usually CBR testing) of the proposed formation during site preparatory groundworks.

ARP give a CBR value of 2% for the shallow natural soils, which seems reasonable, although slightly conservative. Any soft spots encountered within the natural ground would require excavation and replacement with suitable aggregate.

**Contamination & remediation.** Whilst a significant number of samples have been tested by Sirius and ARP, the Sirius data is somewhat out of date (2006) and ARP's scope/risk assessment is lacking in some areas, most notably with respect to:

- Poor assessment of TPH (hydrocarbon) contamination risks
- Test suite is not bespoke to the past use (e.g., no samples scheduled for cyanide & ammonia analysis, known contaminants on former gas works sites)
- Limited number of samples scheduled for VOC analysis
- Limited number of asbestos quantifications
- Although risks to groundwater as dismissed by ARP, there is very limited data to back this up; additional analysis should be undertaken across a greater number of locations to assess risks to controlled waters (most notably, Lees Hall Beck).

ARP's use of statistical analysis is split along the parcel boundaries (Sites 1 to 5) instead of considering the data more holistically. They identify numerous 'outliers' but given the number of locations identified as outliers which "*require further assessment*" it becomes impracticable to treat these individually.

ARP recommend removal of topsoil from Site 1 in the vicinity of TP04 (after further testing to delineate the area affected). This is not needed as TP04 lies in Site 5. Topsoil is 'clean' in Site 1 (based on ARP and Sirius' data). ARP state that contaminated topsoil cannot be placed beneath the proposed soil cover, but this should be possible provided it is placed at no greater than 1m depth.

Instead of dividing the site into Sites 1 to 5 (as per ARP's reports), the following zoning of the site would be more appropriate when assessing contamination risks and remediation proposals (as shown on Drawing 3435/3):

- **Area A** - Greenfield area in the south-west (Site 1): No significant made ground or contamination encountered and no remediation required
- **Areas B1 & B2** - Former Minerva Works gas works and bleach & dye works (Sites 3, 4 & 5): Contamination includes heavy metals, PAH, VOCs and asbestos. 600mm clean soil cover and 100mm hard dig later required in garden/landscaped areas. Excavation and treatment/disposal of contamination hotspots.
- **Area C** - Former industrial building in the north-west (Site 2): Some (relatively minor) arsenic and PAH contamination. 600mm clean soil cover required in garden/landscaped areas.

In addition to the above, it is understood that a remediation contractor (Vertase) have investigated land in the area of former gas holders in the south of Area B and located two no. circular holders which are 16m and 14m in diameter. The holders are backfilled with crushed product, hydrocarbon-contaminated materials, thick tar and 'contaminated water'. Vertase estimate them to be around 2m to 4m deep.

Preparatory works (as part of remediation) are not discussed in great detail by ARP. Such works are likely to include:

- General site clearance of surface materials and vegetation
- Break-up of slabs and hardstand
- Crushing of all suitable artificial hard material (i.e. concrete/brick etc)
- Turnover (excavation, screening and replacement in engineered layers, with nominal compaction) of the full thickness of made ground to enable:
  - Removal of localised fuel/oil contamination within the south of Area B; with subsequent treatment and/or off-site disposal
  - Inspection of the made ground, including any other contamination 'hot-spots'
  - Removal of below ground obstructions
  - Preparation of the ground for highway construction
- Possible excavation of natural soils from beneath made ground to source 'clean' subsoil for use in gardens and landscaped areas
- Backfill of all resultant excavations, with appropriate compaction
- Excavation of up to a maximum depth of 2m beneath proposed adoptable road footprints and controlled re-engineering of selected materials in layers to approximately 650mm below final road levels
- Removal of underground tanks
- Provision of a minimum 600mm thick cover layer of 'clean' soils in all garden and landscaped areas in Areas B & C, with an underlying 100mm thick hard-dig layer in Area B.
- Assessment of the retaining wall in the north of the site by a Structural Engineer.

ARP recommend removal of volatile contaminants (vicinity of WS24, TP36, TP6, TP10) from below building footprints and from within a 2m radius of plots. This is unlikely to be practicable and additional (unidentified) areas of VOC contamination may exist. A more pragmatic approach would be to assess risks during made ground turnover through engineering supervision and additional sampling where necessary. Depending on the extent and nature of VOC contamination identified during the remediation phase, it may be necessary to utilise a hydrocarbon-resistant membrane in plots (rather than the '*methane impermeable barrier*' specified by ARP).

ARP's remediation statement (included as an appendix in their reports) essentially repeats the contamination summary contained in the SI report, and then states the validation procedures for importing clean soil cover (i.e. the number of samples etc required). A more detailed remediation strategy is required which includes consideration of the bullet points listed above.

**Gas.** A limited number of gas wells were installed and monitored by ARP and no consideration was given to placement of their response zones (see comments given on page 4).

Zoning of the site based on GSVs calculated on a hole-by-hole basis is not considered appropriate. A more thorough assessment, which considers the site more holistically, is recommended, looking at worst-case scenarios between boreholes.

The assessment should include information from gas wells which target the made ground and natural strata separately. This may allow zoning of the site (for example, if the made ground is considered a significant source, Area A is unlikely to require significant gas protection. However, if gas concentrations are found to be more significant closer to the landfill off-site to the south, zoning based on distance from this source might be more appropriate).

Methane was detected by Sirius, up to 10% in one borehole in Site 3 (not 1.0% as stated in the ARP Report). In addition, ARP's readings include steady flow rates of up to 14.1lt/hr (WS17), maximum carbon dioxide concentrations of up to 9.3% (WS2) and maximum methane concentrations of up to 1.0% (WS7). Based on these results, the GSVs would be 0.14 for methane, and 1.31 for carbon dioxide, which equates to Amber 1 (NHBC) or CS3 (Wilson & Card).

At this stage, it would be prudent to assume at least **Amber 1** measures for all plots.

**Further work.** Following review of ARP's data, some additional work is recommended. The scope outlined below assumes Harron Homes will have reliance on ARP's reports and is intended to supplement their data.

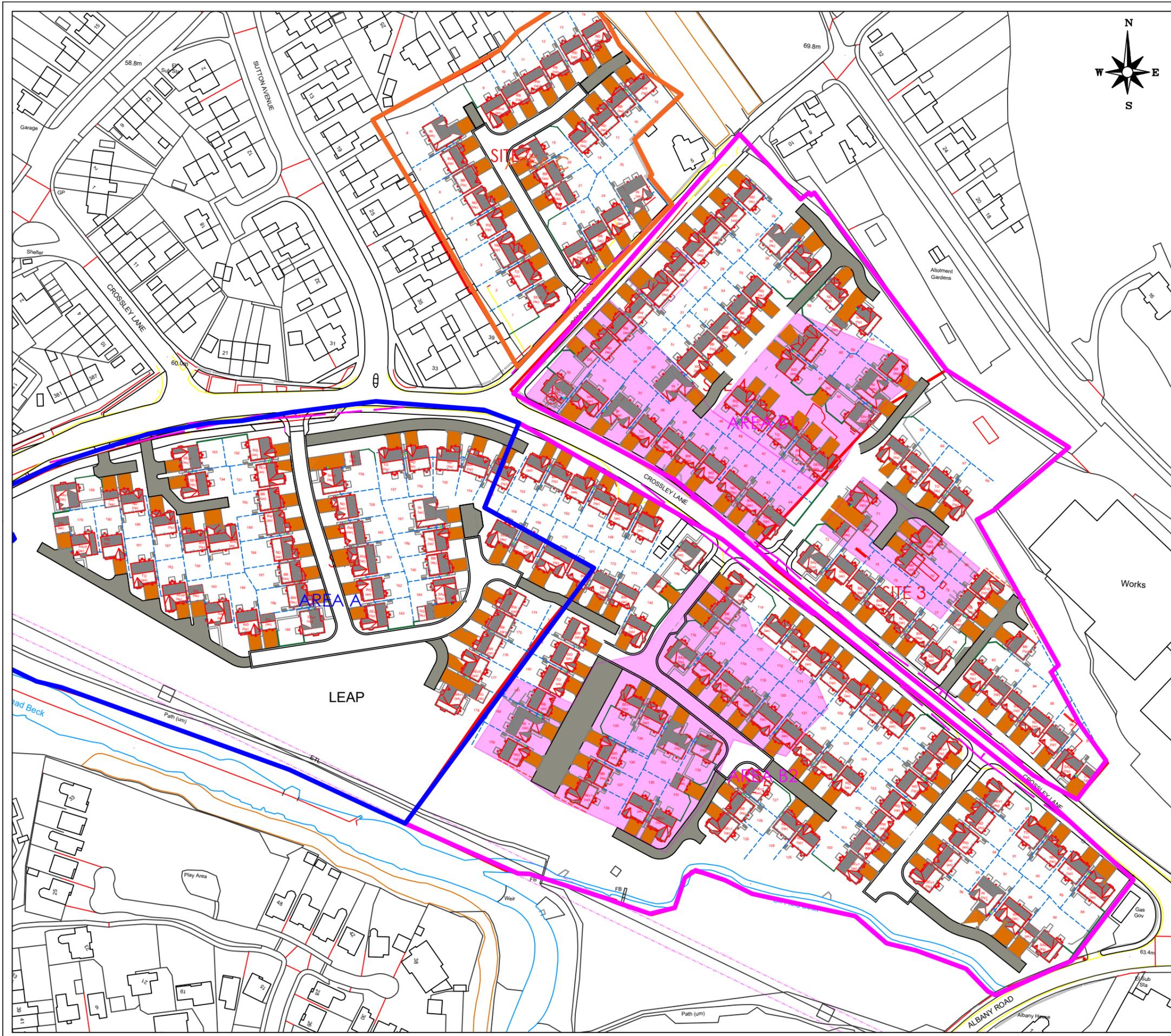
In summary, the following are required:

- Excavation of around 30 trial pits across the site using a tracked excavator to:
  - allow inspection of the natural soils and zone the site as appropriate in terms of foundation recommendations.
  - delineate areas of deep made ground.
- Cable percussion boreholes advanced to rockhead across the site (most notably in areas of soft soils/deep made ground identified in the trial pitting) to enable more thorough inspection of natural soils and to provide sufficient information for pile design.
- Installation of gas wells across the in around 20 no. locations. Boreholes could be advanced using window sampling techniques. Gas wells should then be monitored on at least 6 occasions over 3 months.
- Installation of groundwater monitoring wells in around 5 locations, and chemical testing of groundwater samples on at least 2 occasions.
- Chemical testing on around 25 no samples to supplement ARP's data. The test suite should include ammonia, cyanide, speciated TPH and VOCs.
- Geotechnical analysis on samples of undisturbed clay (where possible) recovered from cable percussion boreholes to allow assessment of compressibility and shear strength.

It might be possible to avoid the need for gas monitoring (and therefore installation of gas wells across the site), if Amber 1 measures were adopted across the site. However, this would require approval from NHBC and the Local Authority.

Slope stability needs to be considered for the steep sloping embankment running along the northern boundary. This would include boreholes along the crest of the slope and geotechnical analysis/modelling. However, this area is not accessible without significant enabling works. Indeed, it may be more economical to simply opt for a robust retaining structure in this area, adopting a broadly 'worst-case' scenario with regards to stability (given the reasonably high costs and timescales involved in an intrusive investigation and assessment).

On completion of the above, the findings should be presented in a report which assesses the site as a whole, and should include ARP's data.



NOTES

**PILED FOUNDATIONS**  
 (made ground and/or soft/loose ground to >2.5m)  
 Elsewhere, strip/trench fill foundations potentially feasible depending on supplementary site investigation

REV.	DESCRIPTION	DATE



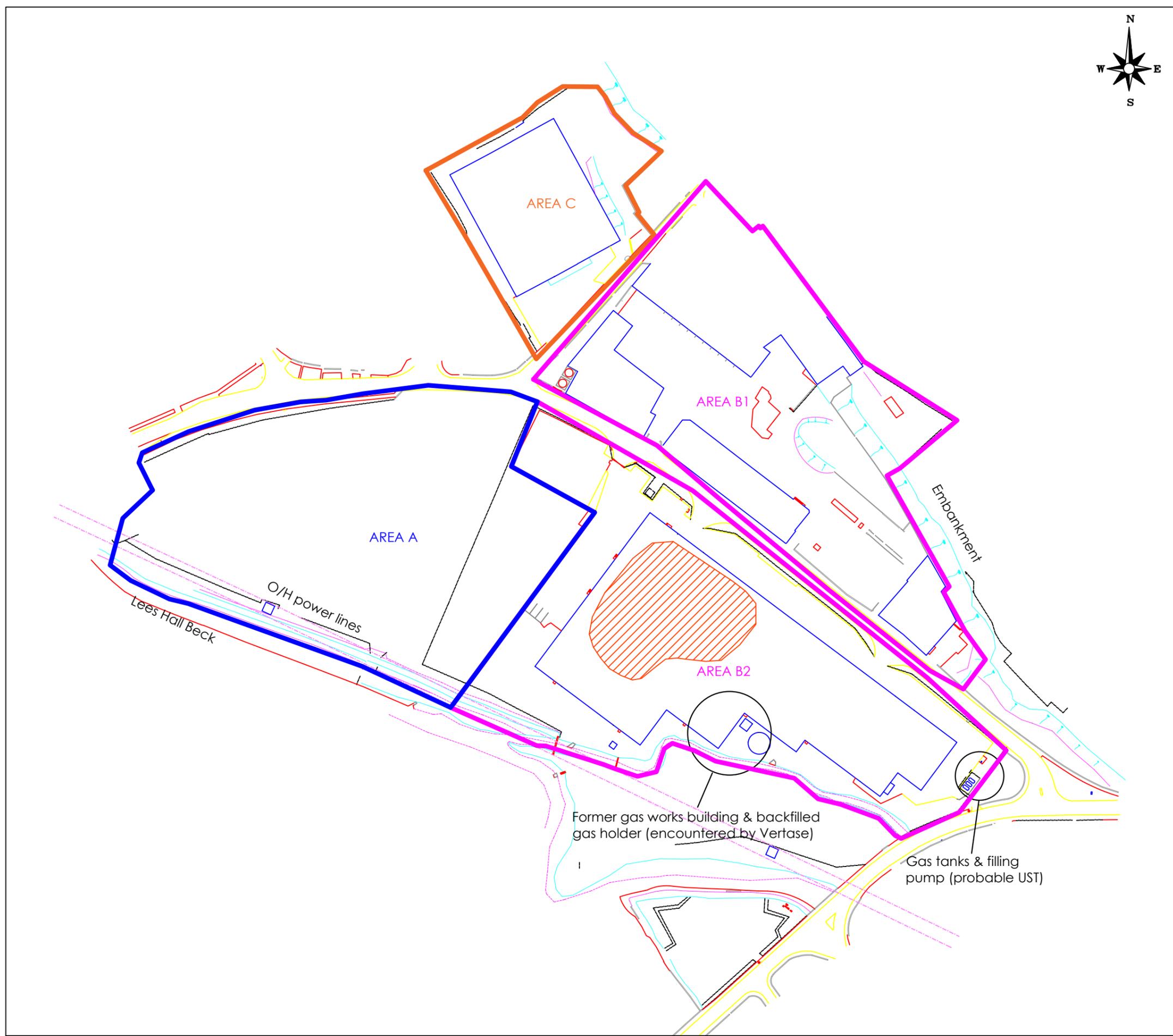
[info@lithos.co.uk](mailto:info@lithos.co.uk)  
[www.lithos.co.uk](http://www.lithos.co.uk)  
 Tel 01937 545330

**HARRON HOMES**

**CROSSLEY LANE, DALTON**

**PRELIMINARY ZONING PLAN - PILED FOUNDATIONS**

DRAWN	MJT	DATE	14/01/2019	STATUS	FOR COMMENT	<input type="checkbox"/>
CHECKED	REG	DATE	14/01/2019	FOR APPROVAL	DRAFT	<input type="checkbox"/>
					FINAL	<input checked="" type="checkbox"/>
SCALE	1:1,500	SHEET	A3	DRAWING NO.	3435/2	REVISION



NOTES

- AREA A - No remediation required
- AREA B - 600mm soil cover and 100mm hard-dig layer
- AREA C - 600mm clean soil cover
- HYDROCARBON HOTSPOT - Grossly contaminated soils encountered by ARP

REV.	DESCRIPTION	DATE

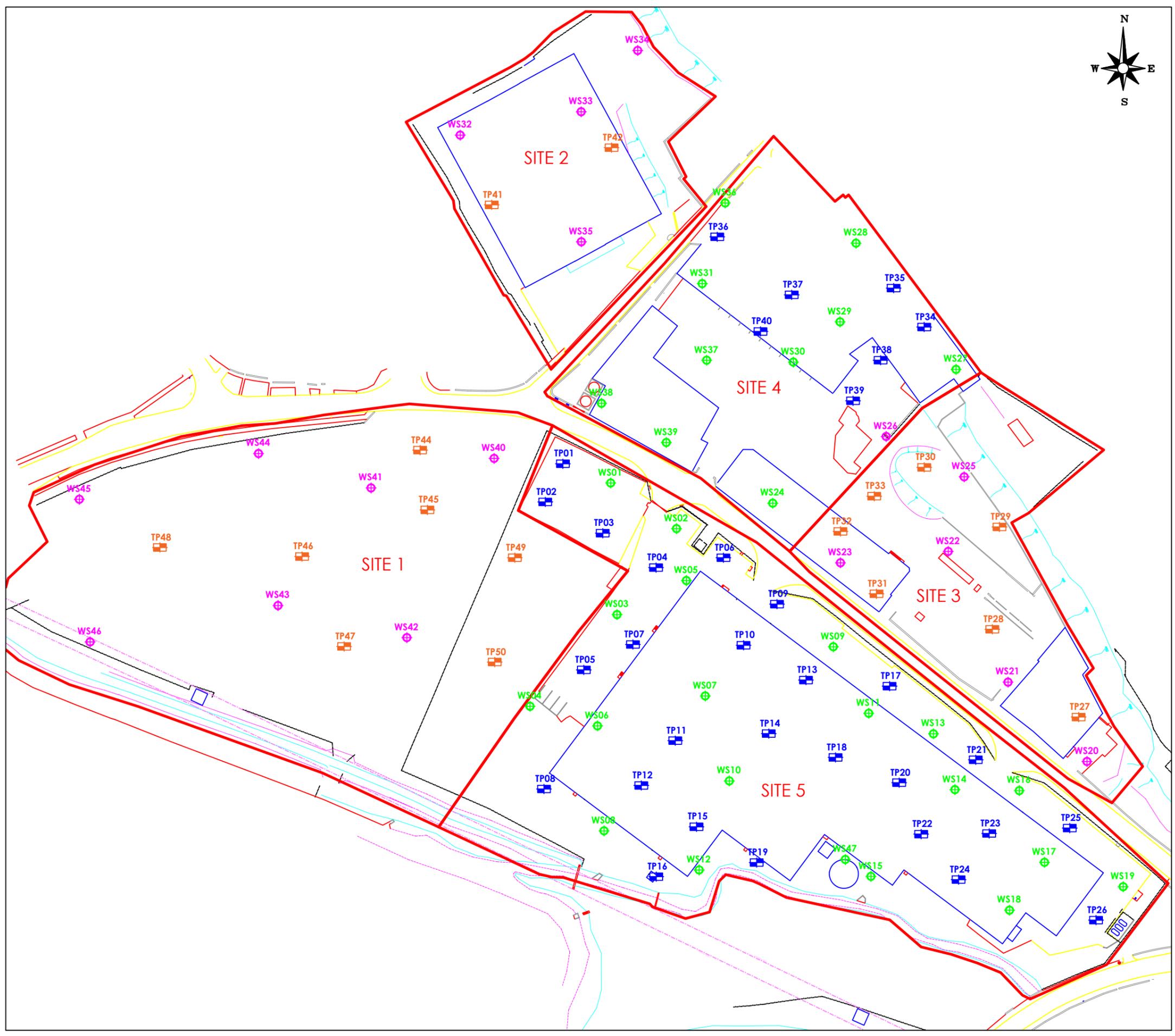
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www.lithos.co.uk  
Tel 01937 545330

HARRON HOMES

CROSSLEY LANE, DALTON

KEY FEATURES & REMEDIATION ZONES

DRAWN	MJT	DATE	14/01/2020	STATUS	FOR COMMENT	<input type="checkbox"/>
CHECKED	REG	DATE	14/01/2020	FOR APPROVAL	DRAFT	<input type="checkbox"/>
					FINAL	<input checked="" type="checkbox"/>
SCALE	1:2,000	SHEET	A3	DRAWING NO.	3435/3	REVISION



- NOTES
- TRIAL PIT ARP REPORT 1
  - TRIAL PIT ARP REPORT 2
  - WINDOW SAMPLE ARP SI ONE
  - WINDOW SAMPLE ARP SI TWO
  - APPROXIMATE SITE BOUNDARY

REV.	DESCRIPTION	DATE



info@lithos.co.uk  
www.lithos.co.uk  
Tel 01937 545330

CLIENT

HARRON HOMES

JOB TITLE

CROSSLEY LANE, DALTON

DRAWING TITLE

EXPLORATORY HOLE LOCATIONS

DRAWN	JBA	DATE	10 01 20	STATUS	FOR COMMENT <input type="checkbox"/>
CHECKED	REG	DATE	14 01 20	FOR APPROVAL	<input type="checkbox"/>
				DRAFT	<input type="checkbox"/>
				FINAL	<input checked="" type="checkbox"/>
SCALE	1:1500	SHEET	A3	DRAWING NO.	3435/6
				REVISION	