LTA 2 Home Zone 3

Ground Investigation Interpretative Report

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Quality Assurance – Approval Status

This document has been prepared and checked in accordance with Waterman Group's IMS (BS EN ISO 9001: 2015, BS EN ISO 14001: 2015 and BS EN ISO 45001:2018)

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Comments

Report updated following revised LMR masterplan Rev J

Comments

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Objectives

Waterman Infrastructure & Environment Ltd was instructed by Graven Hill Village Development Company Limited to undertake a Ground Investigation Report for the proposed redevelopment of the Home Zone 3 area of the Graven Hill Site.

Site Setting

Current Use	The Site currently comprises of the Northern Extent of Anniversary Avenue, unnamed access roads, open brownfield land and former building plots of the "E" Sector of the Former MOD Bicester Site.

Environmental Assessment

When screened against an assessment criterion for a residential with plant uptake end use, localised exceedances of heavy metals, individual PAH and TPH fractions were recorded within asphalt, road subbase and Made Ground.

No asbestos fibres were recorded in any of the samples screened.

Locations recording exceedances within hardstanding and bituminous materials that are to be replaced as part of the redevelopment of the Site are not proposed to pose a risk to end users. Construction workers must adhere to good practices for hygiene during works.

Locations recording exceedances within Made Ground other than hardstanding or bituminous material are within areas proposed to be infilled. As such they are not proposed to pose a risk to end users, however construction workers must adhere to good practices for hygiene during works. Should areas of proposed cut/fill change, this may need to be reassessed.

Any soils intended for re-use on Site or disposal must be assessed for their suitability.

A single reading of carbon dioxide, marginally above the screening value of 5% has been recorded; all other readings are significantly below this level and no flow has been recorded in any holes on the site. Hence, when considering all available information, the Characteristic Situation 1 classification is considered appropriate and hence no ground gas protection measures are considered necessary.

Care and consideration must be given however, to minimising exposure to even marginally elevated carbon dioxide within excavations and RPE shall be used if no other means of mitigation or protection are available.

As part of protection against the potential risk posed by contaminated ground, the mandatory use of PPE when operating within areas of known contamination and when within excavations shall be adhered to at all times and provisions shall be made for appropriate Site hygiene and welfare facilities and dedicated food preparation and eating areas.

The recorded concentrations are not considered to represent a risk to controlled waters receptors.

Geotechnical Assessment

The Site is underlain by a bituminous surface, roadstone, Made Ground and Topsoil, underlain by firm and stiff Oxford Clays.

The existing roadways are typically comprised of 200mm of bituminous surfacing over 150mm of roadstone.

Areas of hardstanding typically comprised of 200mm of concrete over 150mm to 200mm of subbase and 500mm to 700mm of cohesive Made Ground.

Oxford Clays underlying the Site have been shown to have medium to high plasticity and volume change potential. A Plasticity Index of 44% should be adopted for the Oxford Clay underlying the Site. Considerable care should be taken when accounting for differential settlement across the course of the proposed roadways and across residential plots in this area of the Site. Oxford Clays underlying former buildings are likely to heave to a significant extent, whereas those underlying open ground will be anticipated to settle under loading form the proposed fill and buildings.

Foundations

Made Ground is not considered to be suitable bearing strata and hence foundations should be extended through these materials and on adequate bearing strata at deeper levels. Foundations should be placed on uniform founding strata to avoid differential settlement.

The descriptions and results of lab and in-situ testing suggest that trench fill concrete foundations could be placed on the firm Oxford clays at relatively shallow depths (i.e. generally less than 2.5m below existing ground level).

Assuming 0.6m trench fill foundations founded on the firm clays (shear strength in excess of 50kN/m2), ground bearing resistance calculations have been undertaken using Terzaghi's bearing capacity equation in accordance with Eurocode 7 Design Approach 1, Combination 2 and indicate a Ground Bearing Resistance of 212kN/m2 (which equates to an approximate allowable bearing capacity in excess of 95 kN/m2 at 1.50m depth to superseded British Standards).

It has also been assumed that a maximum total settlement of 25mm would be acceptable within the serviceability of the design.

In view of the proposed development layout and levels, widespread tree removal, particularly in the north of the Home Zones 3 Site, and the raising of site levels in places by over 1m (and up to 2.5m in places), piled foundations are considered likely to be the most appropriate solution for certain parts of the Home Zone 3 area. Many of the trees in this area of the Site are mature ash and hawthorn, meaning that their removal has the potential to cause significant localised effects on foundation solutions.

It is recommended that the advice of a specialist piling contractor should be obtained to confirm the suitability of piling and the most appropriate pile type.

Floor Slabs

It is recommended that suspended floor slabs should be adopted due to the localised potential risk of heave of the natural clay soils and the depth of Made Ground/areas where ground levels are to be raised.

Buried Concrete

Buried concrete should be designed in accordance with:

- Concrete in contact with Made Ground: DS2 AC1s
- Concrete in contact with Oxford Clay: DS4 AC3s

General

Compaction testing has shown that cohesive Made Ground and Oxford Clays in excess of 1.00m bgl at the Site are likely to be significantly wet of optimum. It is considered that some of the Made Ground and Clays could be used as an engineered fill, subject to other suitability considerations. It should be noted that suitability for compaction is highly dependent on the initial moisture content of the material to be compacted.

Testing should be undertaken prior to any excavated clays being used as earthworks material. It may be necessary for clays to be allowed to dry or are treated to reduce moisture content (i.e. lime stabilisation).

The groundwater level measured during fieldwork was in the range 0.30m (68.93mOD) to 2.50m (68.74mOD) below ground level. However, these water strikes are considered to be perched water and not representative of the wider groundwater regime at the Graven Hill Site.

Based on observations made during fieldwork, shallow excavations (<1.2m) likely to be stable in the short term. Although if significant depths of Granular Made Ground is encountered there is potential for pit collapse.

1. Introduction

1.1 Objectives

Waterman Infrastructure & Environment Limited (hereafter referred to as 'Waterman') was instructed by Graven Hill Village Development Company Limited (GHVDC) to undertake a Ground Investigation and Interpretative Report for the whole Land Transfer Area 2 site including for the new infrastructure and Home Zones at Graven Hill, Bicester (hereafter referred to as the 'Site'). This report provides specific ground information for the proposed Home Zone 3.

The main objectives of the report are to:

- Investigate ground conditions underlying the Site.
- Investigate current construction of pavements, roadways and hardstanding within the proposed site boundary, most notably in the region of buildings E2, E31 and E6.
- From this information, provide design parameters for foundation and highway design.
- Derive representative geotechnical parameters in general accordance with Eurocode 7 and characterise the ground for the purposes of geotechnical design.
- Provide an investigation of ground contamination as defined by BS1015.
- Assess the suitability of potential materials arising from earthworks activities for re-use on site or disposal.
- Provide an assessment of hazardous gas risk in accordance with CIRIA Report C665 / BS8485 and preliminary recommendations relating to protective measures required in foundations (if any).

The contamination assessment has been undertaken in general accordance with the Land Contamination Risk Assessment (LCRM) 2020 (Environment Agency), and forms a decision record in relation to the assessment of the site. The report provides a conceptual model based on the findings of the ground investigation, an evaluation of potential risks and recommendations relating to any necessary remediation.

The assessment was undertaken in accordance with the scope agreed between Waterman and GHVDC, and with Waterman's standard Terms of Appointment. The benefit of this report is made to GHVDC.

1.2 The Proposed Development

The proposed development comprises a residential and highways development with the provision of highways, footways, cycleways, several phases of residential development, garden space and associated soft landscaping. The proposed Development is shown in the LMR Masterplan (ref: *021-050-102 revN*) included in Appendix A.

1.3 Limitations

The information contained in this report is based on the findings of a ground investigation carried out under the supervision of Waterman, including observations made on site, exploratory hole records, in-situ testing and laboratory test results.

The ground conditions reported relate only to the point of excavation and do not necessarily guarantee a continuation of the ground conditions throughout the non-inspected area of the site. Whilst such exploratory holes would usually provide a reasonable indication as to the general ground conditions, these cannot be determined with complete certainty.

Waterman has endeavoured to assess all information provided to them during this investigation but makes no guarantees or warranties as to the accuracy or completeness of this information.

The scope of this site investigation includes an assessment of the presence of asbestos containing materials in the ground at the site but not within buildings or structures or below ground structures (basements, buried service ducts and the like).

The conclusions resulting from this study are not necessarily indicative of future conditions or operating practices at or adjacent to the site.

2. Methodology

The intrusive investigation was undertaken in general accordance with Eurocode 7, the Code of Practice for Ground Investigation BS 5930 (2015+A1:2020) and the Code of Practice for the Investigation of Potentially Contaminated Sites and its Investigation BS 10175 (2011+A2:2017).

The objectives of the investigation are to characterise the ground conditions, identify any potentially hazardous sources, pathways and receptors and to reduce uncertainties associated with the proposed redevelopment.

2.1 Design of Investigation

The location of exploratory holes, in-situ geotechnical testing and chemical analysis, was chosen so as to assess the quality of ground for the proposed highway and residential construction works.

Soils samples were carefully selected in order to characterise the ground conditions and to target, as far as possible, potential areas of contamination associated with former storage and distribution works.

2.2 Quality Control

A Waterman Geo-Environmental Engineer monitored the performance, the quality of work and health and safety compliance of the specialist contactor, Geotechnics Limited. Appropriate chemical and geotechnical samples were obtained for subsequent testing at a UKAS accredited laboratory.

All contractors, including laboratories, used during this project have been approved by Waterman as a part of in-house Integrated Management System (BS ISO 9001, BS ISO 14001) procedure. This requires all third parties to demonstrate competence and a high standard of work during a regular audit scheme.

2.3 Health and Safety

All work carried out on site was in accordance with Geotechnics Ltd’s Health & Safety Plan.

3. Fieldwork

Fieldwork was carried out as part of a larger investigation at the Site. For the purpose of this report, only exploratory holes relevant to the proposed Home Zone 3 development are considered.

The locations of the exploratory holes excavated, as per Geotechnics Final Factual report (ref: *PC207899 Graven Hill, Bicester, Land Transfer Area 2 (LTA2) Factual Report*), are shown on the Drawings (ref: *WIE11386-147-HZ3-87-100 to - 104*) presented in Appendix A.

3.1 Ground Investigation

The Site was investigated as part of a larger Ground Investigation programme at Graven Hill. Any description hereafter, unless explicitly specified, refers to the section of the Geotechnics Ltd Ground Investigation within the Home Zone 3 Site Boundary, and its immediate surroundings.

The works comprised of the following:

- 14 no. cable percussive boreholes (BH303, BH304, BH305, BH306, BH308, BH309, BH311 – BH315, BH601, BH604 and BH605) were drilled to depths of between 6.00m bgl and 10.45m below ground level (bgl). Inspection pts were excavated at each location to confirm the absence of buried services at depths of up to 1.2m bgl. Standard Penetration Tests (SPT) were carried out at regular intervals to assess the relatively density of granular deposits and the consistency of cohesive strata. Monitoring wells were installed in selected exploratory holes.
- 17 no. trial pits (TP302 – TP305, TP307 - TP310, TP331 – TP334, TP601, TP608 – TP611) were excavated to an average depth of 3.85m bgl using a wheeled mechanical excavator with backactor. Upon completion, excavations were backfilled as far as possible with arisings. Engineering fill was placed and compacted within the excavations in areas of hardstanding and in well trafficked areas to minimise settlement. The surface of the excavation was reinstated to the original conditions.
- Hand shear vane tests were carried out where possible in the trial pits.
- Soakaway testing was undertaken in 2 no. locations (TP608, TP610).
- 1 no. road core (RC301) was undertaken and extended to a depth of 1.20m bgl to prove natural ground.
- 2 no. concrete cores (CC301 and CC302) were drilled, with dynamic sampling follow on to a maximum depth of 5.45m bgl.
- 7 no. surface swale contamination samples (SSC301 - SSC306, SSC605) were taken within former drainage ditches.

All exploratory holes were logged and sampled by Geotechnics Ltd under the direction of the Waterman Engineer. Exploratory hole logs that provide a record of the strata encountered, provided by Geotechnics Ltd, are presented in Appendix B.

3.2 Soil Sampling

During excavation, representative soil samples were obtained from the exposed strata and sealed in one litre plastic tubs with airtight lids, phials and glass jars containing preservatives, as appropriate. The soil samples taken were subject to screening by a photo ionisation detector (PID).

Disturbed and undisturbed samples were taken at regular intervals and retained for geotechnical and geo-environmental testing and logging.

3.3 Monitoring Wells

On completion of drilling, a 50mm diameter slotted HDPE standpipe with gas tap and bung was installed within BH303, BH305, BH312, BH315, BH601 and BH605 to enable future ground gas and groundwater monitoring and sampling. The response zone of wells was targeted so as to assess groundwater levels and the potential for ground gas generation within Made Ground and Natural Ground. Stratum were targeted such that no response zones of wells covered both Made and Natural Ground.

4. Results

Detailed logs of the strata encountered, together with records of the samples taken during both trial pitting and borehole installation and PID readings, are provided in Appendix B. A summary of the geological strata and man-made underground structures encountered is presented below.

4.1 Geological Strata

The strata encountered in the investigation were generally consistent with the anticipated geology; however, in some locations variances in Made Ground and buried anthropogenic horizons were encountered. Several strata were encountered which were not anticipated.

A summary of the geological strata encountered is shown in Table 1.

Table 1: Geological strata encountered

Soil Type	Depth of Top of Stratum (mbgl)	Thickness (m)	Typical Description
Made Ground 1 / Topsoil	0.00	0.10 – 0.40	Firm dark brown slightly sandy slightly gravelly clay with many rootlets. Gravel is angular to subangular fine to coarse sandstone. Recorded as “loose” 0.10m to 0.30m bgl in BH601. Recorded as “Black slightly sandy slightly gravelly silt with many rootlets and rare pockets of orangish grey clay. Gravel is subangular to subrounded fine to coarse limestone and brick” 0.00m to 0.40m bgl in BH605.
Made Ground 2 / Concrete	0.00 – 0.10	0.15 - 0.25	Concrete. Reinforcement recorded in TP302.
Made Ground 3 / Asphalt	0.00	0.10 - 0.20	Asphalt.
Made Ground 4 / Compact Subbase	0.20	0.20	Light brown sandy gravel with high cobble content of angular to subangular limestone. Gravel is angular to subangular fine to coarse limestone, sandstone and brick.
Made Ground 5 / Hardstanding Subbase	0.15 - 0.25	0.15	Black gravelly sand. Gravel is angular to subangular fine to medium ash, clinker, quartzite and granite.
Made Ground 6 / Silty Gravel Surfacing	0.00	0.60 – 1.10	Light brown and grey to black sandy silty gravel with a low cobble content of subangular limestone and brick. Gravel is angular to subangular fine to coarse limestone, brick, clinker, slag, concrete. Occasional rootlets between 0.00m and 0.35m bgl.
Made Ground 7 / Sandy gravelly clay	0.00 - 0.60	0.15 – 2.00	Soft to Stiff light greyish brown to brown slightly sandy slightly gravelly clay with occasional rootlets. Gravel is angular to subangular fine to coarse limestone, sandstone concrete and brick. Occasional decomposed organic material recorded between 1.50m and 2.30m bgl in TP334.

Soil Type	Depth of Top of Stratum (mbgl)	Thickness (m)	Typical Description
Made Ground 8 / Sandy Clayey Gravel	0.20 – 0.60	0.30 – 2.00	Grey and Black slightly clayey sandy gravel. Gravel is angular to subangular fine to coarse granite, brick, concrete, clinker, asphalt and sandstone.
Made Ground 9 / Gravelly Silty Sand	0.25 - 0.40	0.25 - 0.80	Recorded in BH605, TP302, TP333. Red to Brown slightly gravelly slightly silty sand with many pockets (up to 30mm in size) of grey mottled reddish-brown clay. Gravel is subangular to subrounded fine to coarse limestone and glass.
CLAY	0.10 – 2.30	>6.00	Firm to very stiff brown mottled grey and orange-brown CLAY with occasional pockets (up to 4mm in size) of light brown slightly sandy clay. Sandstone boulder recorded at 2.50m to 2.70m bgl in BH308. Recorded as “soft” at 0.10m to 0.50m bgl in BH304, 0.40m to 1.50m bgl in BH309, 1.05m to 3.00m in CC301, 0.90m to 3.15m in CC302, 0.55m to 2.80m in TP310 and 2.50m to 3.10m in TP332
CLAY	2.00 – 4.30	>4.00	Stiff grey, greenish grey or bluish grey slightly sandy CLAY with occasional gypsum crystals and shell fragments. Locally recorded as firm. Typically recorded at circa 3.0m depth. Fissures, typically sub-horizontal and extremely to very closely spaced, smooth and undulating recorded in BH601, BH605 and TP308. Typically, very stiff below 6.00m.

In summary, the former hardstanding areas (roads, yards, etc) typically comprised either macadam or concrete surfacing over a roadstone/subbase layer and commonly over a reworked clay layer including fragments of concrete, brick, ash, etc. In areas of soft landscaping, the topsoil was also often underlain by a thin layer of reworked clay with fragments of brick, concrete, etc,

The natural strata typically comprises firm grey and orange brown Clay over stiff grey, greenish-grey and bluish grey Clay.

4.2 Underground Structures and Obstructions

TP333 was terminated prematurely at 0.45m bgl due to the presence of service tape.

No other underground structures or obstructions are recorded.

4.3 Potential Sources of Contamination

No potential sources of contamination were recorded as part of intrusive investigation.

4.4 Trench Stability

All trenches and inspection pits were recorded as stable.

4.5 Geotechnical and Chemical Analysis

Selected samples were obtained for chemical and geotechnical laboratory testing. The relevant laboratory test results are presented in Appendix C and E.

4.6 Asbestos

No fragments of potentially asbestos based materials were recorded during the intrusive investigation and no fibres were recorded on soil samples screened as part of the laboratory testing.

4.7 Visual and Olfactory Evidence of Contamination

No visual or olfactory evidence of contamination is recorded, although ash, clinker and slag are recorded as part of Made Ground typically underlying some areas of hardstanding.

Occasional very small pockets (typically 10-30mm) of organic material and/or an organic odour was recorded within the natural clays at;

- 3.10m to 3.60m bgl in BH303 (very small pockets and odour);
- 2.00m to 3.90m bgl in BH305 (odour);
- 2.80m to 3.30m bgl in BH313 (odour);
- 1.60m to 1.90m bgl in TP308 (very small pockets);
- 1.50m to 2.30m bgl in TP334 (very small pockets);
- 3.10m to 3.85m bgl in TP601 (very small pockets and odour);
- 2.60m to 4.50m bgl in TP609 (very small pockets); and
- in Made Ground at 0.30m to 0.75m bgl in TP610 (very small pockets).

4.8 Groundwater Levels

Groundwater was encountered during the intrusive investigation and the details of groundwater strikes are presented on the logs included within Appendix B, and are summarised in Table 2 below:

Table 2: Groundwater Strikes

Location ID	Depth Struck (m bgl)	Final Depth (m bgl)	Elevation (m AOD)	Comments
BH312	0.80	0.80	66.91	Seepage in base of Made Ground
BH315	2.50	2.50	68.74	Seepage within firm natural clay
BH604	0.30	0.30	68.93	Seepage in Made Ground beneath concrete surfacing

Location ID	Depth Struck (m bgl)	Final Depth (m bgl)	Elevation (m AOD)	Comments
TP302	0.50	0.50	66.40	Slow Inflow at base of Made Ground
TP308	1.70	1.70	69.97	Seepage within firm natural clay
TP609	1.50	1.50	64.92	Seepage within soft natural clay
	1.60	1.60	64.82	Moderate inflow within soft natural clay

These are interpretated to be perched groundwater and not representative of the wider groundwater regime below the site.

4.9 Ground Gas

As part of the site investigation, the installed boreholes were monitored on 5 occasions over 2 months in order to detect the presence of ground gas. The design of the borehole installations resulted in gas concentrations being recorded from Made Ground or the uppermost horizons of natural ground.

A complete set of ground gas results is included within Appendix G. Below Table 3 summarises the peak carbon dioxide and methane gas results that were recorded on all visits over the 5-visit monitoring period for each of the boreholes.

Table 3: Ground gas monitoring summary

Monitoring Point	Peak Gas Concentration (%)			Steady Gas Concentration (%)		
	CH_4	CO_2	O_2	CH_4	CO_2	O_2
BH303	<0.1	1.6	7.9	<0.1	1.6	7.9
BH305	<0.1	3.4	18.3	<0.1	2.1	18.8
BH306	<0.1	5.3	13.6	<0.1	5.3	13.7
BH312	<0.1	0.3	19.2	<0.1	0.3	19.3
BH315	<0.1	0.7	20.5	<0.1	<0.1	20.7
BH601	<0.1	3.1	17.8	<0.1	3.1	17.8
BH605	<0.1	0.9	19.5	<0.1	0.6	19.5

Gas flows in the same monitoring wells ranged between -3.10 and 0.01 litres per hour.

Barometric pressure during monitoring visits varied between 994mbar and 1014mbar.

Maximum carbon monoxide concentration of 5ppm.

No hydrogen sulphide recorded.

5. Geotechnical Testing

5.1 In-Situ Testing

Standard Penetration Tests (SPT's) were undertaken at regular intervals within the boreholes to provide 'N' values for empirical assessment of strength and density parameters. Detailed results of the SPT tests and blow counts are included on the borehole logs included in Appendix B, as part of geotechnical figures presented in Appendix F and a summary is presented in Table 4 below:

Table 4: Standard penetration test results

Stratum / Geological Origin	Range of SPT 'N' Values	Number of Tests	Range of Corrected SPT N_{60} Values	Comments	Derived Values Range of φ' or cu
Made Ground 7 / Sandy Gravelly Clay	1	1	1	Density: Very low Strength, field description of "Soft".	c_u = <20kPa
Made Ground 8 / Sandy Clayey Gravel	29	1	24	Density: Medium Dense, high cobble content could be creating an unrepresentative value.	34°
Soft CLAY	1 - 13	3	1 - 11	Very low to Medium Strength	c_u = <20kPa – 45kPa
Firm CLAY	5 – 21	14	4 - 26	Low to High Strength, improving with depth	c_u = 20kPa – 105kPa
Stiff CLAY	(8) 15 – 42	19	13 - 44	Medium to Very High Strength, improving with depth. Value in brackets is interpreted to be from a pocket of sand and so is not considered representative.	c_u = 55kPa – 185kPa

5.2 In-Situ Hand Shear Vane Testing

Hand Shear Vane Tests were undertaken within cohesive deposits in trial pits, where possible. The results are summarised below in Table 5 and are presented in full on the logs and records of intrusive investigations included within Appendix B.

Table 5: Hand Shear Vane Testing

Stratum/Geological Origin	Range of Shear Vane Values (kPa)	Number of Tests
Made Ground 7 / Sandy Gravelly Clay	53kPa-130kPa	7
Soft CLAY	39kPa – 45kPa	3
Firm CLAY	44kPa – 102kPa	22
Stiff CLAY	82kPa - 111kPa	4

5.3 Laboratory Testing

Representative soil samples were scheduled for:

- Particle Size Distribution testing;
- Natural moisture content and Atterburg limits;
- pH value and water soluble sulphate (SD1 Suite);
- Triaxial Undrained Shear Strength Tests;
- Oedometer Consolidation Testing; and,
- Compaction Testing

The results are summarised below and presented in Appendix E.

5.4 Particle Size Distribution Testing

1 no. sample of Made Ground underwent particle size distribution testing via wet sieving in accordance with BS EN ISO 17892-4:2016 so as to more accurately determine the nature of the material.

The sample was collected from BH314 at a depth of 0.20-0.60m bgl. The material, described on logs as "Light brown sandy clayey gravel with a high cobble content of angular to subangular limestone. Gravel is angular to subangular fine to coarse limestone, sandstone and brick" was found to be consisting of 31% Cobbles, 49% Gravel, 13% Sand and 7% Silt (including Clay).

5.5 Natural Moisture Content and Plasticity Index

Samples of natural cohesive material were taken for moisture content and plasticity index determinations. The test results are included in Appendix E and are summarised in Table 6 below. The modified plasticity index can be used as an indicator of volume change potential of the soil and is calculated as the plasticity index of the soil multiplied by the fraction of particles less than 425μm.

Table 6: Volume change potential

Stratum / Geological Origin	Range of Plasticity Indices % (Modified)	Volume Change Potential	Range of Natural Moisture Content %
Made Ground 7 / Sandy Gravelly Clay	50	High	33
Soft CLAY	41 – 45	High	27 – 38

Stratum / Geological Origin	Range of Plasticity Indices % (Modified)	Volume Change Potential	Range of Natural Moisture Content %
Firm CLAY	26 - 44	Medium to High	21 – 39
Stiff CLAY	41	High	36

5.6 pH Value and Water Soluble Sulphate (SD1 Suite)

The Aggressive Chemical Environment for Concrete classifications for the soil types identified at the site have been determined in accordance with BRE Special Digest 1:2005 (SD1). SD1 requires that sites are first identified as being in one of four categories based on natural ground / 'Brownfield' conditions and pyrite content. The site has been categorised as: Brownfield - Non-pyrite.

The results of laboratory testing are included in Appendix C and summarised in Table 7 below:

Table 7: Summary of SD1 suite analysis

Stratum / Geological Origin	Characteristic Water-Soluble Sulphate Value (mg/l SO4)	Characteristic pH Value	Total Potential Sulphate (%)
Made Ground 7 / Sandy Gravelly Clay	**510** (101 – 547, 5 no. samples)	**5.53** (5.53 – 8.42, 5 no. samples)	**0.24**
Made Ground 8 / Sandy Clayey Gravel	**400** (1 no. sample)	**10.98** (1 no. sample)	-
CLAY	**1850** (38 – 1945, 9 no. samples)	**4.83** (4.83 – 8.12, 9 no. samples)	**0.09 – 12.3**

As the characteristic value of sulphate is less than 3000mg/l and the characteristic pH is greater than 5.5 within the Made Ground, the concentrations of magnesium, nitrate and chloride are not considered significant in determining the design sulphate class within these lithologies.

The total potential sulphate values and oxidisable sulphate values suggest the presence of pyrite.

5.7 Undrained Triaxial Testing

The shear strength of undisturbed samples of the natural clay soils was determined by quick undrained triaxial tests (single and multi-stage) on single 100mm diameter specimens at a series of confining pressures. The results of these tests are presented in Appendix E, graphically in Appendix F and are summarised in Table 8 below:

Table 8: Triaxial test results

Location ID (Depth m bgl) / Geological Origin	Undrained Shear Strength (kN/m^2)	Initial Moisture Content (%)	Comments
BH303 (3.60-4.05)	87	34.5	Intermediate Failure, High Strength
BH303 (6.00 – 6.45)	141	26.1	Brittle Failure, High Strength
BH304 (2.30 – 2.75)	86	25.2	Brittle Failure, High Strength

BH308 (3.50 – 3.95)	84	31.6	Brittle Failure, High Strength
BH309 (1.20 – 1.65)	37	41.6	Brittle Failure, Low Strength
BH309 (3.20 - 3.65)	102	29.0	Intermediate Failure, High Strength
BH313 (2.30 -2.75)	37	27.8	Intermediate Failure, Low Strength
BH314 (2.40 – 2.85)	86, 85, 83	23.6	Intermediate Failure, High Strength
BH314 (4.50 – 4.95)	112	21.1	Brittle Failure, High Strength
BH315 (3.50 - 3.95)	65	25.7	Brittle Failure, Medium Strength
BH601 (3.40 – 3.85)	67	28.4	Brittle Failure, Medium Strength
BH604 (2.30 – 2.75)	67	27.7	Intermediate Failure, Medium Strength
BH605 (2.30 – 2.75)	80	22.3	Intermediate Failure, High Strength
BH605 (4.50 – 4.95)	49	27.9	Intermediate Failure, Low Strength

The majority of the results for Clays ranged between 65kN/m² and 110kN/m², indicating clays of medium and high strength, which are consistent with the descriptions presented within the exploratory hole logs.

5.8 Oedometer Consolidation Testing

Oedometer consolidation testing was undertaken on 7 samples of cohesive material in accordance with BS EN ISO 17892-5:2017. The results of the consolidation testing are presented alongside their relevant voids ratio/applied pressure ($e/\log_p$) plots in Appendix E and summarised within Table 9 below:

Table 9: Oedometer Consolidation Results

Location ID / Depth (m bgl)	Strata	Initial Water Content (%)	Initial Void Ratio (e_0)	Applied Pressure (kN/m²)	m_v (m²/MN)	c_{v50} (m²/yr)	c_{v90} (m²/yr)	Void Ratio (e)
BH303 (3.60-4.05)	CLAY	30.08	0.844	100-200	0.20	0.31	1.30	0.782
BH304 (2.30-2.75)	CLAY	25.94	0.670	100-200	0.15	0.37	1.50	0.633
BH309 (3.20-3.65)	CLAY	23.03	0.632	100-200	0.14	0.89	3.61	0.577
BH313(2.30-2.75)	CLAY	29.95	0.778	100-200	0.20	1.64	6.98	0.690
BH314(2.40-2.85)	CLAY	25.09	0.660	100-200	0.14	1.92	7.92	0.613
BH601(3.40-3.85)	CLAY	30.32	0.759	100-200	0.16	0.53	2.01	0.714
BH604(2.30-2.75)	CLAY	27.90	0.753	100-200	0.22	2.04	8.58	0.645

Note: Only values from a loading scenario (150kN/m²) similar to the proposed residential end use have been presented here,

5.9 2.5kg Dry Density / Moisture Content Relationship Testing

Dry Density / Moisture Content Relationship testing was undertaken on 1 sample of Made Ground and 2 samples of clay to assess the feasibility of re-compaction of shallow fills at the site. The results of the compaction tests are presented within Appendix E and summarised within Table 10 below.

Table 10: Dry Density / Moisture Content Relationship Results

Stratum / Geological Origin	Location ID & Depth (m bgl)	MDD (Mg/m^3)	Initial Moisture Content %	OMC %	> 95% of MDD?	<5% air voids?
Made Ground 7 / Sand Gravelly Clay	TP309 (0.70 – 1.20)	1.77	31.3%	15.5%	N	Y
CLAY	TP608 (0.50 – 1.00)	2.02	12.0	7.5	Y	Y
	TP610 (1.60 – 2.00)	1.77	28.1	13.0	N	Y

The compaction data has been assessed by comparing the results against criteria commonly used in earthworks to achieve an adequate density for engineered fills. The criteria summarised in the above table indicate whether the samples could achieve in excess of 95% of maximum dry density (a requirement often included in highways specifications) and whether they could be compacted to less than 5% air voids ratio (a requirement applied where raft foundations are to be adopted).

6. Generic Environmental Assessment Criteria

The information requirements for generic quantitative risk assessment will depend on:

- The substance being assessed;
- The receptors being considered;
- The pathways being considered; and
- The complexity of the site.

The outline conceptual model developed for the site has identified 2 potential contaminant linkages. These potential contaminant linkages have been investigated and the results assessed against generic assessment criteria. The generic assessment criteria selected for each potential contaminant linkage are summarised in Table 11 below:

Table 11: Generic assessment criteria

Source	Pathway	Receptor	Generic Assessment Criteria
Contaminated Soils	Direct contact, inhalation	Future users of the proposed Development	Category 4 Screening Levels (C4SLs), LQM/CIEH S4ULs (Copyright Land Quality Management Limited reproduced with permission; Publication Number S4UL3060. All rights reserved), CL:AIRE (2009) PAH assessment using Benzo(a)pyrene surrogate marker assessment
Mobile contaminants associated with historical uses of the Site	Leaching migration through preferential pathways/existing drainage ditches	Adjacent watercourses	Water Regulations Advisory Scheme Information and Guidance Note Category 4 Screening Levels (C4SLs), LQM/CIEH S4ULs (Copyright Land Quality Management Limited reproduced with permission; Publication Number S4UL3060. All rights reserved), CL:AIRE (2009) PAH assessment using Benzo(a)pyrene surrogate marker assessment

The generic assessment criteria used in this report are included in Appendix I.

7. Quantitative Environmental Risk Assessment – Risk Estimation

7.1 Regulatory Context

This assessment has been undertaken in general accordance with the Land Contamination Risk Management (LCRM) regulations (Environment Agency, 2020). The environmental risk assessment includes the following:

- outline Conceptual Model for the Site;
- results of Intrusive Ground Investigation;
- confirmation of Generic Assessment Criteria used to assess risks;
- assessment of results against Generic Assessment Criteria;
- formulation of a new Conceptual Model for the Site;
- identification of potentially unacceptable risks; and
- recommendations for further action.

This report forms a decision record for the contaminant linkages identified, the generic assessment criteria used to assess risks, the unacceptable risks identified and the proposed next steps in relation to the site. The report also provides an explanation of the refinement of the outline conceptual model following the ground investigation, the selection of criteria and assumptions, the evaluation of potential risks and the basis for the decision on what happens next.

The assessment is in respect of the construction of new roadways, with additional footpaths, junctions and proposed housing, garden space and associated soft landscaping.

In order to assess the contamination status of the Site, with respect to the proposed end use, it is necessary to assess whether the Site could potentially be classified as "Contaminated Land", as defined in Part IIA of the Environmental Protection Act 1990 and Contaminated Land Statutory Guidance 2012. This is assessed by the identification and assessment of potential contaminant linkages. The linkage between the potential sources and potential receptors identified needs to be established and evaluated.

To fall within this definition, it is necessary that, as a result of the condition of the land, substances may be present in, on or under the land such that:

a) significant harm is being caused or there is a significant possibility of such harm being caused; or

b) significant pollution of controlled waters is being caused, or there is significant possibility of such pollution being caused.

It should be noted that DEFRA has advised (Ref. Section 4, DEFRA Contaminated Land Statutory Guidance 2012) Local Authorities that land should not be designated as "Contaminated Land" where:

a) the relevant substance(s) are already present in controlled waters;

b) entry into controlled waters of the substance(s) from land has ceased; and

c) it is not likely that that further entry will take place.

These exclusions do not necessarily preclude regulatory action under the Environmental Permitting (England and Wales) Regulations 2016, which make it a criminal offence to cause or knowingly permit a water discharge of any poisonous, noxious or polluting matter to controlled waters. In England and Wales, under The Water Resources Act 1991 (Amendment) (England and Wales) Regulations 2009, a works notice may be served by the regulator requiring appropriate investigation and clean-up.

The potential contaminant linkages identified in Section 6 have been evaluated using the Generic Assessment Criteria described in Appendix I. The results of this evaluation are reported below:

7.2 Risk to Human Health

The following chemical contamination testing was carried out:

Road Surfacing

- 1 no. sample tested for heavy metals
- 2 no. samples tested for speciated PAHs and Phenols

Road Subbase

- 1 no. sample tested for heavy metals and speciated PAHs
- 1 no. sample tested for TPH CWG and BTEX
- 2 no. samples screened for asbestos fibres

Hardstanding Subbase

- 2 no. samples tested for heavy metals
- 3 no. samples tested for speciated PAHs
- 1 no. sample screened for TPHs and BTEX
- 1 no. sample tested for Soil Organic Matter content
- 1 no. sample screened for asbestos fibres

Topsoil

- 4 no. sample screened for heavy metals and speciated PAHs
- 1 no. sample screened for asbestos fibres
- 2 no. samples screened for Soil Organic Matter content

Made Ground

- 1 no. sample tested for heavy metals and speciated PAHs
- 3 no. samples screened for TPHs and BTEX
- 4 no. samples screened for asbestos fibres
- 1 no. sample tested for BRE SD1 Short Suite
- 1 no. sample tested for pH

Natural Ground

- 1 no. sample tested for heavy metals and speciated PAHs
- 2 no. samples screened for BRE SD1 Full Suite
- 1 no. sample screened for asbestos fibres
- 3 no. samples tested for Soil Organic Matter content

Exceedances against a residential end use, in line with the proposed end use for this area of the wider Graven Hill Site, are shown Watermans Drawing "*WIE11386-147-87-300- HZ3 resi exceedances to WIE11386-147-87-304- HZ3 resi exceedances*" included in Appendix D.

When the residential with plant uptake end use is assessed, the following exceedances were recorded:

- BH305 at 0.10m Exceedances of Aromatic C21 – C35. Material is compact subbase.
- BH305 at 1.00m Exceedance of Beryllium. Material is cohesive Made Ground.
- BH313 at 0.30m Exceedances of individual PAH's. Material is compact subbase.
- BH314 at 0.10m Minor exceedance of Beryllium. Material is bituminous surfacing.
- TP304 at 0.10m Exceedances of individual PAH's. Material is bituminous surfacing.
- TP304 at 0.50m Exceedance of Beryllium. Material is ashy Made Ground.
- TP305 at 0.40m Exceedance of individual PAH's. Material is ashy Made Ground.
- TP334 at 1.00m Minor exceedance of Beryllium. Material is cohesive Made Ground.
- RC301 at 0.10m Exceedances of individual PAH's. Material is bituminous surfacing.
- RC301 at 0.50m Exceedance of Beryllium. Material is granular Made Ground.
- CC302 at 0.25m Minor exceedance of Beryllium. Material is gravelly sand.
- SSC302 at 0.10m Exceedance of Zinc. Material is swale sediment.

The existing bituminous materials will be removed and TP334 is in an area of proposed soft landscaping. In addition, the sample from TP334 is from 1.00m depth and hence is not considered a risk to future site users. The samples from TP304, TP305, SSC302 and CC302 are beneath proposed residential properties however ground levels are to be raised in this area by circa 1m, hence the material is not considered to represent a risk to future site users. <u>Hence, no remedial action is considered necessary in respect of recorded contamination.</u>

The whole LTA2 site area is to be the subject of a cut and fill operation and hence it is possible that some material won from this area of the Site could be used as engineered fill and as such the results from scheduled chemical analysis have also been evaluated against a commercial generic assessment criteria (GAC). When the results of chemical analysis were compared against a commercial GAC, no exceedances were recorded.

No asbestos fibres have been recorded in soil samples from the Home Zone 3 area, however, isolated occurrences of asbestos have been recorded across the wider site. When isolated detections are recorded on a site, Waterman notes that drawing conclusions regarding the distribution and assessing the associated risks can be difficult, due to the following issues:

- Asbestos does not always conform to a normal spacial distribution in comparison with chemical contaminants where concentrations generally diminish with distance from a central source area;
- In standard soil sampling, asbestos is either present or not in a given soil sample; however, non-detection in one location does not preclude it from being in a location immediately adjacent;
- While statistical assessment is suitable for a population of quantified contamination results, it is inadvisable to apply statistical assessment to a dataset of asbestos in soil results, again due to its tendency to not follow a normal spacial distribution as discussed above; and

* Contemporary guidance is based on the premise that there is no "safe" exposure level, as any exposure would increase the receptor's lifetime cancer risk. Consequently, a more conservative risk assessment approach is required.

Any materials that are to be imported onto the Home Zone 3 site will need to be proven clean and acceptable for the future end use.

7.3 Risk to Controlled Waters

7 No. samples of sediment were taken from existing surface swales in the site area. At the time of sampling, the surface swales were dry. No exceedances were recorded when the results of chemical analysis were compared against residential end-use generic assessment criteria (GAC).

7.4 Risk to Construction Workers

Construction workers have a much shorter exposure time and as such the screening criteria used to assess the long-term exposure risk to end-users are considered unnecessarily conservative, particularly with due consideration of standard best practice health and safety measures adopted on construction sites that will minimise day-to-day exposure. The slightly elevated concentrations of contaminants recorded in site soils are therefore considered to represent a very low risk to construction workers and is not considered further in this assessment.

Construction workers shall adhere to good practices for maintaining appropriate hygiene during works. Provision of appropriate facilities for good welfare must be provided. Furthermore, personal protective equipment (PPE) should be used to protect from contact with contaminated soils.

7.5 Ground Gas

Data obtained from Public Health England (ukradon.org) indicates that the Site is not anticipated to be at risk from radon.

Ground Gas Characterization and Hazard Assessment

An empirical, semi-quantitative approach has been used to characterize the ground gas risk for the site. This approach derives an appropriate gas screening value (GSV), or several GSVs if the site is zoned. The GSV is then used to select an appropriate Characteristic Situation (CS) for design and selection of the choice of protective measures.

The borehole flow rate Q_{hg} (in l/h) has been calculated for each monitoring location and each monitoring event (for each hazardous gas) using the following equation:

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

Where: -

Q_{hg} is the borehole hazardous gas flow rate
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 % volume/volume).

Calculation of borehole hazardous gas flow rate – *Qhg*

As the maximum positive recorded flow rate is <0.01l/hr, indicating this is below the monitoring limit, then all hazardous gas flow rates (Qhg) will be calculated as **0.01** as a matter of best practice**.**

As the dataset is considered representative, comprehensive and captures temporal and atmospheric variation, the GSV is assessed using the maximum Q_{hg} measured for all the monitoring events, i.e. **0.01l/hr.** Notwithstanding this designation, a worst case check indicates that when the plausible worst case conditions are calculated for each stratum or zone, a greater hazard is not considered likely hence the above GSV should be adopted to select protective to reflect worst case conditions.

On the basis of the worst case methane and carbon dioxide concentrations and the highest gas flow readings, worst case GSV's of 0.0001l/hr for methane and 0.0053l/hr for carbon dioxide are calculated.

The calculated GSVs are consistent with Characteristic Situation 1, Very Low Hazard Potential. A single reading of carbon dioxide, marginally above the screening value of 5% has been recorded, whilst all other reading are significantly below this level and no flow has been recorded in any holes on the site. Hence, when considering all available information, the **Characteristic Situation 1** classification is considered appropriate and hence no ground gas protection measures are considered necessary.

8. Geotechnical Assessment

8.1 Proposed Development

This assessment has been prepared on the understanding that the site is to be developed with the introduction of new highways, footpaths, cycleways, residential properties, carparking, private gardens and associated soft landscaping. Much of the site area will be raised by the importation of clean soils from elsewhere in the development site. If development proposals change, it may be necessary to revise the conclusions and recommendations made in this report and Waterman IE should be contacted to provide further advice.

8.2 Characteristic Values

Based upon the site investigation data and a review of the derived values summarised in Section 5, characteristic values can be assigned to each strata. EC7 defines the characteristic value of a soil or rock as a cautious estimate of the value affecting the occurrence of the limit state. The characteristic values to be used in design are highlighted in Table 12 below:

Table 12: Characteristic values for geotechnical design

Stratum / Geological Origin	Strength / Density Descriptor	Range of Derived Values	Undrained Strength (c_u - kPa)	Angle of Shearing Resistance (φ' – deg)
Made Ground 7 / Sandy Gravelly Clay	Typically described as “Soft” although stiffening with depth	N_{60} = 1 NMC @ 0.70 – 1.50m bgl = 23% - 33% OMC = 15% PI = 50% MDD = 1.77Mg/m^3	<20kPa	
Made Ground 8 / Sandy Clayey Gravel	Medium Dense, high cobble content	N_{60} = 24		34
CLAY	Soft	c_u = <20kPa – 45kPa PI = 42%	30kPa	
	Firm	c_u = 44kPa – 105kPa NMC @ 0.00m - 1.50m bgl = 21 – 24% NMC @ 1.50m – 3.00m bgl = 23 - 33 PI = 26 – 44% m_v – 0.16 – 0.22 m^2/MN	50kPa	
	Stiff to Very Stiff	c_u = 82kPa – 111kPa NMC @ 1.00m bgl = 16% PI = 41% m_v – 0.14 – 0.20 m^2/MN	75kPa	

8.2.1 Shrinkability / Volume Change Potential

Oxford Clay has been shown to have medium to high plasticity and volume change potential. It is recommended that a Plasticity Index of 44% be adopted for the Oxford Clay. Considerable care should be taken when accounting for differential settlement across the course of roadways and individual plots in this area of the Site. Oxford Clays underlying former buildings are likely to heave to a significant extent, whereas those underlying open ground will be anticipated to settle under loading from the proposed structures.

8.2.2 Design Class for Concrete

Based on the characteristic values derived from SD1 testing, the Design Sulphate (DS) and Aggressive Chemical Environment for Concrete (ACEC) classifications are considered to be:

- Concrete in contact with Made Ground: DS2 AC1s
- Concrete in contact with Oxford Clay: DS4 AC3s

8.2.3 Shallow Foundations

Made Ground is not considered to represent a suitable bearing strata and hence foundations should be extended through these materials and placed on adequate bearing strata at deeper levels. Foundations should be placed on uniform founding strata to avoid differential settlement.

The descriptions and results of laboratory and in-situ testing suggest that trench fill concrete foundations could be placed on the firm or stiff Oxford Clays at relatively shallow depths (i.e. generally less than 2.5m below existing ground level).

Assuming 0.6m trench fill foundations founded on the firm clays (shear strength in excess of 50kN/m^2), ground bearing resistance calculations have been undertaken using Terzaghi's bearing capacity equation in accordance with Eurocode 7 Design Approach 1, Combination 2 and indicate a Ground Bearing Resistance of 212kN/m^2 (which equates to an approximate allowable bearing capacity in excess of 95 kN/m^2 at 1.50m depth to superseded British Standards). This would be increased at deeper foundation depths and where stiff clay is exposed at founding level. It has also been assumed that a maximum total settlement of 25mm would be acceptable within the serviceability of the design.

The design bearing resistance quoted above has been estimated in accordance with EC7, Design Approach 1. Bearing resistance and settlement are functions of shape and depth of foundation, and the magnitudes of inclined, static and variable loads and these should be checked as part of detailed geotechnical design.

Identification of the appropriate founding stratum on site must be undertaken by an experienced engineer. If necessary, Waterman should be contacted to provide further advice.

8.2.4 Piled Foundations

In view of the proposed development layout and levels, widespread tree removal, particularly in the north of the Home Zones 3 Site, and the raising of site levels in places by over 1m (and up to 2.5m in places), piled foundations are considered likely to be the most appropriate solution for certain parts of the Home Zone 3 area. Many of the trees in this area of the Site are mature ash and hawthorn, meaning that their removal has the potential to cause significant localised effects on foundation solutions.

It is recommended that the advice of a specialist piling contractor should be obtained to confirm the suitability of piling and the most appropriate pile type.

The final design of the piles will be the responsibility of the piling contractor. The carrying capacity of the actual pile groups will in part depend on the number, type and size of pile chosen by the contractor and the quality of workmanship.

The piles should be designed based on the requirements of Eurocode 7 and guidance such as CIRIA Report 181, Piled Foundations in Weak Rock.

The influence of the overlying Made Ground should be ignored in the pile capacity calculations. During detailed pile design the choice of factors of safety should ensure that appropriate safe working loads and settlement tolerances are met.

Subject to any piling trials, an acceptable percentage of piles should be load tested to at least twice working load. All piles should be integrity tested.

Consideration should be given to the re-use of pile arisings if bored piles are used. It may be possible to re-use pile arisings subject to risk assessment; however, certainty of use and volume should be confirmed in accordance with the requirements of CLAIRE guidance.

Construction plant should be provided with an adequate working platform in line with the requirements of BRE report, "BR 470: Working Platforms for Tracked Plant". Again, further advice should be sought from the temporary works designer.

8.2.5 Earthworks / Pavement Design

The results of compaction testing undertaken on samples of Made Ground 7 (Sandy Gravelly Clay) and Oxford Cays indicate that, in their current form (moisture content):

- Made Ground 7 could be recompacted to achieve <5% air voids but not >95% of MDD ;
- Oxford Clays could be recompacted to achieve <5% air voids but not >95% of MDD although where clays have a significantly lower moisture content, the >95% of MDD can be achieved.

Based upon the results obtained, selected materials could be used as an engineered fill, subject to other suitability considerations. It should be noted however that suitability for compaction is highly dependent on the initial moisture content of the material to be compacted and that there are significant variations in moisture content recorded at the site.

8.2.6 Floor Slabs

It is recommended that suspended floor slabs should be adopted due to the localised potential risk of heave of the natural clay soils and the depth of Made Ground/areas where ground levels are to be raised.

8.2.7 Groundwater / Stability of Excavations

Comments relating to the stability of excavations (i.e. trial pits) and groundwater seepages are included in the logs in Appendix B. The groundwater level measured during fieldwork was in the range 0.30m (68.93mOD) to 2.50m (68.74mOD) below ground level. However, these water strikes are considered to be perched water and not representative of the wider groundwater regime at the Graven Hill Site.

Based on observations made during fieldwork, shallow excavations (<1.2m) are likely to be stable in the short term. Although if significant depths of Granular Made Ground is encountered there is potential for pit collapse.

Consideration should be given to the re-use of arisings from foundation trenches / drainage runs etc. If in a localised area where contamination has been encountered, it may be possible to reuse foundation arisings subject to risk assessment; however, certainty of use and volume should be confirmed in accordance with the requirements of CLAIRE guidance.

In line with BS6031, all excavations should be examined daily by a competent person to ensure that they remain safe. Where the sides cannot be sloped back to a safe angle, as approved by a competent and experienced person, their continued stability should not be taken for granted. Vertical or steep faces should be provided with support unless instructed otherwise by a competent person.

9. Conclusions

9.1 Environmental Assessment

9.1.1 Ground Contamination

When test results were screened against a residential with plant uptake end use, localised areas of contamination were identified, generally within macadam and shallow Made Ground, typically with only minor exceedances of the relevant screening values.

The existing bituminous materials will be removed and the exceedance within TP334 is from 1.00m depth in an area of proposed soft landscaping and hence is not considered a risk to future site users.

The samples from TP304, TP305, SSC302 and CC302 are beneath proposed residential properties however ground levels are to be raised in this area by circa 1m, hence the material is not considered to represent a risk to future site users if left in its current location.

No asbestos fibres have been recorded in soil samples from the Home Zone 3 area.

Hence, no remedial action is considered necessary in respect of recorded contamination.

9.1.2 Ground Gas

On the basis of the worst case methane and carbon dioxide concentrations and the highest gas flow readings, worst case GSV's of 0.0001l/hr for methane and 0.0053l/hr for carbon dioxide are calculated. These values are consistent with Characteristic Situation 1, Very Low Hazard Potential.

A single reading of carbon dioxide, marginally above the screening value of 5% has been recorded, whilst all other reading are significantly below this level and no flow has been recorded in any holes on the site. Hence, when considering all available information, the **Characteristic Situation 1** classification is considered appropriate and hence no ground gas protection measures are considered necessary.

9.2 Geotechnical Assessment

9.2.1 Shallow Foundations

Made Ground is not considered to represent a suitable bearing strata and hence foundations should be extended through these materials and placed on adequate bearing strata at deeper levels. Foundations should be placed on uniform founding strata to avoid differential settlement.

The descriptions and results of laboratory and in-situ testing suggest that trench fill concrete foundations could be placed on the firm or stiff Oxford Clays at relatively shallow depths (i.e. generally less than 2.5m below existing ground level).

Assuming 0.6m trench fill foundations founded on the firm clays (shear strength in excess of $50kN/m^2$), ground bearing resistance calculations have been undertaken using Terzaghi's bearing capacity equation in accordance with Eurocode 7 Design Approach 1, Combination 2 and indicate a Ground Bearing Resistance of $212kN/m^2$ (which equates to an approximate allowable bearing capacity in excess of 95 kN/m^2 at 1.50m depth to superseded British Standards). This would be increased at deeper foundation depths and where stiff clay is exposed at founding level. It has also been assumed that a maximum total settlement of 25mm would be acceptable within the serviceability of the design.

The design bearing resistance quoted above has been estimated in accordance with EC7, Design Approach 1. Bearing resistance and settlement are functions of shape and depth of foundation, and the magnitudes of inclined, static and variable loads and these should be checked as part of detailed geotechnical design.

9.2.2 Piled Foundations

In view of the proposed development layout and levels, widespread tree removal, particularly in the north of the Home Zones 3 Site, and the raising of site levels in places by over 1m (and up to 2.5m in places), piled foundations are considered likely to be the most appropriate solution for certain parts of the Home Zone 3 area. Many of the trees in this area of the Site are mature ash and hawthorn, meaning that their removal has the potential to cause significant localised effects on foundation solutions.

It is recommended that the advice of a specialist piling contractor should be obtained to confirm the suitability of piling and the most appropriate pile type.

The final design of the piles will be the responsibility of the piling contractor. The carrying capacity of the actual pile groups will in part depend on the number, type and size of pile chosen by the contractor and the quality of workmanship.

9.2.3 Floor Slabs

It is recommended that suspended floor slabs should be adopted due to the localised potential risk of heave of the natural clay soils and the depth of Made Ground/areas where ground levels are to be raised.

9.2.4 Buried Concrete

Based on the characteristic values derived from SD1 testing, the Design Sulphate (DS) and Aggressive Chemical Environment for Concrete (ACEC) classifications are considered to be:

- Concrete in contact with Made Ground: DS2 AC1s
- Concrete in contact with Oxford Clay: DS4 AC3s

APPENDICES

Appendix A Site Plans

- **Site Redline Boundary (WIE11386-3a & 3b-07-001 - Home Zones 3 Red Line Boundary-Site Plan)**
- **Proposed Development Plan (021-050-102 revJ Overall Masterplan)**
- **Ground Investigation Hole Location Plan (WIE11386-147-87-100 to 104 – Home Zone 3 GI Location Plan)**

1:2500	0		50m	100m
1:1250	0		25m	50m
1:500	0	5m	10m	20m
1:200	0	2m	4m	8m
1:100	0	1m	2m	4m
1:50	0	0.5m	1m	2m

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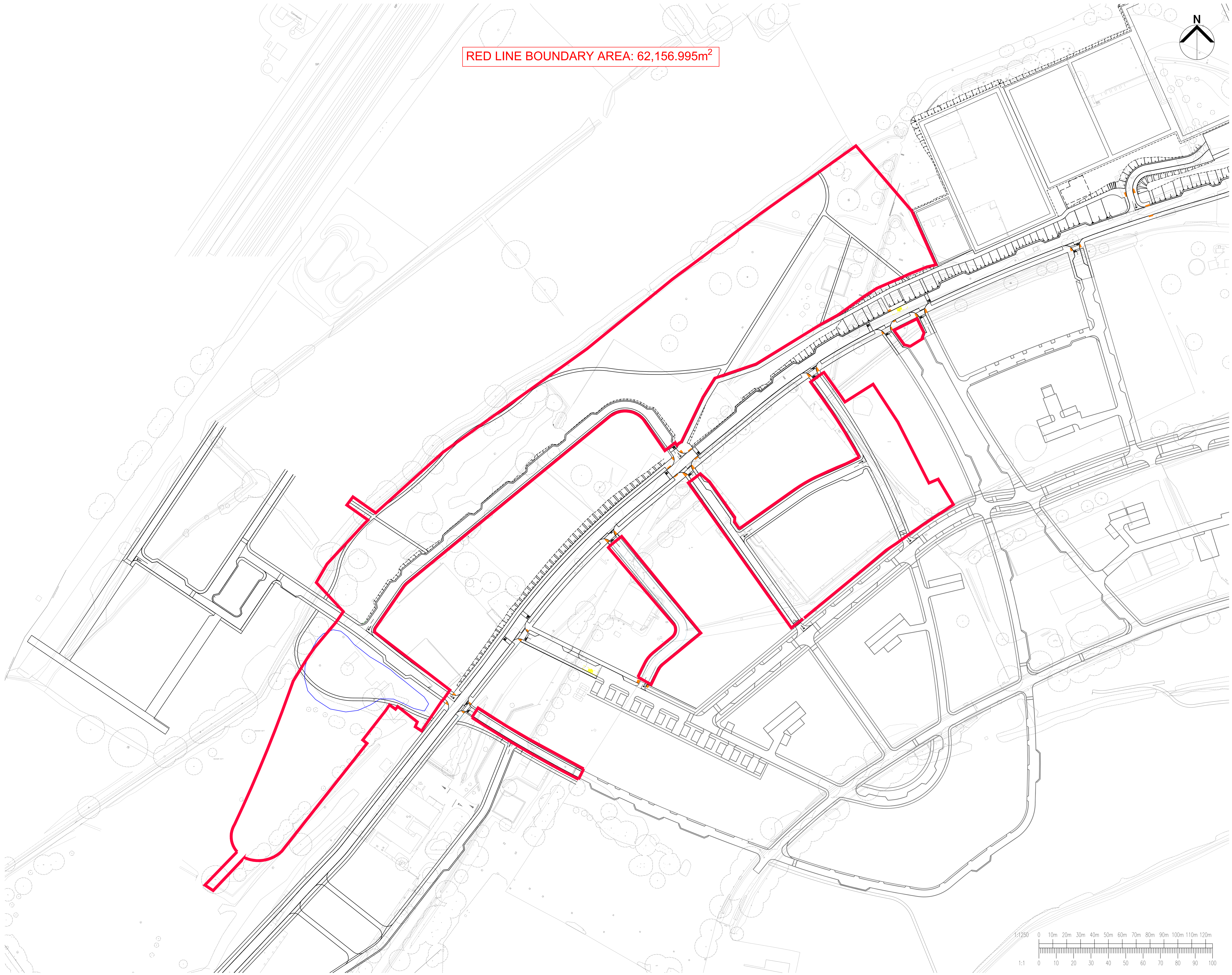
client: Graven Hill Village Development Company Ltd

site: Graven Hill, Bicester

drawing title: Overall Masterplan NTS

drafted by: LMR	checked: LMR
scale: NTS@A1	date: May 2021
drawing number: 021 - 050 - 102	revision: J



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2. ALL DIMENSIONS AND LEVELS ARE TO BE CHECKED ON SITE BY THE CONTRACTOR PRIOR TO PREPARING ANY WORKING DRAWINGS OR COMMENCING ON SITE.
3. THE CONTRACTOR MUST ENSURE AND WILL BE HELD RESPONSIBLE FOR THE OVERALL STABILITY OF THE BUILDING/STRUCTURE/EXCAVATION AT ALL STAGES OF THE WORK.
4. ALL WORK BY THE CONTRACTOR MUST BE CARRIED OUT IN SUCH A WAY THAT ALL REQUIREMENTS UNDER THE HEALTH AND SAFETY AT WORK ACT ARE SATISFIED.
5. ALL WORK IS TO BE CARRIED OUT IN COMPLIANCE WITH THE REQUIREMENTS OF THE RELEVANT STATUTORY AUTHORITIES AND REGULATIONS.
6. ROAD LAYOUT AND HIGHWAY WORKS SHALL BE IN ACCORDANCE WITH DMRB AND OXFORD COUNTY COUNCIL (OCC) STANDARDS.

Rev	Date	Description	By
A01	21.01.21	ISSUE	DP

Amendments

Project
GRAVEN HILL, BICESTER

Title
PHASE 3A AND 3B
RED LINE BOUNDARY

Client
Graven Hill Village Development Company Limited

5th Floor One Cornwall Street Birmingham B3 2DX
t 0121 212 7700
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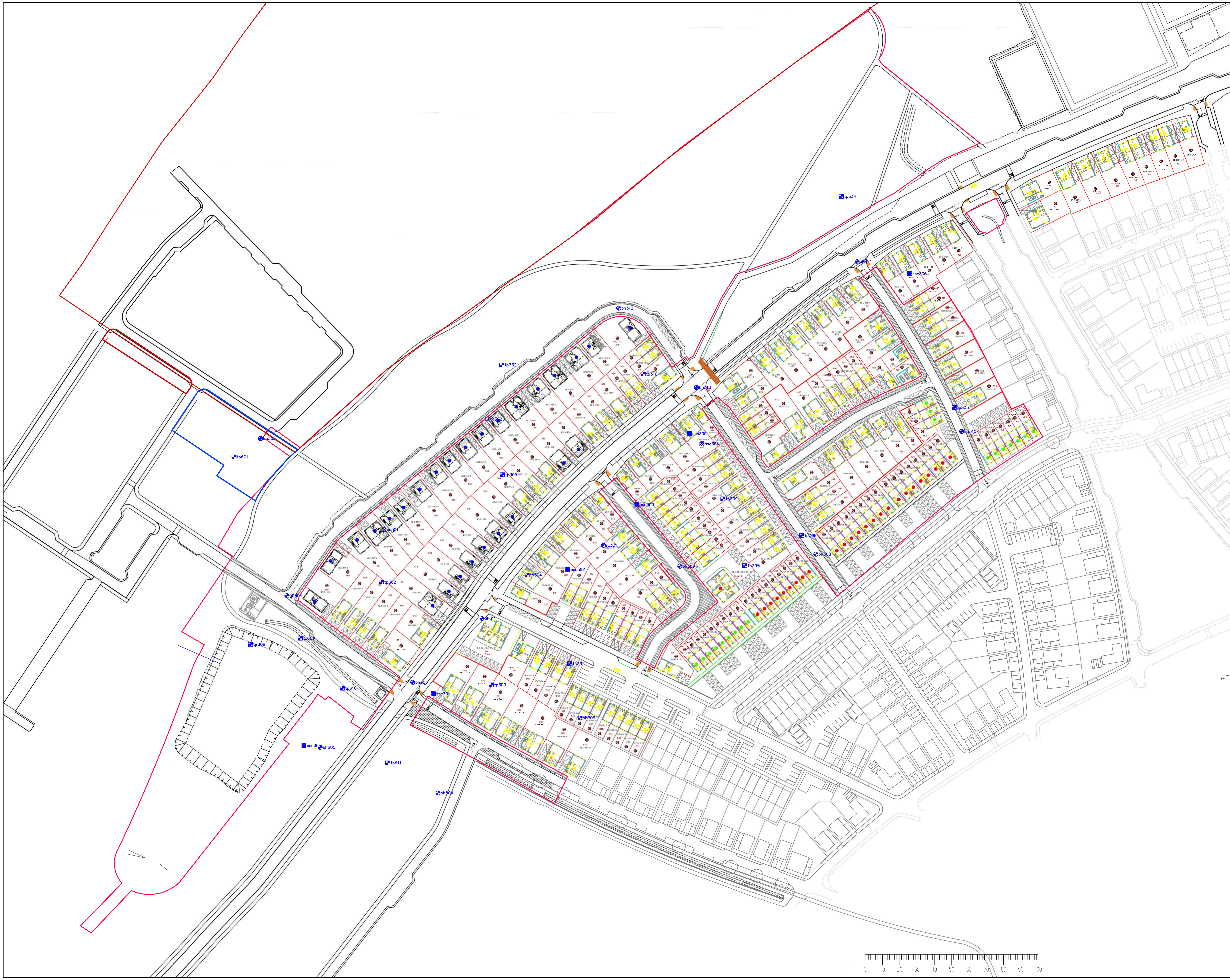
Drawing Status
PRELIMINARY

Designed by	ST	Checked by	DP	Project No WIE11386
Drawn by	ST	Date	NOV 2020	
Scales @ A1 work to figured dimensions only	1:1250			Computer File No WIE11386-3a & 3b-07-001 - Phase 3a & 3b Red Line Boundary.dwg

Publisher	Zone	Category	Number	Revision
WIE	3A&B	07	001	A01

File Path \\s-bm\WIEL\Projects\WIE11386_GH0_LTA 2\#W0147_ROADS_OUTLINE_LTA2_Got PO17_CAD\07_Legal\



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Any discrepancies should be referred to the Engineer prior to work being put in hand.

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5. ALL WORK IS TO BE CARRIED OUT IN COMPLIANCE WITH THE REQUIREMENTS OF THE RELEVANT STATUTORY AUTHORITIES AND REGULATIONS.

bh301 CABLE PERCUSSIVE BOREHOLE LOCATIONS
tp601 TRIAL PIT LOCATIONS
cc302 CONCRETE CORE LOCATIONS
ssc303 SWALE SEDIMENT CONTAMINATION LOCATIONS

Rev	Date	Description	By
A02	02.08.22	MASTERPLAN UPDATED TO LMR REV CC	TB
A01	03.11.21	GI LOCATIONS ADDED	TB

Amendments

Project
GRAVEN HILL, BICESTER

Title
LAND TRANSFER AREA 2
HOME ZONES 3
GI LOCATION PLAN
SHEET 1 OF 5

Client
Graven Hill Village Development Company Limited

Waterman

5th Floor, 1 Cornwall Street, Birmingham, B3 2DX
0121 212 7700
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Drawing Status
PRELIMINARY

Designed by	TB	Checked by	PE	Project No	WIE11386
Drawn by	TB	Date	03.11.21		
Scales @ A1				Computer File No	
work to figured dimensions only				WIE11386-HZ3-87-100 - GI Location Plan A02.dwg	

Publisher	Zone	Category	Number	Revision
WIE	HZ3	87	100	A02

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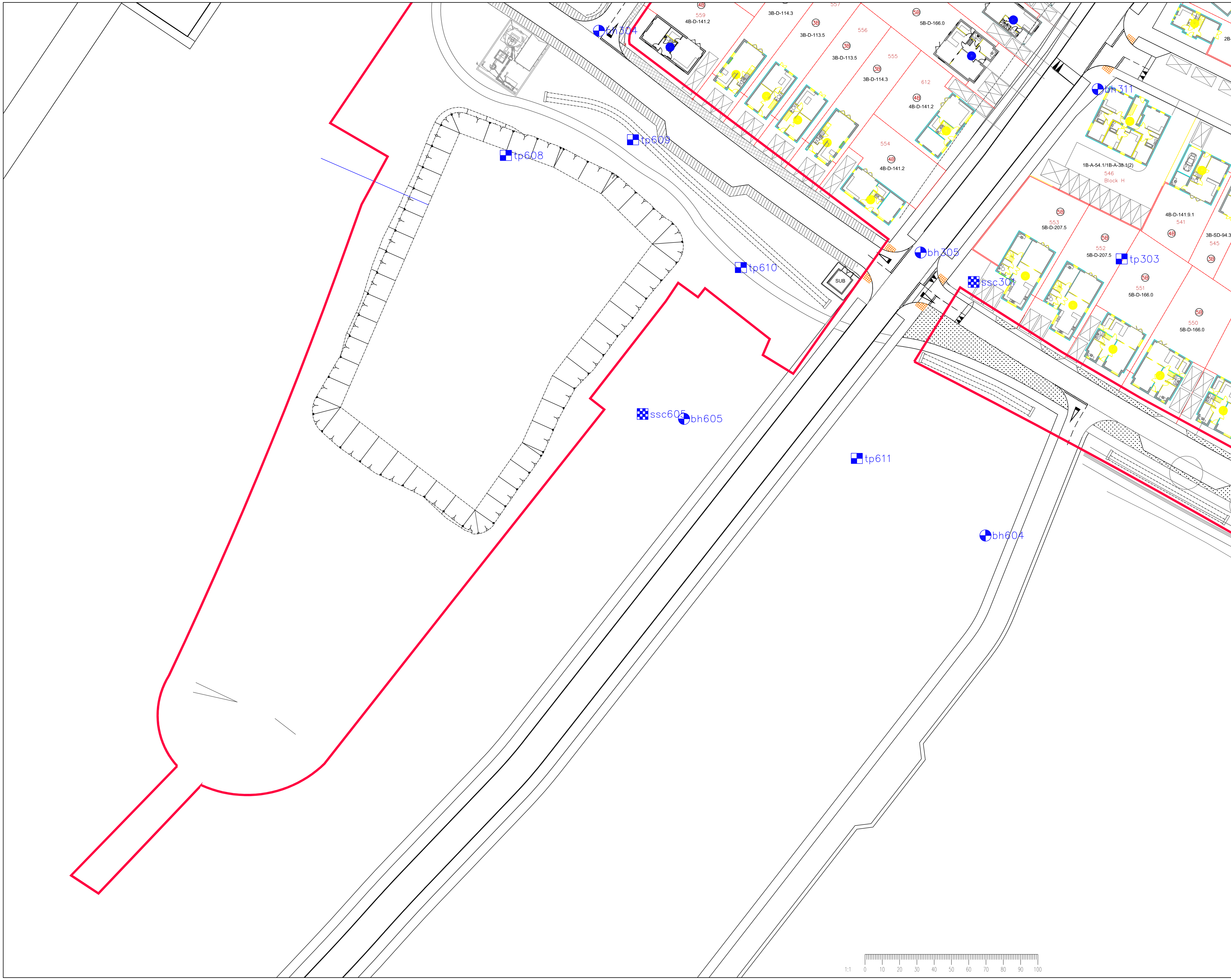
File Path N:\Projects\WIE11386_GH0_LTA 2\WIO147_ROADS_OUTLINE_LTA2_Got POI7_CAD87_GI\Phase 3 & 3B\



This drawing should not be scaled. Dimensions to be verified on site.
Any discrepancies should be referred to the Engineer prior to work being put in hand.

GENERAL NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL ENGINEER'S, ARCHITECT'S OR OTHER RELEVANT DRAWINGS AND SPECIFICATIONS.
2. ALL DIMENSIONS AND LEVELS ARE TO BE CHECKED ON SITE BY THE CONTRACTOR PRIOR TO PREPARING ANY WORKING DRAWINGS OR COMMENCING ON SITE.
3. THE CONTRACTOR MUST ENSURE AND WILL BE HELD RESPONSIBLE FOR THE OVERALL STABILITY OF THE BUILDING/STRUCTURE/EXCAVATION AT ALL STAGES OF THE WORK.
4. ALL WORK BY THE CONTRACTOR MUST BE CARRIED OUT IN SUCH A WAY THAT ALL REQUIREMENTS UNDER THE HEALTH AND SAFETY AT WORK ACT ARE SATISFIED.
5. ALL WORK IS TO BE CARRIED OUT IN COMPLIANCE WITH THE REQUIREMENTS OF THE RELEVANT STATUTORY AUTHORITIES AND REGULATIONS.

bh301	CABLE PERCUSSIVE BOREHOLE LOCATIONS
tp601	TRIAL PIT LOCATIONS
cc302	CONCRETE CORE LOCATIONS
ssc303	SWALE SEDIMENT CONTAMINATION LOCATIONS

Rev	Date	Description	By
A02	02.08.22	MASTERPLAN UPDATED TO LMR REV CC	TB
A01	03.11.21	GI LOCATIONS ADDED	TB

Amendments

Project
GRAVEN HILL, BICESTER

Title
LAND TRANSFER AREA 2 HOME ZONE 3 GI LOCATION PLAN SHEET 2 OF 5

Client
Graven Hill Village Development Company Limited

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Drawing Status
PRELIMINARY

Designed by	TB	Checked by	PE	Project No	WIE11386
Drawn by	TB	Date	03.11.21	Computer File No	WIE11386-HZ3-87-100 - GI Location Plan A02.dwg
Scales @ A1 work to figured dimensions only					

Publisher	Zone	Category	Number	Revision
WIE	HZ3	87	101	A02

File Path N:\Projects\WIE11386_GHI0_LTA 2\WIO147_ROADS_OUTLINE_LTA2_Got POI7_CAD\87_GI\Phase 3 & 3B\