APPLiED GEOLOGY

REPORT ON
GROUND INVESTIGATION
AT
HOWES LANE,
BICESTER

REPORT STATUS SHEET

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EXECUTIVE SUMMARY

Proposed Development	Development of the existing fields for commercial and residential end use with associated landscaping/gardens, swales, access roads and infrastructure.
Site Description	The site is located off Howes Lane, approximately 1.75km west of Bicester town centre and covers an area of c.20ha comprising three fields. Adjacent agricultural fields bound the site to the north and west, Howes Lane to the east and Middleton Stoney Road to the south.
Site History	The site has comprised undeveloped fields since 1875. A drainage ditch/stream runs along the northeastern boundary flowing to the south/southeast. A quarry is indicated off the southeast corner c.25m away (1898-1966). By 1967 much of the surrounding areas have been developed and further residential development to within 100m east of site has occurred by 1976. The site itself remains three undeveloped fields to the present day.
Anticipated Geology	Published information indicates that the site is underlain by solid geology of the Cornbrash Formation with no overlying drift deposits. Made Ground is not anticipated.
Other Pertinent Desk Study Data	No surface water abstractions within 500m of the site; No current or historical records of landfills sites within 250m of the site; No recorded pollution incidents within 250m of the site; No recorded petrol/fuel sites identified within 250m; Cornbrash Formation is designated as Secondary A Aquifer; Site is not within a Source Protection Zone, no potable water abstractions within 1km; The site is outside of any floodplain; Site is not in a radon affected area, with <1% of homes above the Action Level. No radon protection measures are therefore considered necessary for new properties; No ecologically sensitive areas within 500m of the site.
Scope of Investigation	Fifty-nine machine excavated trial pits, six rotary cored boreholes, groundwater monitoring and sampling and chemical and geotechnical laboratory testing of soils.
Ground Conditions	Made Ground was not encountered. Agricultural Topsoil was encountered at surface across the site to depths of generally between 0.25m to 0.35m bgl, locally up to 0.70m bgl. Cornbrash Formation was recorded beneath the Topsoil, predominantly comprising an initial shallow limestone overlying clay, underlain by a deeper stronger limestone band. Groundwater seepages were recorded in six of the trial pits at depths of c2-2.5m bgl, deeper groundwater was recorded in four of the six boreholes during drilling at depths of between 7.3m and 9.5m bgl. There was one instance of groundwater strike rising above ground level indicating sub-artesian pressure in R4. During subsequent monitoring groundwater was recorded at generally between 1.6m and 2.6m bgl in all six of the standpipes. From a study of the reduced groundwater levels a flow direction towards the east can be inferred.
Geo-environmental Assessment	Marginal elevated concentrations of arsenic were recorded at four locations in the natural Cornbrash Formation, however since these are all from the natural Cornbrash Formation and there is no credible on-site source, these are considered to be natural background levels resident in the local geology. One concentration of sulphate from the groundwater samples slightly exceeded the UK Drinking Water Standard (DWS), however, UK DWS are not considered wholly relevant to the hydrogeological regime under the site and the marginal nature of the exceedance suggests the concentration is not of a concern to Controlled Water receptors. All other test results fall either below the relevant screening value or the laboratory limit of detection. The asbestos screening tests did not detect the presence of any (ACM). WAC testing on the natural Cornbrash Formation indicates compliance with inert criteria. Site is essentially a greenfield site and no sources of contamination were identified.
Geotechnical Assessment	Pad or trench fill foundations are considered feasible bearing within the stiff clay of the Cornbrash Formation and significant groundwater ingress is not expected in excavations. Based on a review of the existing topography and the proposed commercial unit's layouts a maximum cut in the order of c.1m from the northwest area and a corresponding maximum fill of c.1m in the centre-east of the area will be required. It will be necessary to produce a detailed specification for the earthworks detailing methods, controls and verification testing with target end performance criteria. Ground bearing floor slabs should be feasible for the commercial units provided any desiccated materials are removed and a suitably designed granular mattress is constructed. Floor slabs for the proposed houses will need to be suspended in proximity to trees or hedges or where Made Ground exceeds 0.6m depth. Ground conditions comprise impermeable/ very low permeability soils and soakaways are not considered feasible. Sulphate resisting concrete in line with DS-2 AC-2 will be required where in contact with the Cornbrash Formation. Further testing may allow this class to be downgraded to DS-1.

1.0 INTRODUCTION

1.1 Objectives and Scope of Investigation

An area of land off Howes Lane, Bicester (the site) is being considered for redevelopment by Albion Land Two Limited (the Client). The proposals for the site comprise the development of the existing fields for commercial and residential end use with associated landscaping/gardens, swales, access roads and infrastructure.

Applied Geology was appointed by Bailey Johnson Hayes consulting engineer to the Client, to undertake a desk study/Phase I assessment and preliminary Phase II ground investigation in order to:

- assess the potential for hazardous substances or conditions to exist at the site that might warrant mitigation or remediation appropriate to the intended end use proposed by the Client.
- establish geological conditions and geotechnical parameters to assist in the safe and economic engineering design of the proposed development.

The terms of reference/brief for the works were mutually developed between Bailey Johnson Hayes and Applied Geology and are outlined in our proposal and estimate reference AG18-3356-04 dated 30th May 2018.

The scope of works undertaken by Applied Geology comprised:

- A site inspection and walkover survey,
- A review of the following desk study sources:
  - GroundSure – GeoInsight & EnviroInsight environmental databases.
  - GroundSure – MapInsight historical maps.
  - British Geological Survey (BGS) - published information & on-line borehole database.
  - Multi-Agency Geographical Information for the Countryside (MAGIC) on-line database.
  - Environment Agency Web Site.
- Ground investigation together with sampling, monitoring and a programme of laboratory testing.
- Assessment and reporting of the results of the works.

Underground service plans for the site were obtained by Applied Geology on 4th July 2018. A topographic survey drawing by Blue Plan drawing No. 1553, dated 12th February 2012, was provided by Bailey Johnson Hayes.

1.2 Report Layout

This report presents a brief description of the site, the desk study data and the factual results of the intrusive investigations carried out. An interpretation of the ground conditions and a discussion/assessment of the findings is presented in the later report text sections. The main text of the report has been produced in a concise format, including the use of data tables to summarise key information where possible. The report should be read in conjunction with the general procedures detailed in Appendix

F and General Notes given at the end of the main text, which provide details of investigation techniques, assessment methodology and standards, health & safety and limitations and exceptions of the report. Drawings and factual data including exploratory hole records, laboratory testing results and desk study records are presented in the other Appendices.

2.0 SITE DESCRIPTION AND PROPOSALS

2.1 Site Description

The site is located on the western side of Howes Lane, Bicester, approximately 1.75km west of Bicester town centre. The Ordnance Survey grid reference for the centre of the site is 456381 223088 as shown on the Site Location Plan in Appendix A.

The site is approximately 'L' shaped with approximate maximum extents of 300m by 590m and covers a total area of c.20ha. The topographic survey indicates a consistent gentle slope to the east with a maximum difference in elevation of approximately 4.8m from c. 86.5mOD to 82mOD. The topographic survey forms the base of the Exploratory Hole Location Plan, Drawing No AG2873-18-02 Rev3, in Appendix A.

A site inspection/walkover was undertaken by Applied Geology on 10th August 2018. Access to the site was gained off Howes Lane, Bicester. At the time of the inspection, the site comprised three rectangular fields, all oriented approximately north-south and each comprising roughly one third of the total site area. Two of the fields formed south and west of the site and the third formed the north of the site. Both the northern and western fields were occupied by c.1-2m tall maize crops whilst the southern field was cleared of the crops. The topographic survey indicated a pond in the field adjacent to the northwest corner of the western field and a stream / drain along the northern boundary of the northern field, however due to the dense foliage these were not observed.

The site was bound to the south and east by Middleton Stoney Road (B4030) and Howes Lane respectively and to the north and west by agricultural fields. The site entrance was an opening in the hedge off Howes Lane.

There were semi mature trees along the margins of the three fields.

2.2 Site Proposals

The proposals for the site comprise a mixed commercial and residential development with associated roads and infrastructure. The outline proposals are shown on a series of drawings by Bailey Johnson Hayes dated November 2018 and comprising the following:

- 'Phase I External Works Plan' ref. S1209-PH1-03E;
- 'Phase I Site Sections' ref. S1209-PH1-04E;
- 'Phase I Swale Details' ref. S1209-Ph1 – 05D;
- 'Phase I Residential Site Section' ref. S1209-PH1-07B.

The proposed commercial development area comprises a 'Large Employment Plot' in the southern and western fields covering c. 2/3 of the whole site area with attenuation swales in the southeast and soil bunds / mounds formed along the northern, western and southern margins. The Employment Plot in the centre, south and west is to be split into two separate levels with units on the lower eastern area having proposed finished floor levels (FFL) of 83.80m OD and the unit in the west has a proposed FFL of 85.30m OD. A 'Small Business Allocation' is proposed in the centre / north (FFL of 84.80m OD) while a residential development is proposed in the north and northeast of the site with associated landscaping and 'Play Area'. The development has been split into two phases with Phase I including the lower eastern commercial development plateau, small business allocation, residential development and infrastructure. Phase II comprises the upper western plateau of the employment area.

3.0 DESK STUDY INFORMATION

The desk study findings are summarised below with the full Groundsure Report and selected Historical Ordnance Survey Maps included in Appendix B.

Site History	• **1875-1880 & 1881-1885** – Site and surrounding area is agricultural fields. A footpath transects the site from west to east. There is a drainage ditch/stream along the northeast boundary flowing south/southeast. Parker's Barn is located on the northwest boundary. King's End Farm is located to the east. A kiln, workhouse and hospital are located c.750m to the northeast. • **1898** – Bignell Park is now located to the south on the southern side of the road. A quarry is indicated off the SE corner of site on the opposite side of the crossroads. The kiln NE of the site is now a quarry. • **1919-1923** – The footpath on site is no longer shown. Parker's Barn is renamed Feoffee Barn. The quarry off the SE corner is now labelled 'Old Quarry'. Limekiln Quarry c. 750m NE of the site is now 'Old Quarry'. A limekiln and quarry c.500-600m to the north adjacent to tower and pumping station. A railway now runs east-west 750m N of the site. • **1950** – The hospital NE of the site is now Market End House. • **1966** – The Old Quarry off the SE corner of site is no longer shown on the map. A very small pond c.4m diameter now shown adjacent to the SW corner with another pond indicated along the boundary with Feoffee Barn. The road along the southern boundary is now labelled B4030. • **1967-1971** – The former Limekiln Quarry and surrounding areas have been developed into residential areas. Bicester American Elementary School has been built 250m NE of site. Limekiln and quarry to the north no longer shown. • **1976-1981** – Residential development has extended to within 100m east of site. • **1984**-**1985** – Feoffee Barn is no longer shown on the map. Residential development has expanded up to Howes Lane east of the site. Overhead power lines now transect the southwest corner of site. • **1995** – Police headquarters are located on the former Limekiln Quarry c.500m north. • No further significant changes to present day.
Anticipated Geology and Ground Conditions	• Published BGS Map indicates site underlain by solid geology of the Cornbrash Formation with no overlying drift deposits. • Nearest BGS archive borehole (64m to northeast) indicates Topsoil to 0.7m bgl overlying coarse rubbly limestone with firm to stiff clay becoming very stiff from 1.0m with coarse limestone from 2.4m. • Site is not in a radon affected area, with <1% of homes above the Action Level. No radon protection measures are therefore considered necessary for new properties.

Mining/Quarrying	• Site not indicated to be within area of underground coal or other mining. • Site not in area associated with natural cavity formation. • There are 3 no. historical surface ground workings and 1 no. current ground working (status – ceased) within 50m of site, possibly the old quarry to the southeast. • There is a former quarry and limekiln c.500-600m to the north (1919-1971 historical maps) and a former quarry and kiln c.750m to the northeast (1875-1970 historical maps).
Hydrology	• Nearest surface watercourse is a small stream along the northern boundary of the site which flows to the southeast. • No water quality data available. • There are no surface water abstractions within 500m of site. • There is 1 no. active licensed discharge consent 318m northwest of site for sewage discharges with the receiving water labelled as a tributary of Pingle Stream. • The site is outside of any floodplain.
Hydrogeology	• Cornbrash Formation underlying site is a Secondary A Aquifer. • Nearest groundwater abstraction license is 731m SE – for General Farming and Domestic. • Groundwater Vulnerability is designated as Minor Aquifer/High Leaching Potential. • Likely groundwater flow direction is to the southeast, following topography.
Other Environmental data	• There are 3 no. 'Unspecified Old Quarries' 13-18m S, 1 no.' Unspecified Quarry' 22m S and 2 no. 'Unspecified Heaps' 256-262m SE from between 1880 and 1966 which have been potentially infilled. • 1 no. Unspecified Tank c.6m to west from 1922. • There are 31 Electricity Substations between 109-444m from site predominantly to the southeast/south with 8 to the northeast. • 6 current industrial land usages within 250m. Due to the distance they are not of great significance to site. • 1 no. EA historic landfill 518m to NE at 'Gowell Farm' for inert, industrial, commercial and household waste. • No recorded petrol/fuel site within 500m. • The site is within an existing nitrate vulnerable zone. • No pollution incidents within 250m. • No environmentally sensitive ecological designations within 500m.

4.0 CONCEPTUAL SITE MODEL

4.1 Diagrammatical Illustration

The Conceptual Model for the site, showing the main elements of the surface and subsurface conditions and including the potential contaminant sources, pathways and receptors identified from the desk study information is presented in Appendix A as Drawing No AG2873-18-03. The potential sources, pathways and receptors are defined in the following sections:

4.2 Sources

The findings of the desk study have not identified any obvious sources on site with the exception of:

- Possible pesticides;
- Sulphates in cohesive layers of Cornbrash;
- Hydrocarbons are unlikely to be present, however, this would need to be confirmed by testing.

The former limestone quarry located c.25m from the southeast corner of the commercial development is of limited size (c.30m x 70m), has been infilled for at least 60 years and is not recorded as a landfill. Furthermore, the former quarry is separated from the site by the road, roundabout, associated infrastructure trenches and drainage ditches, which could inhibit the flow of any migrating ground gas. The feature is c.400m from the proposed residential development. The former quarry is therefore not considered a credible source of ground gas.

4.3 Pathways

- Human dermal contact;
- Human ingestion via soil directly or via bioavailable contaminants within vegetables grown in contaminated soils (assuming private gardens are proposed in residential areas);
- Human inhalation of dust or vapours;
- Leaching and/or migration through permeable soils (Cornbrash Formation);
- Direct contact with buried concrete/water supply services.

4.4 Receptors

- End user residents, workers, visitors, customers (Human Health);
- Cornbrash Formation – Secondary A Aquifer (Controlled Waters);
- Stream along northern boundary of site (Controlled Waters);
- Buried foundation/substructure concrete (Building Materials);
- Water supply services (Building Materials).

4.5 Source/Pathway/Receptor Linkage and Assessed Risk

Source-pathway-receptor (SPR) linkages are tabulated below together with the qualitatively assessed risk. The risk to ground workers and construction workers is not included here due to the short-term exposure times that they will be subject to and the assumption that good hygiene practices will be adopted on site and the appropriate use of relevant PPE/RPE will be adhered to when exposed to potentially contaminated soils. Comments regarding contamination issues with respect to ground workers and construction workers are included in the health and safety section of the Standard Procedures included as Appendix F.

Source	Pathway	Receptor	Risk*
Potential contaminants within Topsoil including pesticides.	Inhalation, ingestion, dermal contact.	End users	Low
	Migration and Leaching	Secondary A Aquifer/ watercourse	Low
Elevated sulphates in natural soils	Direct contact, leaching and contact with groundwater	Buried concrete	Low
Hydrocarbon contaminants within soils (not anticipated)	Direct contact	Water supply services	Low-negligible

*** Definition of Risk Categories**

Negligible - Contaminants that might have unacceptable impact on key receptors, are unlikely to be present, or, no pathway is envisaged.

Low Risk: Contaminants may be present but are unlikely to be at levels to have unacceptable impact on key receptors, or pathways are likely to be minimal.

Medium Risk: Contaminants are probably present and might have an unacceptable impact on key receptors. Pathways may also be present therefore remedial measures may be necessary to reduce the risks.
High Risk – Contaminants probably or certainly present and pathways are probably also present. Therefore, contaminants are likely to have an unacceptable impact on key receptors and remedial measures are likely to be necessary to reduce the risks to acceptable levels.

5.0 GROUND INVESTIGATION WORKS

5.1 Fieldwork

The following scope of fieldwork was undertaken:

- 6 No Rotary Cored Boreholes (ref. R1 to R6) to depths of between 6m and 12m below ground level (bgl);
- 59 No Machine Excavated Trial Pits (ref. TP1 to TP59) to depths of between 0.55m and 4.4m bgl.

The borehole and trial pit records are included in Appendix C together with the SPT calibration certificate whilst the in-situ test results are included in Appendix D.

The rotary boreholes were advanced through the stiff strength material using rotary open techniques with SPTs at approximately 1m intervals. Upon encountering hard rock strata drilling progressed via rotary methods using air mist flush and coreline obtaining core of c. 90mm diameter.

The locations of the exploratory holes were selected by Bailey Johnson Hayes, set out on site by Applied Geology and were constrained by crops in the fields and the presence of overhead services. The sampling strategy for the exploratory hole locations was to provide best overall coverage given the access constraints. In general, the trial pits were carried out on an approximate 40-60m grid.

The positions of the exploratory holes were defined by handheld GPS whilst levels were estimated from the nearest spot height /contours on the topographical survey. The locations of the exploratory holes are presented on Drawing No. AG2873-18-02 Rev 3 in Appendix A.

5.2 Instrumentation and Monitoring

On completion of boring, 50mm inside diameter HDPE standpipes were installed in all boreholes as detailed below, with further details included in the relevant borehole logs in Appendix C:

- R1, response zone 7.0 to 12.0m bgl, in Cornbrash Formation;
- R2, response zone 7.0 to 11.5m bgl, in Cornbrash Formation;
- R3, response zone 9.5 to 11.5m bgl, in Cornbrash Formation;
- R4, response zone 8.5 to 11.5m bgl, in Cornbrash Formation;
- R5, response zone 9.0 to 12.0m bgl, in Cornbrash Formation;
- R6, response zone 3.0 to 6.0m bgl, in Cornbrash Formation.

Washed quarzitic gravel (6-10mm) was used as the filter medium with a hydrated bentonite seal installed above. Each standpipe was fitted with a flush metal cover concreted in place. Monitoring visits for groundwater level were undertaken on four occasions between the 24th of August 2018 and the 19th of September 2018. The monitoring results are included in Appendix D. The standpipes were developed on

the first visit and then R1, R3, R4 and R6 were sampled using volume purge methods on the second visit with samples dispatched to the laboratory for analysis.

5.3 Laboratory Testing

Geotechnical laboratory testing was undertaken generally to BS1377 on selected samples and comprised the following:

- 26 No natural moisture content tests;
- 26 No Atterberg limit tests;
- 6 No particle size distribution test;
- 6 No particle density test;
- 6 No Moisture Content / Dry Density Relationship – 2.5 kg rammer;
- 6 No Moisture Content / Dry Density Relationship – 4.5 kg rammer;
- 10 No BRE SD1 Greenfield suite tests;
- 10 No BRE SD1 Greenfield and pyrite suite tests;
- 27 No Franklin point load tests to ISRM 1985;
- 9 No Unconfined compressive strength (UCS) to ISRM 1985.

Chemical testing was undertaken based upon the desk study, walkover and site observations during the fieldwork. 13 no. samples of the Topsoil and 17 no. samples of the Cornbrash Formation were analysed for the following suite of contaminants:

- Selected metals suite [arsenic, cadmium, chromium (total), copper, mercury, nickel, lead, zinc, selenium];
- Speciated (16 US EPA) Polycyclic Aromatic Hydrocarbons (PAH);
- pH;
- Water soluble sulphate;
- Soil organic matter.

Three samples from each field (9 no. total) were submitted for Total Petroleum Hydrocarbon (TPH) to the Criteria Working Group (CWG) methodology, together with benzene, toluene, ethylbenzene, xylene (BTEX) and methyl-tert-butyl ether (MTBE). Six samples of Topsoil and three samples of the Cornbrash were screened for the presence of asbestos containing material (ACM) within the soil. Six samples of Topsoil and six samples of the Cornbrash were tested for a targeted pesticide suite. Three samples of Cornbrash were tested for inert waste acceptance criteria (WAC).

Four water samples taken during the 2nd monitoring phase were analysed for the following suite of contaminants:

- Selected metals suite [arsenic, boron, beryllium, cadmium, chromium (total), copper, mercury, nickel, lead, zinc, selenium, vanadium];
- Speciated (16 US EPA) Polycyclic Aromatic Hydrocarbons (PAH);
- pH;
- Sulphate;
- Hardness;
- TPH (CWG speciation including BTEX + MTBE) semi-volatile organic compounds (SVOC) and volatile organic compounds (VOC).

Laboratory test results are included in Appendix E.

6.0 GROUND CONDITIONS

6.1 Strata Encountered

Topsoil was encountered from ground level across the whole site, generally to depths of 0.25m to 0.35m bgl but locally up to 0.7m bgl overlying weathered limestone of the Cornbrash Formation. The Cornbrash Formation comprised bands of limestone interbedded with clay bands. Full details of the strata encountered are given on the borehole records presented in Appendix C.

6.2 Topsoil

Agricultural soils were recorded across the site to a generally to a depth of between 0.25m and 0.35m bgl but locally to 0.70m bgl (TP15) directly overlying the in-situ natural Cornbrash Formation strata. The Topsoil comprised soft dark brown sandy silty clay with limestone and rare quartzite pebbles. Frequent rootlets and occasional roots <8mm diameter were also noted.

6.3 Cornbrash Formation

The Cornbrash Formation was recorded directly beneath the Topsoil in all of the locations across the site. The Cornbrash Formation generally comprised an initial shallow limestone band overlying clay which is underlain by a deeper limestone band. The shallower limestone was recovered as clayey sandy gravel, the clayey sandy matrix was orangish brown and the limestone was grey, light grey, and bluish and greenish grey.

Where shallow (<2m bgl) limestone was encountered, this was fully penetrated with the excavator (8T wheeled backhoe 'JCB 3CX') in 34 of the 59 trial pit locations using a toothed bucket with qualitative ease of dig noted as 'moderate' to 'hard'. However, the limestone was significantly harder to dig from shallow depth in 18 trial pits resulting in the pits being terminated at depths of between 0.55m and 1.4m bgl. The locations of the 'hard to dig' limestone at shallow depth were generally in the southwest corner (TP1, TP11 and TP12), southeast corner (TP38, TP 39 and TP40) and in the north of the site (TP31, TP32, TP46, TP47, TP's 50-53 and TP59). Where deeper limestone was encountered at depths of between 1.9m and 3.3m bgl this was also too hard to penetrate with the plant used.

Two trial pits encountered clay to depth (TP8 and TP14). Five trial pits encountered firm to stiff light brown and bluish grey sandy silty clay with rare limestone gravel overlying the deeper limestone (TP15, TP19, TP22, TP24 and TP55). The remaining thirty-four trial pits encountered the shallow limestone overlying clay.

Two of the rotary cored locations encountered clay with limestone gravel at shallow depths (R1 and R5). The remainder of the rotary cored locations encountered limestone directly below the Topsoil. The deep Cornbrash Formation encountered in the rotary cored locations from depths between 1.88m and 3.40m bgl comprised a series of interbedded stiff clay and generally 'weak', occasionally 'very weak' and 'strong' to 'medium strong' limestone horizons (strength terms from BS EN 14689-1:2003). Pyrite speckling (possible representing sulphates) was encountered only in R3 between 8.90m and 8.93m and also between 9.03m and 9.07m bgl.

The results of twenty-five Atterberg Limit tests on samples of the Cornbrash Formation have given variable results with two thirds of uncorrected Plasticity Indices within the range of 10% and 21% and the final third between 25% and 33% giving a modal average of 21%. Corrected Plasticity Indices ranged from 7.5% to 25% with two higher outliers of 28% and 31%. Liquid limits were generally between 30% and 42% with two lower values of 27% and nine higher results of between 48% and 65%.This indicates the clays to be of low to medium plasticity and low to medium shrinkability. Moisture contents of between 8.1% and 24% were also recorded.

Uncorrected SPT 'N' values in cohesive Cornbrash Formation were recorded between 39 and >50. Using the empirical relationship between SPT 'N' and undrained shear strength together with the mean Plasticity Index of 21% and corresponding f_1 value of 5.4 (after Stroud), an equivalent shear strength range of between c.200kN/m^2 and c.>270kN/m^2 (very high shear strength) is indicated. An SPT 'N' versus depth plot is included in Appendix A.

The results of five particle size distribution tests on samples from TP8, TP14, TP15, TP19 and TP22 have indicated proportions of gravel ranging from 2.1% to 52.40%,sand from 8.1% to 33.3% and fines from 27.5% to 89.8%.

The results of five light compaction (2.5kg rammer) and five heavy compaction (4.5kg rammer) tests on samples from TP8, TP14, TP15, TP19 and TP22 at depths of between 0.5m and 0.7m bgl returned maximum dry densities of between 1.56Mg/m^3 and 1.76Mg/m^3 for light compaction and 1.70Mg/m^3 and 1.94Mg/m^3 for heavy compaction respectively. Optimum moisture content results for the compaction tests were recorded at between 17% and 21% for light compaction and between 11% and 17% for heavy compaction respectively. The same five samples were also submitted for particle density determinations and recorded results of between 2.54Mg/m^3 and 2.69Mg/m^3.

Unconfined compressive strength (UCS) testing was carried out on samples of the 'hard limestone rock' from recovered core and these tests have given results of between 3.4 and 51.2MPa (corresponding generally with technical rock strengths in the range of weak to medium strong - BS EN 14689-1:2003 strength terms). A UCS Vs depth plot is included in Appendix A and this indicates a wide range of values between c. 5 and 51.2MPa between 3.5m to 6m whilst more consistent values of between 3.4 and 15MPa were recorded between 9.5m and 11m bgl.

Point load tests were also undertaken by Applied Geology on selected limestone core samples recording Is_{50} values of between 0.05 and 4.39MN/m^2 for the axial tests and 0.04 and 3.36MN/m^2 for the diametrical tests.

The UCS and Point Load results have been plotted against depth (in Appendix A) however, both plots appear to show no general trend in distribution.

6.4 Groundwater

Groundwater was encountered in four of the six boreholes during drilling (R2, R3, R4 and R5) at depths of between 7.3m and 9.5m bgl. The groundwater recorded in R4 was initially struck at 8.5m bgl and rose to 1m above ground level after 20 minutes indicating artesian pressure. During subsequent monitoring groundwater was recorded at generally between 1.60m and 2.60m bgl, with the exception of R4 (the location where sub-artesian groundwater was recorded during drilling) where levels

as shallow as 0.91m bgl were recorded and at R5 on visit 1 where a level of 1.0m bgl was recorded. The deepest groundwater was generally recorded in the north and west of the site and the shallowest groundwater was in the centre and east of the site. From a study of the reduced groundwater levels (mOD) a flow direction towards the east can be inferred generally following the topography.

6.5 Contamination

No obvious visual or olfactory evidence of contamination was observed during the field work.

7.0 GEOENVIRONMENTAL ASSESSMENT

7.1 Human Health Risk Assessment

The results of the chemical testing on soils have been assessed as described in Appendix F, with specific details as follows:

- Proposed end-use – predominantly commercial end use with residential area in the north of site;
- Assuming two datasets based on the site's history and the proposed redevelopment (1) Residential and (2) Commercial;
- Screening criteria – (1) as details of proposed developments not know both residential with and without plant uptake criteria have been used, assuming 2.5% SOM;
- Screening criteria – (2) commercial, assuming 6% SOM.

The spreadsheets summarising the laboratory results and relevant screening values for each dataset are presented in Appendix E.

Residential Dataset

In the dataset for the area allocated for residential use, the majority of the determinands were either below the limit of detection or below the relevant screening value with the exception of Arsenic where four samples of the natural Cornbrash strata (TP50, TP55, TP56 and TP57) recorded values of between 40 and 43mg/kg, which exceeds the screening value for arsenic for residential with plant uptake (37mg/kg) and also three of the samples exceed the residential without plant uptake value (40mg/kg). These exceedences are considered marginal and, as they are all from natural Cornbrash strata allied to no plausible on-site sources of arsenic, are likely to be natural background levels resident in the local geology and therefore not indicative of contamination.

The results of the hydrocarbons testing recorded values of below the laboratory limit of detection.

The results of targeted pesticide suite testing recorded results below the laboratory limit of detection.

The asbestos screening tests did not detect the presence of ACM.

Commercial Dataset

The determinands in the second dataset all fall below either the limit of detection or the corresponding screening value for a commercial end use.

The results of the hydrocarbons testing recorded values of below the laboratory limit of detection.

The asbestos screening tests did not detect the presence of any ACM.

7.2 Controlled Waters Risk Assessment

The exploratory locations did not encounter Made Ground and no visual or olfactory contamination was observed. The laboratory testing on soil samples has not recorded any concentrations of any contaminants above what could be deemed typical background concentrations and many of the determinands were recorded at less than detection limits.

Groundwater was encountered in all of the boreholes and groundwater from selected boreholes were sampled and submitted for contamination analysis for a range of commonly occurring contaminants. The spreadsheet summarising the laboratory results and relevant screening values are presented in Appendix E. The determinands typically fell below either the limit of detection or below the relevant screening value with the exception of one concentration of sulphate (310mg/l) in R3 within the natural Cornbrash Formation, which slightly exceeds the UK DWS (250mg/l). However, UK DWS are not considered wholly relevant to the hydrogeological regime beneath the site and have been used as an initial screen only and this together with the marginal nature of the exceedance suggests the concentration is not a concern to controlled waters receptors. Sulphate is mainly an issue for buried concrete design included in Section 8.0.

Based on the context of the site and the proposed redevelopment, there is considered to be a negligible risk to Controlled Waters.

7.3 Disposal of Soil Arisings

General comments regarding the procedures for the assessment of waste soil for off-site disposal purposes is included in Appendix F. As requested, waste acceptance criteria (WAC) tests were undertaken on three samples of natural soil and the results demonstrate compliance with the WAC limits for inert landfills.

It is recommended that the results are provided to the proposed landfill site for confirmation of waste classification.

7.4 Conclusions and Recommendations of Geo-Environmental Assessment

The site is essentially a greenfield site and no sources of contamination were identified. The above risk assessments have established a negligible risk to human health and controlled water receptors. It is therefore, considered that remedial actions are not warranted for this development and no further assessment is required for the commercial development areas.

Issues with respect to ground gas and potential effects of contaminants on buried concrete and water supply pipework are included in Section 8.0.

8.0 GEOTECHNICAL ASSESSMENT

8.1 General

The outline proposals provided to date indicate the commercial development in the centre and south of site comprises five portal frame units with associated parking and loading/service areas as well as roads and infrastructure. The small business development area in centre/north is currently understood to comprise seven small units. No specific details have been given about the residential area at the time of writing. There are swales indicated in the east and centre/north of site, a 'Play Area' in the centre/north and a foul water pumping station in the northeast and the south of the northern field. Landscaping and public open space areas are indicated to be included as part of the development. It is understood that a scheme of cut and fill earthworks will be required to create the required levels for the development. The cut and fill balance is not yet available, although the existing topography suggests that the west/northwest of the site will be cut with the fill placed over the east/southeast of the site.

The investigations have identified Topsoil (around 0.3m thick) underlain by the Cornbrash Formation, which is generally weathered to a clay in the upper horizons with limestone rock bands variably above at shallow depth from 0.55m and below from 4.40m. Artesian water pressure was encountered at 8.50m in R4 during drilling but subsequent monitoring showed the water level to be just below ground and slightly deeper (up to c.2.5m) in other installations. However, groundwater levels are likely to exhibit seasonal fluctuations.

8.2 Earthworks

Based upon the proposed finished floor levels of the commercial areas, and a review of the existing topography, a maximum cut in the order of 1m has been estimated from the northwest of the Phase 2 area and a corresponding maximum fill of c.1m in the southeast of the Phase 2 area (FFL of 85.30m OD) in order to create level plateaus for the proposed units. The earthworks in the Phase 1 area are estimated at up to a maximum of 0.5m of cut in the west and between 0.5m to 1.5m of fill in the east (FFL of 83.80m OD). The small business allocation in the centre / north of the site is estimated to require <0.5m of cut and up to c. 1m of fill (FFL of 84.80m OD).

Samples from the Cornbrash Formation strata encountered in areas of possible cut from the west of the site have been tested for earthworks suitability and the results of the testing are included within Appendix E.

The classification of soils has been made with respect to the general requirements given in the Manual of Contract Documents for Highway Works, Specification for Highway Works: Volume 1: 2009 [SHW] for use as Earthworks Material and BS 6031:2009 'Code of Practise for Earthworks'. It should be noted and clear reference made to the fact that the engineering performance of an earthworks material can be greatly influenced by the moisture content at time of assessment and excavation/placement and compaction. With variation in the moisture content, the end performance of a material can be both improved and reduced, and consideration should be given to the management of the moisture as a key element of any

earthworks control. With respect to this, the information included in the following sections should be used for guidance on the potential use of the material, with additional testing required prior to use to confirm acceptability.

The grading limits chosen for comparison to the results of the laboratory analysis were taken from the SHW Table 6/2, with the description of the material being referenced from SHW Table 6/1 and Table 6/2. Both light (2.5kg rammer) and heavy (4.5kg rammer) compaction tests, together with particle size distribution, plasticity index, moisture content and particle density analyses were carried out on six samples of the cohesive Cornbrash Formation strata. The results of the testing are summarised in the table below.

Particle Density (Mg/m^3)	Plastic Limit (%)	Natural moisture content (%)	Optimum moisture content (%)		Maximum dry density (Mg/m^3)		Material class (SHW Table 6/2)	SHW description (SHW Table 6/1)
2.54 – 2.75	22 – 34	14 – 24	17 – 24 (2.5kg)	11 – 17 (4.5kg)	1.56 – 1.76 (2.5kg)	1.70 – 1.94 (4.5kg)	2C (2no.) & 2B (4no.)	Stoney cohesive & Dry cohesive General Fill

It is likely that during earthworks and mass excavation materials in some areas of the site will contain a variable proportion of limestone gravel, which will likely dictate the material class (i.e. 2C or 2A/2B). It is also likely there will be some oversized limestone fragments arising from excavations on site that may require screening, segregation and/or crushing.

The results of twenty-five Atterberg limit tests indicate the cohesive Cornbrash Formation materials to have plasticity index values generally of between 20% and 33% with nine results recorded in a lower range of between 10% and 19%. Natural moisture contents for the strata ranged between 8.1% and 24%. Assessing these results in isolation from gravel content / grading analysis, half of the results (13no.) would be classified as Class 2B (Dry Cohesive), 8no. samples would be classed as 2A (Wet Cohesive) and 5no. would be borderline Class 2A/2B.

Based on the assumption that the Earthworks Specification will require a minimum 100% dry density of the 2.5kg rammer tests and less than 5% air voids, the recorded natural moisture contents indicate that 28 of the 30 results fall within the likely acceptability envelope (moisture contents of between 11.5% and 26.5%) and therefore, within an acceptable range of moisture contents for use as general fill in the cut and fill exercise. Although there is some variance in the compaction, plasticity and moisture content results. The remaining two results are slightly dry of the acceptability envelope and may require some moisture modification prior to use.

There could be an option to use lime or cement to modify the moisture content of overly wet fill or stabilise soft materials. However, should this option be chosen then careful consideration would need to be given to the recorded values of total potential sulphate within the Cornbrash Formation soils. The British Insitu Paving Association document ‘Stabilisation of Sulphate Bearing Soils – Guidelines for Best Practice’ recommends that disruption associated with sulphate expansion is greatly enhanced at Total Potential Sulphate (TPS) concentrations above 0.25%. On the basis of these test results the use of lime/cement to assist with moisture modification of the

proposed fill materials will need careful consideration and cement/lime suitability laboratory testing may be worth consideration.

It will be necessary to produce a detailed specification for the earthworks detailing methods, controls and verification testing with target end performance criteria. This could initially be based upon the guidance in the Manual of Contract Documents for Highway Works, Specification for Highway Works: Volume 1: 2009 [SHW] and BS 6031:2009. Prior to any filling, proposed formation levels should be stripped of Topsoil and any other soft, organic, desiccated, loose or otherwise unsuitable materials and proof rolled. Further laboratory testing to assess the acceptability of materials will be required prior to filling. It is recommended that validation of the earthworks is carried out by an independent party.

8.3 Foundation Design

General

It is considered that the in-situ Cornbrash Formation strata at the site are suitable to support conventional strip/trench fill or pad foundations. These must be placed below any disturbed ground and also beneath any soft or loose natural materials. It will be necessary to embed the foundations within the in-situ more competent Cornbrash Formation strata beneath these materials.

A minimum founding depth of 0.9m will also apply to the site to allow for seasonal effects, unless foundations are placed on 'solid' limestone. Further deepening will be required in the influencing area of any existing, recently felled or proposed trees/ shrubs in accordance with current guidance, such as the NHBC Chapter 4.2. In particular care will be needed to ensure that foundations are placed below any potentially desiccated soils in the areas of the existing hedgerows on the site. All foundations below 1.5m bgl will require anti-heave precautions in line with current standards and according to location.

It is possible that foundation excavations may span both clay and limestone strata and it is recommended that where this occurs light mesh reinforcement is included to mitigate the effects of any potential minor differential settlement.

If ground conditions, significantly at variance to those described herein are encountered, specialist geotechnical advice should be sought to make appropriate assessment and recommendations with regards to foundations.

Commercial Development

For industrial units (and any residential apartment blocks) strip/trench fill (up to 1m wide) and pad foundations (up to 2m x 2m) competently designed to the above requirements may adopt an allowable bearing pressure of up to 150kN/m^2. This is based on lower-bound shear strength parameters and using traditional methods of bearing capacity assessments e.g. as set out in Tomlinson 7th Edition to provide a factor of safety of 3 against bearing capacity failure whilst limiting total settlements to less than 25mm.

From a study of the existing topography it is possible that up to 2m of engineered fill will need to be placed beneath parts of some of the units. As such, where founding on engineered fill is necessary it should be possible to achieve an allowable bearing

pressure in the order of 100-125 kN/m^2 for strip/pad foundations with dimensions as assumed above, provided that an adequate Earthworks Specification is adopted. This should include requirements such as minimum compaction (100% of the 2.5kg rammer maximum dry density), minimum air voids (<5%), minimum shear strength (>50 kN/m^2) and minimum CBR (>5%).

Residential Development

It is considered that traditional housing could be supported upon strip/trench fill footings of standard dimensions supported upon the in-situ Cornbrash Formation strata. Subject to the final proposed layout the developer may wish to carry out supplementary investigation and testing to confirm specific design information for this area, particularly if houses are to be located on areas of fill.

8.4 Floor Slabs

Commercial

Following earthworks it is anticipated that formation soils will comprise a combination of Cornbrash Formation and Engineered Fill. Provided that any softened/loosened or desiccated materials (such as may be present beneath former hedgerows) are removed from beneath the cut formation, the formation is proof rolled and Engineered Fills are placed to a suitable specification and verified a ground bearing slab constructed on a granular mattress of appropriately designed thickness is considered suitable. Given that the estimated thickness of fill beneath some parts of the slabs will be less than 1.5m and provided the fill is placed to a good quality under strict control then differential settlement is expected to be small.

Residential

NHBC guidance suggests ground bearing floor slabs may be adopted where the depth of Made Ground is <0.6m and where there is no risk of ground heave. Given the presence of shrinkable soils together with hedgerows along field boundaries it is considered likely that floor slabs will need to be fully suspended over a ventilated void for plots in some areas. However, where plots are located away from hedgerows / trees and Made Ground is <0.6m thick then ground bearing slabs may be feasible according to location. Plot specific assessment would be required.

8.5 Excavations

Excavations for the foundations and service trenches are expected to be in firm to stiff Cornbrash Formation clay. Limestone bands should be expected (c. 0.3-1.1m thick) within the Cornbrash Formation strata, which may require more powerful and larger excavation plant and / or breakers. The trial pits suggest that these materials may be stable in open vertical cut in the very short term, although they may become unstable if left open for longer periods potentially leading to catastrophic sudden collapse. Trench support or the angle of batter should be designed by an appropriately qualified engineer or competent person to suit the required depth and the ground and groundwater conditions. Any trenches requiring man access will require appropriate supports and assessments in line with current guidance and legislation.

Whilst standing water levels in the standpipes were relatively shallow in places these relate potentially to sub-artesian water strikes at depth and observations of the trial pits indicated only seepages in the upper c.2-2.5m. Therefore, significant groundwater ingress is not expected, although it is recommended that some provision for obtaining sump pumping equipment is made to control any minor seepages or localised flows from limestone bands and run off in wet weather conditions.

8.6 Pavement Design

As part of the site preparation, Topsoil should be stripped from the development areas.

Based on a review of classification testing, soil type, construction conditions and reference to IAN 73/06, an equilibrium CBR value of 5% is recommended for the Cornbrash Formation clays.

An equilibrium CBR value for the proposed engineered fill will be governed by the Earthworks Specification and the quality of the compaction and moisture control of the filling operation. However, provided the filling is carried out competently and is closely controlled and validated then typically a minimum CBR value of 5% can be achieved.

Based on the measured plasticity the Cornbrash Formation materials are considered unlikely to be frost susceptible.

8.7 Soakaways / Site Drainage

The ground conditions underlying the site comprise dominant clay with subordinate hard limestone rock bands. These conditions are anticipated to be practically impermeable / of very low permeability. Hence, conventional soakaways are not considered viable and an alternate off-site drainage solution is recommended. Specific soakaway or permeability testing have, therefore, not been carried out as part of this investigation.

8.8 Buried Concrete and Services

As defined by BRE Special Digest 1, Concrete Aggressive Ground, 2005 the Design Sulphate Class and the Aggressive Chemical Environment for Concrete (ACEC) has been assessed for the Cornbrash Formation. Of the 10No. pyrite suite tests, one of the samples indicated that the Cornbrash Formation is ‘potentially pyritic’. Following the results of the geotechnical testing, the characteristic values for the Cornbrash Formation have been determined as below:

- water soluble sulphate: 350mg/l;
- total potential sulphate: 0.3%;
- pH: 7.9.

The results of the sulphate tests carried out have identified the Design Sulphate Class to be DS-2 with the Aggressive Chemical Environment for Concrete (ACEC) being AC-2 (assuming mobile groundwater) as defined by the BRE Special Digest 1, Concrete Aggressive Ground, 2005 for a Greenfield site and mobile groundwater regime. Further reference should be made to BRE Special Digest 1 for requirements

in respect of types of cement and aggregate to be used and variations in type of concrete construction.

The current sulphate assessment included 10no. total potential sulphate results, one of which is elevated, which has resulted in the DS-2 classification. However, with further sampling and testing it may be possible to statistically demonstrate that DS-1 conditions are appropriate.

The results of the laboratory testing undertaken have indicated concentrations of TPH at less than the threshold for Polyurethane pipes. Barrier supply pipes, therefore, may not be necessary on this site. It should be noted that the full suite of testing required by the UKWIR guidance has not been undertaken as part of this investigation and such testing may be required by the Water Authority once the pipeline routes are known. Further guidance on this subject is included within Appendix F.

8.9 Conclusions and Recommendations of Geotechnical Assessment

Traditional pad or trench fill foundations are considered feasible bearing within the stiff clay of the Cornbrash Formation adopting allowable bearing pressure of up to 150kN/m^2 whilst limited total settlement of <25mm.

A detailed Earthworks Specification is considered necessary for the scheme to stipulate the appropriate end performance of the fill as floor slabs, roads and potentially also foundations will bear upon the fill. In addition, local slopes to the proposed cut/fill plateaus will be composed of fill and hence the earthworks will need to be of a high standard.

Ground bearing floor slabs constructed on a granular mattress should be suitable for the commercial units provided that any softened/loosened or desiccated materials are removed, the formation is proof rolled and Engineered Fill is placed to a suitable specification.

Floor slabs for the proposed housing will need to be suspended in proximity to trees (due to the presence of shrinkable soils) in accordance with NHBC standards. Ground bearing floor slabs may be feasible for locations away from trees where Made Ground is <0.6m thick.

Gas protection measures are not considered necessary and no radon protection measures are required for either the commercial or residential areas.

The ground conditions underlying the site are anticipated to be practically impermeable/of very low permeability. Hence, conventional soakaways are not considered viable and an alternate off-site drainage solution is recommended.

Sulphate resisting concrete will be required in line with DS-2 AC-2 for foundations placed in contact with the Cornbrash Formation. Further testing may allow this class to be downgraded to DS-1 and remove the need for sulphate resisting concrete.

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GENERAL NOTES

a) Albion Land Two Ltd (the Client) has requested that a Desk Study and combined geotechnical and geoenvironmental ground investigation ("The investigation") be performed in order to provide guidelines for safe site development and long term usage. The scope of work is as defined in Section 1 of this report.

b) The "investigation" was conducted and this report has been prepared for the sole internal use and reliance of the Client This report shall not be relied upon or transferred to any other parties without the express written authorisation of Applied Geology Limited. If any unauthorised third party comes into possession of this report they rely on it at their peril and the authors owe them no duty of care and skill.

c) The findings and opinions conveyed via this "investigation" report are based on information obtained from a variety of sources as detailed within this report, (eg desk study data, service plans, proposal layouts etc) and which Applied Geology Limited believes are reliable. Whilst Applied Geology Limited has used all reasonable care in obtaining and using this data, it does not guarantee its reliability.

d) The report represents the findings and opinions of experienced geoenvironmental consultants. Applied Geology Limited does not provide legal advice and the advice of lawyers may also be required.

e) The opinions presented in this report are based on findings derived from a site inspection and walkover and offsite surveys, a review of records and historical sources, comments made by interviewees (if relevant), and the findings of the physical investigation. The assumed subsurface geological profiles and other plots are generalised by necessity and have been based on the information found at the locations of the exploratory holes and depths sampled and tested. Other Conditions could exist between exploratory hole locations which have not been identified and therefore have not been taken into account in assessments. Applied Geology Limited has not found indicators that suggest that hazardous substances exist at the site at levels likely to warrant mitigation or consideration appropriate to the end use stated by the Client.

LIST OF REFERENCES COMMONLY USED BY APPLIED GEOLOGY IN REPORTS

SECTION/TITLE	AUTHOR/PUBLICATION
LABORATORY TESTING	
BS 1377-1:2016 Method of Test for Soils for Civil Engineering Purposes	BSI
SITE WORK	
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BS 5930:2015. Code of Practice for Ground Investigations	BSI
BS 10175:2011 & A1:2013 Code of Practice for the Investigation of Potentially Contaminated Sites	BSI
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BRE 211 Protecting New Buildings from Radon. 2015.	BRE
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The LQM/CIEH S4ULs for Human Health Risk Assessment, 2015. S4UL3159.	Chartered Institute of Environmental Health. Land Quality Management.
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CLEA Software (Version 1.071). 2015.	Environment Agency