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1.0 INTRODUCTION AND SCOPE

Hill Partnerships Ltd (hereafter abbreviated to *Hills*) instructed *Geo-Environmental Investigations Ltd* (hereafter abbreviated to *GEI*) in July 2015 to carry out an environmental and geotechnical site investigation on a site at Townsend Lane, Harpenden, Hertfordshire.

It is proposed to develop the site with 26 traditional-style detached houses with private gardens, parking spaces and new access roads to be constructed from Townsend Lane. A layout plan of the proposed development is presented in Figure 4. At the time of writing, no planning application has been submitted yet.

2.0 SITE LOCATION AND DESCRIPTION

Figures 1 and 2 show location and boundaries of the site; Figure 3 is an aerial photo. Photographs taken during the recent investigation are presented in Appendix A of this report.

The site consists of a trapezoid-shaped level arable field of approximately 1.654 hectares, located on the western outskirts of Harpenden. Townsend Lane runs along the north-eastern and north-western site boundaries. Low-rise residential housing is located to the north-east and south-east of the site. Townsend Nursery is located to the north and north-west of the site, between the site in the south and the Nicky Line in the north. The site is bordered by arable land in the south-west, from which it is separated by a tall hedge, which lines the site boundary on all dies. Three stands of very tall conifers are located along the south-eastern site boundary; all are located just outside the site. Two mature oak trees are located within the hedge along the north-western site boundary, and are located just within the site. At the time of the site investigation, the site itself consisted of a recently harvested stubble field where cereal had been grown. In many places, gravel-size flint nodules were visible on the ground surface. No anthropogenic structures or any other surface features were found on the site. Access to the site was via farm tracks leading to the southern corner of the site.

3.0 SITE HISTORY

The oldest available maps date to 1879 (1:2,500) and 1884 (1:10,560). They show the site as undeveloped agricultural land. Although Townsend Lane already existed no built structures were shown within more than 500 m of the site. The railway line now known as the Nicky Line was the only man-made feature in the area. The map did not show the hedge now delineating the south-western site boundary, so the site may have formed part of a larger parcel of agricultural land.

The condition of the site appeared unchanged on the 1898 1:2,500 map, but a small gravel pit was now shown approximately 100 m to the north-east of the site, on the other side of the Nicky Line. A single structure had been erected along a path approximately 250 m south-west of the site. The 1899 and 1901 maps showed no changes to the site or the surrounding area.

By 1924-1925, Harpenden had significantly expanded westwards. The site itself remained undeveloped agricultural land, but The Rosery, probably a farm, had been established to the south-east of the site. Several other small structures had also appeared along Townsend Road near the site. The gravel pit to the north-east of the site seemed to be no longer active, but was still shown as a landscape feature.

By 1938, Townsend Nursery or its precursor had been established to the north-west between site and railway line, but the 1:10,560 map did not indicate any other changes. The 1950-1951 1:10,560 map did not show any changes to site or surrounding area.

By 1965, low-rise residential development had extended as far as the north-eastern site boundary: the detached houses surrounded by private gardens found lining this section of Townsend Lane now had been built. The plot with two large structures located between the north-western site boundary and the Nicky Line was now identified as Townsend Nursery. The presence of trees was indicated along the south-eastern site boundary, and an orchard was now shown to the south-east of the site. The buildings named as The Rosery on older maps remained but seem to have been renamed (illegible on the maps). The site itself remained as undeveloped agricultural land, and the south-western site boundary was still undefined.

By 1978, the orchard and associated structures to the south-east of the site had given way to a group of detached houses with gardens around Hartwell Gardens, a cul-de-sac branching off Townsend Lane. No changes in landuse were shown on the site itself.

The historical maps suggest that the site has never been developed and only ever been used as agricultural (arable) land since the middle of the 19th century. The site has been used for the cultivation of crops by Rothamsted Research Limited, formerly known as Rothamsted Experimental Station, for many years.

The *Groundsure* Geoinsight report suggests that "occasional small scale/minor chalk mining may have occurred but of restricted extent" (see Appendix C, page 20). Anecdotal evidence from Rothamsted scientists consulted by *GEI* confirmed that some localised extraction of soft chalk had occurred in the local area late in the 19th or early in the 20th century at shallow levels. The soft chalk thus extracted was mostly used as an additive to reduce the acidity of local agricultural soils. However, none of the information available to *GEI* suggests that any shallow chalk extraction has definitely taken place on the development site itself.

The small gravel pit located on the far side of the Nicky Line to the north-west of the site is mentioned in both the *Envirocheck* Mining and Ground Stability Data Sheet and in the *Groundsure* Geoinsight report (see pages 1 and 18 of these reports respectively, Appendices B and C respectively). This was the Fatcornersend Farm Gravel Pit, a small former open-cast sand and gravel pit located approximately 103-108 m north-west of the site (BGS Recorded Mineral Site No 168845). This is the closest ground working for which any tangible evidence exists, apart from the construction of the Nicky railway line.

4.0 GEOLOGY AND GROUND CONDITIONS

According to the published geology (BGS Sheet 39 Solid & Drift Edition, West London, 1:100,000), the site is underlain by the Quaternary-Pliocene Clay-with-flints Formation above the Santonian-Turonian Lewes Nodular Chalk Formation and Seaford Nodular Chalk Formation (undifferentiated). There are no records of artificial ground on this site. Extracts of geological maps are included in Appendix B.

In 2010, a 61.00 m deep borehole was drilled at 44 West Common Way, Harpenden, approximately 220 m to the north-east of the site. In this location, the Clay-with-Flints Formation extended to a depth of 4.00 mbgl, and was underlain by 6.00m of discoloured Chalk above 2.00 m of Clay mixed with chalk, before firm white Chalk with flints was encountered at a depth of 12.00 mbgl.

The published geology was confirmed by the 2015 site investigation, which comprised sixteen narrow-diameter windowless sampler holes and three light cable percussive boreholes. Figure 5 shows the location of all excavations.

No Made Ground was encountered anywhere on the site. The thickness of the topsoil ranged from 0.22 m to 0.75 m. In all excavations the Topsoil was underlain by firm to stiff/becoming stiff orange-brown silty sandy Clay with scattered fine to coarse angular and subangular flint gravel, limonite staining, traces of lignite and locally traces of fine chalk gravel. In some of the excavations, this stratum, which was identified as the Clay-with-Flint Formation, was found to include discrete substantial layers of orange-brown silty clayey Sand with scattered flint gravel and limonite staining. In WS3, 1.55 m of silty sandy Clay was found to overlie 2.00 m of clayey Sand, within which the borehole terminated at 4.00 mbgl. In WS8, 2.50 m of clayey Sand was found immediately below the Topsoil, overlying stiff to very stiff silty sandy Clay. In WS9, 5.65 m of stiff to very stiff silty sandy Clay was underlain by 4.00 m of silty clayey Sand. This borehole was terminated within the Sand at 10.00 mbgl. In WS12, 1.80 m of clayey Sand was found sandwiched below 0.72 m and above 1.80 m of stiff to very stiff silty sandy Clay.

The underlying Lewes Nodular Chalk and Seaford Chalk Formations (undifferentiated) was encountered in ten out of sixteen windowless sampler holes, and in all three light cable percussive boreholes. However, the depths at which the top of the Chalk was encountered was extremely variable, ranging from 1.50 mbgl in WS7 in the southern corner of the site to > 10.00 mbgl in WS9, which was drilled to 10.00 mbgl without reaching the top of the Chalk. BH1, drilled to a depth of 25.00 mbgl, encountered Chalk at 6.40 mbgl. The top of the Chalk was found at 3.70 mbgl in BH2 and at 2.90 mbgl in BH3.
The upper part of the Chalk on this site consists of a weathered soft structureless Chalk with a putty/clayey consistency, some local limonite staining and rare flint nodules. In some of locations, this soft Chalk contained scattered small hard nodular chalk lithorelicts. In WS1, the consistency of the Chalk changed to soft to firm between 9.00 and 10.00 mbgl. Hard white Chalk was recorded from 14.00 mbgl in BH1, from 15.00 mbgl in BH2 and from 16.50 mbgl in BH3.

According to the *Envirocheck* data presented in Appendix B, the site is located in an area with a very low potential for collapsible ground stability hazards, no (page 4 of the *Envirocheck* Mining and Ground Stability Datasheet) or low (page 4 of the *Envirocheck* Mining and Ground Stability Datasheet and page 3 of Ground Stability Data maps appended to the same) potential for shrinking or swelling clay, and a very low (page 4 of the *Envirocheck* Mining and Ground Stability Datasheet) or moderate (page 4 of the *Envirocheck* Mining and Ground Stability Datasheet and page 2 of Ground Stability Data maps appended to the same) potential for ground dissolution stability hazards. The latter refers to the Chalk.

The *Groundsure* Geoinsight report presented in Appendix C rates the risk of collapsible ground stability hazards as very low, the risk from shrinking/swelling clay on site as low, and the risk of ground dissolution of soluble rocks (the Chalk) as moderate. This is further elaborated on page 30 of the *Groundsure* Geoinsight report: "very significant soluble rocks are present with a moderate possibility of local natural subsidence due to high surface or subsurface water flow. Do not load the land or undertake building work before obtaining specialist advice. Do not dispose of drainage to the ground. Some possibility [of] groundwater pollution. Maintain drainage infrastructure. For new build, specialist site investigation and stability assessment may be necessary before construction. Construction work may cause subsidence". According to information obtained from the Peter Brett Associates (PBA) mining cavities database cited by *Groundsure,* natural cavities in the form of one sinkhole and one solution pipe have been identified approximately 65.0 m north-west of the site. The location of these is shown on page 19 of the *Groundsure* Geoinsight report (feature 17). The extremely variable depth of the top of the Chalk encountered during this investigation suggest that such features may be present on this site as well.
In our opinion, the risks posed by potential ground dissolution hazards on this site should be classed as moderate, and the potential risk posed by shrinking/swelling clay as low.

Despite the presence of significant layers of sand within the Clay-with-Flints Formation, the potential risk arising from running sand has been classified as negligible, as this sand appears to be clayey/silty.

5.0 HYDROGEOLOGY AND HYDROLOGY

According to aquifer designation and groundwater vulnerability maps currently available on the Environment Agency website, the solid geology on this site, the Lewes Nodular Chalk Formation and Seaford Nodular Chalk Formation (undifferentiated).has been classified as Principal Aquifer. The overlying Clay-with-Flints Formation has been classed as an Unproductive Stratum – however, this formation does include significant layers and lenses of clayey silty sand, which would increase its permeability. In addition, the thickness of the superficial geology on site is extremely variable, ranging from 1.50 m to > 10.00 m. The soils on site are Soils of Intermediate Leaching Potential (I1).
According to the Environment Agency website, the site lies in a Total Catchment Groundwater Source Protection Zone (Zone 3), in a Surface Water Safeguard Zone and in a Surface Water Nitrate Vulnerable Zone.

The nearest surface water feature is located approximately 250 m south-east of the site.

No groundwater was encountered in any of the boreholes during the recent site investigation.

6.0 ENVIRONMENTAL INFORMATION AND CONCERNS

The historical maps indicate that the site area has never been developed, and has been used for arable farming since records began. For many years it has been farmed by the Rothamsted Research Limited, formerly known as Rothamsted Experimental Station.

The *Groundsure* Geoinsight report suggests that "occasional small scale/minor chalk mining may have occurred but of restricted extent", and anecdotal evidence from Rothamsted scientists consulted by *GEI* confirmed that some localised extraction of soft chalk had occurred in the area late in the 19th or early in the 20th century at shallow levels. The soft chalk thus extracted was mostly used as an additive to reduce the acidity of local agricultural soils. However, there is no concrete evidence for any actual chalk extraction on site – indeed, this would have required the removal of a minimum of 1.50 m of overburden, and much greater thicknesses of Clay-with-Flints in many parts of the site. No Made Ground or evidence for the anthropogenic disturbance of the natural soils overlying the Chalk was encountered during this site investigation.
In our opinion it is likely that people searching for chalk may have concentrated on areas where the top of the Chalk was located closer to, or at, surface level.

The historical information reviewed did not reveal any instances of potentially contaminating landuse on site, with the possible exception of the use of herbicides, pesticides or fertilisers common in agricultural landuse. However, with the exception of DDT which is persistent, most of these chemicals, particularly older pesticides and herbicides, tend to have a fairly short half-life.

With the exception of a railway line constructed during the 19th century and closed down by Beecham, no potentially contaminating landuse was identified in the surrounding area. In our opinion, this disused railway line now known as the Nicky Line located to the north-west of the site is very unlikely to have had any detrimental impact on the site.

According to Environment Agency data, there are no records of any historic or current landfill sites within 1000 m of the site. It appears that any small-scale local chalk or sand/gravel pits, such as the Fatcornersend Farm Gravel Pit, were probably not used for waste disposal.

7.0 RADON, METHANE AND CARBON DIOXIDE

The 2007 British Geological Survey/Health Protection Agency *Indicative Atlas of Radon in England and Wales* places the Harpenden area in a low to moderate radon potential class, indicating that the site lies in an area where the ground is susceptible to low levels of radon

emissions but with small sub-areas susceptible to moderate or high levels of radon emissions: between 1 and 3 percent of homes in this area are considered to be at or above the Radon Action Level of >200 Bq m^{-3}. This is in agreement with the data provided by the British Geological Survey map *Radon Potential Based on Solid Geology* (Review of "Natural" Contamination in Great Britain, South, 1; 1 625 000, 1995), and the NRPB *Radon Atlas of England* (NRPB-R290, 1996).
According to the maps included in British Geological Survey Technical Report WP/95/1, *Methane, carbon dioxide and oil seeps from natural sources and mining areas: characteristics, extent and relevance to planning and development in Great Britain (1995)*, Harpenden lies in an area of low susceptibility to methane, carbon dioxide and oil seeps, both at the surface and underground.

However, Chalk has the potential to produce carbon dioxide. Due to the presence of Chalk below the site it was decided to carry out a programme of gas monitoring for reassurance. Installations were placed in five of the shallow boreholes, and gas monitoring will be carried out monthly for six months. The gas monitoring results will be presented in a separate ground gas risk assessment.

8.0 FLOOD RISK

According to Environment Agency data, the site is not at risk from flooding from rivers.

The site is located in an area at very low risk from surface water flooding, with the exception of the northern corner of the site, which is located in an area of low (i.e. slightly higher) surface water flooding.
In our opinion the information found on the Environment Agency website is more differentiated and therefore more accurate that the Flood Risk and Groundwater Susceptibility Map included on page 6 of the *Landmark Sitecheck* Combined Report No. 65802702_1 739372071#140184590 provided to *GEI* by *Hills*, which shows the entire site and surrounding area as simply "susceptible to groundwater flooding". However, the tabulations on pages 13 and 24 of the same report states that the risk posed to the site from groundwater flooding associated with 1:75 year, 1:200 year or 1:1000 year rainfall events are negligible.

9.0 SITE INVESTIGATION

The *GEI* site work was carried out in two phases in August 2015.

From 10th to 12th August, sixteen narrow diameter windowless sampler holes were drilled across the site, using a tracked Dando Terrier rig. The depth of these boreholes ranged from 2.00 mbgl to 10.00 mbgl. WS1 and WS9 were drilled to a depth of 10.00 mbgl. WS2, WS5, WS6, WS7, WS8, WS10, WS12, WS13 and WS14 were drilled to a depth of 5.00 mbgl. WS14 was terminated at 4.00 mbgl. WS3, WS4 and WS16 reached a depth of 3.00 mbgl, and WS11 was terminated at a depth of 2.00 mbgl.

The top of the weathered softened Chalk was encountered in WS1 at 2.93 mbgl, in WS2 at 2.70 mbgl, in WS4 at 2.60 mbgl, in WS5 at 2.30 mbgl, in WS6 at 1.50 mbgl, in WS7 at 4.50 mbgl, in WS12 at 4.80 mbgl, in WS13 at 2.10 mbgl, in WS15 at 2.90 mbgl and in WS16 at 2.00 mbgl. All other excavations were terminated within the Clay-with-Flints Formation, including WS9 at 10.00 mbgl.
No groundwater was encountered in any of these locations. Gas and groundwater monitoring installations were emplaced in WS1, WS2, WS6, WS11 and WS16.
Soil samples were taken in 1 – litre amber screw-top glass jars at every strata change, and all excavations were logged by *GEI.*

The second phase of site works was carried out from 19th to 22nd August 2015, when three light cable percussion boreholes were drilled to depths of 25.00 – 25.50 mbgl. BH1 was drilled in the eastern part of the site. BH2 was located in the northern part of the site. BH3 was located in the south-western part of the site. These boreholes were sampled for stratigraphic description only, and no installations were placed in them. No groundwater was encountered in any of these locations.

Standard Penetration Tests and Cone Penetration Tests were carried out in all boreholes except WS16, which was drilled as a gas monitoring hole, in accordance with *BS 5930:1999, Code of Practice for Site Investigations, Section 4, 25.2.* The data from all boreholes are presented in Table 1 on pages 10 to 14 below.

Table 1: SPT Data and N-Values from *GEI* Boreholes

Borehole	Depth (mbgl)	75	75	75	75	75	75	N
WS1	1.00	2	2	3	3	4	5	15
	2.00	2	3	5	6	7	6	24
	3.00	1	0	1	1	1	1	4
	4.00	1	1	2	1	1	1	5
	5.00	1	1	2	1	2	2	7
	6.00	1	3	3	4	6	7	20
	7.00	4	5	5	5	4	4	18
	8.00	2	2	3	4	3	2	12
	9.00	4	5	5	5	7	8	25
	10.00	4	5	5	4	4	5	18
WS2	1.00	1	2	4	5	5	4	18
	2.00	1	2	3	3	10	13	29
	3.00	1	2	2	2	2	1	7
	4.00	1	1	-	1	-	1	2
	5.00	2	2	2	3	3	2	10

Table 1: SPT Data and N-Values from *GEI* Boreholes (continued)

Borehole	Depth (mbgl)	75	75	75	75	75	75	N
WS3	1.00	2	3	4	4	5	6	19
	2.00	2	2	4	5	5	7	21
	3.00	4	4	5	6	5	5	21
WS4	1.00	2	2	2	3	3	4	12
	2.00	1	1	1	2	1	1	5
	3.00	1	2	2	2	3	3	10
	4.00	1	1	1	2	1	2	6
WS5	1.00	1	1	2	2	3	4	11
	2.00	3	3	4	5	3	3	15
	3.00	1	1	2	1	4	5	12
	4.00	4	4	2	3	3	2	10
	5.00	1	3	3	3	3	4	13
WS6	1.00	1	2	3	4	3	3	13
	2.00	3	2	1	2	1	2	6
	3.00	1	1	2	2	2	1	7
	4.00	8	9	4	3	3	3	13
	5.00	1	0	1	1	1	1	4
WS7	1.00	3	4	2	3	3	4	12
	2.00	2	3	3	3	4	6	16
	3.00	2	4	5	5	4	5	19
	4.00	1	2	2	3	4	6	15
	5.00	3	4	4	4	5	4	17
WS8	1.00	2	3	4	4	5	7	20
	2.00	1	3	4	5	6	8	23
	3.00	2	2	3	3	4	5	15
	4.00	4	3	3	3	3	4	13
	5.00	2	3	3	2	1	2	8
WS9	1.00	1	3	5	6	7	7	25
	2.00	2	3	6	5	4	5	20
	3.00	2	2	2	3	3	4	12
	4.00	2	3	6	4	4	5	19
	5.00	3	4	6	4	5	5	19

Table 1: SPT Data and N-Values from *GEI* Boreholes (continued)

Borehole	Depth (mbgl)	75	75	75	75	75	75	N
WS9	6.00	3	4	6	9	9	11	35
	7.00	1	3	3	4	4	5	16
WS10	1.00	1	3	2	3	4	7	16
	2.00	2	2	3	4	4	6	17
	3.00	2	3	3	3	4	5	15
	4.00	1	2	3	3	3	5	14
	5.00	1	2	3	2	3	3	11
WS11	1.00	0	1	1	1	1	1	4
WS12	1.00	3	3	4	4	5	7	20
	2.00	2	4	6	5	5	8	24
	3.00	2	2	3	3	3	4	13
	4.00	2	2	2	2	3	3	10
	5.00	1	-	1	1	1	1	4
WS13	1.00	1	3	3	3	3	3	12
	2.00	2	2	2	2	2	3	9
	3.00	1	2	2	2	3	3	10
	4.00	2	3	3	3	3	3	12
	5.00	2	3	4	3	2	3	12
WS14	1.00	1	1	1	2	2	2	7
	2.00	1	2	2	4	4	6	16
	3.00	2	2	3	4	5	6	18
	4.00	5	6	7	7	11	11	36
	5.00	4	5	6	7	8	9	30
WS15	1.00	2	2	3	4	5	6	18
	2.00	2	1	2	2	2	3	9
	3.00	1	2	2	1	1	2	6
	4.00	2	2	2	4	3	3	12

Table 1: SPT Data and N-Values from *GEI* Boreholes (continued)

Borehole	Depth (mbgl)	75	75	75	75	75	75	N
BH1	1.50	1	3	3	4	4	4	15
	2.50	2	2	4	3	5	4	16
	3.50	3	6	5	5	5	4	21
	4.50	4	4	4	5	6	5	20
	6.50	4	4	3	5	5	4	17
	8.00	3	3	4	6	4	3	17
	9.50	4	4	5	6	6	5	22
	11.00	4	4	4	5	8	8	25
	12.50	4	3	5	5	6	6	22
	14.00	3	5	5	6	6	7	24
	15.50	6	7	7	8	10	14	39
	17.00	8	12	15	15	14	6 (27mm)	>50
	18.50	11	14	14	16	18	2 (5mm)	>50
	20.00	10	15	18	21	11 (19 mm)	-	>50
	21.50	13	12	17	17	16 (25 mm)	-	>50
	23.00	15	10 (43 mm)	20	22	8 (11 mm)	-	>50
	24.50	15	10 (27 mm)	15	19	16 (17 mm)	-	>50
BH2	1.50	3	4	4	4	5	6	19
	2.50	4	3	4	4	5	5	18
	3.50	8	9	11	6	5	5	27
	4.50	1	1	2	2	1	2	7
	6.50	2	2	1	1	1	3	7
	8.00	1	1	3	2	4	4	13
	9.50	2	2	2	2	3	2	9
	11.00	5	7	7	7	6	6	26
	12.50	5	7	9	7	6	7	29
	14.00	6	6	8	8	7	9	32
	15.50	7	7	9	9	10	11	39
	17.00	8	8	10	12	16	12 (30 mm)	>50
	18.50	7	10	9	12	15	14 (28 mm)	>50
	20.00	9	12	12	15	15	8 (35 mm)	>50
	21.50	10	14	13	15	17	5 (15 mm)	>50
	23.00	10	15	15	16	17	2 (6 mm)	>50
	24.50	15	10 (50 mm)	18	22	10 (22 mm)	-	>50
BH3	1.50	2	4	4	6	5	5	20
	2.50	3	4	5	5	7	6	23

Table 1: SPT Data and N-Values from *GEI* Boreholes (continued)

Borehole	Depth (mbgl)	75	75	75	75	75	75	N
BH3	3.50	1	0	2	2	1	2	7
	4.50	1	2	2	3	2	2	10
	6.50	2	3	3	3	4	3	13
BH3	8.00	3	3	2	2	4	4	12
	9.50	3	4	3	3	4	6	16
	11.00	3	5	5	7	7	6	25
	12.50	2	4	4	3	5	5	17
	14.00	3	3	6	6	8	8	28
	15.50	7	12	10	11	13	14	48
	17.00	8	10	10	11	12	13	46
	18.50	10	13	14	15	15	6 (30 mm)	>50
	20.00	9	9	12	12	15	11 (39 mm)	>50
	21.50	10	14	16	15	17	2 (5 mm)	>50
	23.00	16	9 (45 mm)	15	15	20 (19 mm)	-	>50
	24.50	15	10 (25 mm)	18	19	13 (14 mm)	-	>50

The site work was carried out in general accordance with the standard protocols set out in those sections of *BS 5930:1999, Code of Practice for Site Investigations* still in force, as well as *BS EN ISO 14688-1:2002 (Part 1: Identification and description) and BS EN ISO 14688-2: 2004 (Part 2: Identification for a classification), Geotechnical investigation and testing – Identification and classification of soil*, and with *BS 10175:2011, "Investigation of potentially contaminated sites - Code of Practice"*.

Figure 5 shows the locations of all *GEI* excavations. The logs of all boreholes are presented in Appendix E.

10.0 LABORATORY TESTING

Twenty-eight soil samples were selected for chemical analysis or geotechnical testing and conveyed in cool boxes to *QTS Environmental Ltd*, a UKAS, NAMAS- and M-Certs - accredited laboratory. Table 2 on pages 15 and 16 below presents the details of the samples selected for chemical analysis; Table 3 on page 16 shows the samples scheduled for geotechnical testing.

Four soil samples were scheduled for the QTS Spectrum Basic Suite, which includes arsenic, water-soluble boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, zinc, asbestos screen, total cyanide, pH, organic matter, total sulphate as SO_4, sulphide, total organic carbon (TOC), EPH, TPH CWG banding, phenols, speciated PAHs and asbestos screen.

Twenty-one soil samples were scheduled for CLEA Metals, which include arsenic, barium, water-soluble boron, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium and zinc.

Three soil samples were selected for leachable metals, which includes arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium and zinc.

One sample was scheduled for the determination of pesticides and herbicides.

Two samples were scheduled for Atterberg limits/plasticity tests; one sample was selected for particle size analysis (sieve).

Table 2: Details of the Samples submitted for Chemical Analysis

Sample No	Location	Depth (mbgl)	Description	Analyses Scheduled
TL1	WS1	0.75 – 1.00	Clay-with-Flints: sandy Clay	Spectrum Basic Suite, Leachable Metals
TL2	WS1	1.00 – 2.00	Clay-with-Flints: sandy Clay	CLEA Metals Suite
TL7	WS2	GL – 1.00	Topsoil and Clay-with-Flints: sandy Clay	CLEA Metals Suite
TL8	WS2	1.00 – 2.00	Clay-with-Flints: sandy Clay	CLEA Metals Suite
TL11	WS3	GL – 0.45	Topsoil	Spectrum Basic Suite
TL14	WS3	2.00 – 3.00	Clay-with-Flints: clayey Sand	CLEA Metals Suite
TL16	WS4	0.60 – 1.00	Clay-with-Flints: sandy Clay	CLEA Metals Suite
TL17	WS4	1.00 – 2.00	Clay-with-Flints: sandy Clay	CLEA Metals Suite
TL18	WS5	GL – 0.50	Topsoil	CLEA Metals Suite
TL19	WS5	0.50 – 2.30	Clay-with-Flints: sandy Clay	Spectrum Basic Suite, Leachable Metals
TL21	WS6	GL -.0.30	Topsoil	CLEA Metals Suite
TL22	WS6	0.30 – 1.50	Clay-with-Flints: sandy Clay	CLEA Metals Suite

Table 2: Details of the Samples submitted for Chemical Analysis (continued)

Sample No	Location	Depth (mbgl)	Description	Analyses Scheduled
TL24	WS7	GL – 0.35	Topsoil	CLEA Metals Suite
TL25	WS7	0.35 – 1.00	Clay-with-Flints: sandy Clay	CLEA Metals Suite, Leachable Metals
TL27	WS8	GL – 0.50	Topsoil	CLEA Metals Suite
TL30	WS9	GL – 0.35	Topsoil	CLEA Metals Suite
TL31	WS9	0.35 – 1.10	Clay-with-Flints: sandy Clay	CLEA Metals Suite
TL33	WS10	GL – 0.40	Topsoil	CLEA Metals Suite
TL35	WS10	1.00 – 2.00	Clay-with-Flints: sandy Clay	CLEA Metals Suite
TL36	WS11	GL – 0.70	Topsoil and Clay-with-Flints: sandy Clay	CLEA Metals Suite
TL38	WS12	GL – 0.48	Topsoil	Spectrum Basic Suite, Leachable Metals, Pesticides and Herbicides
TL42	WS13	0.40 – 2.10	Clay-with-Flints: sandy Clay	CLEA Metals Suite
TL44	WS14	1.00 – 2.00	Clay-with-Flints: sandy Clay	CLEA Metals Suite
TL47	WS15	GL – 0.40	Topsoil	CLEA Metals Suite
TL48	WS16	GL – 0.48	Topsoil	CLEA Metals Suite

Table 3: Details of the Samples submitted for Geotechnical Testing

Sample No	Location	Depth (mbgl)	Description	Analyses Scheduled
TL32G	WS9	1.10 – 4.00	Clay-with-Flints: sandy Clay	Atterberg Limit
TL35G	WS10	1.00 – 2.00	Clay-with-Flints: sandy Clay	Atterberg Limit
TL45	WS14	4.00 – 5.00	Clay-with-Flints: sandy Clay and silty clayey Sand	Particle Size Analysis: Sieve

The results of the chemical analyses are presented in Appendix G. The results for samples TL1 to TL14 are presented in QTS report No. 15-34918. QTS Report No. 15-34919 contains the results for samples TL16 to TL27. The results for samples TL30 to TL38 are presented in QTS Report No. 15-34920. QTS Report No. 15-34922 features the results for samples Tl42 to TL48.
Appendix F contains the geotechnical laboratory results.

11.0 ENVIRONMENTAL RISK ASSESSMENT

11.1 Conceptual Model, Pathways and Receptors

No Made Ground was encountered anywhere on this site. A thin layer of topsoil was found overlying the Clay-with-Flints Formation, which consists of a heterogeneous mixture of sandy silty Clay with flint and silty clayey Sand. The weathered and softened top of the underlying Lewes Nodular Chalk and Seaford Chalk Formations (undifferentiated) was encountered at depths ranging from 1.50 to 6.40 mbgl, but was not found in WS10, which terminated in Clay-with-Flints at 10.00 mbgl.

According to aquifer designation and groundwater vulnerability maps currently available on the Environment Agency website, the solid geology on this site, the Lewes Nodular Chalk Formation and Seaford Nodular Chalk Formation (undifferentiated).has been classified as Principal Aquifer. The overlying Clay-with-Flints Formation has been classed as an Unproductive Stratum – however, this formation does include significant layers and lenses of clayey silty sand, which would increase its permeability. In addition, the thickness of the superficial geology on site is extremely variable, ranging from 1.50 m to > 10.00 m. The soils on site are Soils of Intermediate Leaching Potential (I1).
According to the Environment Agency website, the site lies in a Total Catchment Groundwater Source Protection Zone (Zone 3) and in a Surface Water Safeguard Zone.

The historical maps suggest that the site has never been developed and only ever been used as agricultural (arable) land since the middle of the 19th century. The site has been used for the cultivation of crops by Rothamsted Research Limited, formerly known as Rothamsted Experimental Station, for a number of years. No indications for any significant potential sources of soil or groundwater contamination on site were found.

The *Groundsure* Geoinsight report suggests that “occasional small scale/minor chalk mining may have occurred but of restricted extent”, and anecdotal evidence from Rothamsted scientists consulted by *GEI* confirmed that some localised extraction of soft chalk had occurred in the local area late in the 19th or early in the 20th century at shallow levels. However, none of the information available to *GEI* suggests that any shallow chalk extraction has definitely taken place on the development site itself. No Made Ground or evidence for the anthropogenic disturbance of the natural soils overlying the Chalk was encountered during this site investigation. In our opinion it is likely that people searching for chalk may have concentrated on areas where the top of the Chalk was located closer to, or at, surface level.

The Chalk underlying the site may naturally give rise to the formation of carbon dioxide. In order to produce a comprehensive assessment of the risk potentially posed by carbon dioxide, gas monitoring installations have been placed in five locations, and monitoring will be carried out monthly for six months.

The small gravel pit located on the far side of the Nicky Line to the north-west of the site was the Fatcornersend Farm Gravel Pit, a small former open-cast sand and gravel pit located approximately 103-108 m north-west of the site (BGS Recorded Mineral Site No 168845). This is the closest ground working for which any tangible evidence exists, apart from the construction of the Nicky railway line. In our opinion, this is very unlikely to pose a significant risk of any significant harm to the site, as there are no records of it having been backfilled with waste.
No historical or current landfill sites were located within 500 m of the site. No other potential sources of contamination were identified within the vicinity of the site.

In order for a significant hazard to be present, at least one plausible pathway must exist between the potential contaminant(s) and the potential receptor(s), whether human or controlled waters.

Theoretically there are two potential receptors for contaminants that may be present on the site:

- Human beings: site workers during the construction of the foundations and other earthworks of the planned new development as well as any associated ground works, including the installation of any buried services.

- Human beings: the future residents of the planned houses with private gardens.

- Controlled waters: the site is underlain by a highly variable thickness of Clay-with-Flints. Although classified as an Unproductive Stratum, on this site this formation includes significant bodies of sand. This stratum is underlain by Chalk, the top of which was encountered at 1.50 mbgl in one location. This is a Principal Aquifer. However, no groundwater was encountered down to a depth of 25.50 mbgl, and there are reasons to believe that the local water table is located at significant depths. No significant water courses or bodies of controlled water have been identified near the site.

The most likely pathways between contaminants and potential receptors on this site are:

- Physical contact (dermal contact), inhalation of dust or vapours and ingestion of contaminated materials whilst on site for site workers during construction of the foundations of the planned new development and any associated ground works including the construction of new access roads and gardens, as well as the installation of new buried services. However, these pathways will only function if contaminant sources are located on or close to the site.

- Physical contact (dermal contact), inhalation of dust and ingestion of contaminated materials for future residents, particularly as all proposed houses will have private gardens. However, these pathways will only function if contaminant sources are located on or close to the site. Any risk potentially posed by carbon dioxide arising naturally from the underlying Chalk over time can be mitigated by incorporating appropriate gas protection into the foundations of the new buildings.

- Transport of leachable contaminants from the Topsoil and/or the Clay-with-Flints into the underlying Chalk could occur, particularly via the sandy parts of the latter. However, these pathways can only function if contaminant sources are located on the site.

11.2 Contaminants

Four samples were found to have total arsenic concentration above the current *LQM/CIEH* S4ULs for residential landuse with (37 mg/kg) and without home-grown produce (40 mg/kg): sample TL35 from WS10 at 1.00 – 2.00 mbgl yielded 112 mg/kg arsenic; sample TL14 from WS3 at 2.00 – 3.00 mbgl was found to contain 90 mg/kg arsenic; 51 mg/kg arsenic were detected in sample TL19 from WS5 at 0.50 – 2.30 mbgl, and sample TL22 from WS6 at 0.30 – 1.50 mbgl contained 41 mg/kg arsenic. No leachable arsenic was identified.

No other elevated concentrations of any metals were identified. With the exception of barium, boron, vanadium and zinc, the concentrations of all leachable metals were below their respective detection limits. Those leachable metals detected were present in very low concentrations.

No phenols, CWG banded aromatic or aliphatic petroleum hydrocarbons, BTEX or MTBE were detected in any samples. Sample TL11 from WS3 at GL – 0.45 mbgl was found to contain 0.17 mg/kg fluoranthene and 0.16 mg/kg pyrene. No other polyaromatic hydrocarbons were detected in any other samples.

One sample, TL38 from WS12 at GL – 0.48 mbgl, had been scheduled for determination of pesticides and herbicides. No organochlorine pesticides, organophosphorus pesticides, triazine herbicides, phenyl urea herbicides, phenoxy acidic herbicides or pyrethroids were detected.

No asbestos was detected in any of the samples screened for asbestos.

11.3 Risk Assessment

11.3.1 Risk Assessment – Human Health

Quantitative *RBCA (Risk Based Corrective Action*) Version 2.6 Tier 1 and Tier 2 risk assessments have been carried out for the analyte arsenic. None of the other analytes tested for were found to be present in sufficient concentrations for meaningful modelling across the site. The *RBCA* gives a reasonable guide to groundwater risks, and Version 2.5 includes plant uptake. The *RBCA* software used includes American toxicological data and default parameters. Where *CLEA* data in the form of SGVs (Soil Guidance Values) or British toxicological data are available, these have been used in the *RBCA* assessment. *RBCA* Version 2.5 has been configured to accept the *CLEA* SGV approach.
The new *LQM* S4ULs issued in November 2014 have been taken into consideration in this risk assessment. Even though most of the private gardens included in this development appear to be rather small, as a precautionary measure the levels for residential landuse with home-grown produce were selected.
The detailed *RBCA* data sheets for arsenic are presented in Appendix H of this report. Appendix J presents statistical data sheets for a wider range of analytes.

The site-specific *RBCA SSTL* for arsenic is 31 mg/kg, slightly lower than the generic current *LQM/CIEH* S4ULs for residential landuse with (37 mg/kg) and without home-grown produce (40 mg/kg).
Six samples tested exceeded the *RBCA SSTL:* sample TL2 from WS1 at 1.00 – 2.00 mbgl contained 33 mg/kg arsenic; sample TL14 from WS3 at 2.00 – 3.00 mbgl contained 90 mg/kg arsenic; sample TL17 from WS4 at 1.00 – 2.00 mbgl contained 35 mg/kg arsenic; sample TL19 from WS5 at 0.50 – 2.30 mbgl contained 51 mg/kg arsenic; sample TL22 from WS6 at 0.30 – 1.50 mbgl contained 41 mg/kg arsenic; and sample TL35 from WS10 at 1.00 – 2.00 mbgl contained 112 mg/kg arsenic. However, no leachable arsenic was detected.
However, in two of these samples the exceedance with all guideline values was marginal, and in four out of six samples the material concerned was located below 1.00 mbgl, including the highest levels reported, at depths below the critical zone for human health risk assessment. Statistical analysis shows that the mean arsenic concentration is 30.8 mg/kg, which is well within the *LQM/CIEH* S4UL and the *RBCA SSTL.* Defra guidance suggests the use of the mean of a data set rather than single results in risk assessments in *Guidance on Comparing Soil Contamination Data with a Critical Concentration*, Claire 2008.

As no Made Ground is found on the site and no activities or land-use likely to impact soils with arsenic have been carried out on this site, we conclude that the elevated arsenic detected locally is not due to anthropogenic influences, but a natural phenomenon most probably caused by secondary iron (limonite) enrichment of the soils. In our opinion, even the elevated arsenic levels found on this site are not likely to present a significant risk to human health. However, we recommend the emplacement of 400 mm of low arsenic Topsoil in the future gardens, certainly in the areas around WS5 and WS6, where elevated arsenic was proven in shallow soils.

11.3.2 Risk Assessment – Controlled Waters

The potential risk to groundwater has been assessed using the Environment Agency's *"Hydrogeological risk assessment for land contamination", Remedial Targets Worksheet Release 3.1,* Workbook Issue October 2006. This methodology is based on a risk assessment approach incorporating a source-pathway-receptor analysis that leads to the derivation of site specific remediation criteria (if required), based on an assessment of the potential impact on the identified receptor. The methodology uses a tiered approach to determine risk based remedial targets.

For this site, Tier 1 risk assessments have been carried out for arsenic, chromium, lead, nickel, copper and zinc. In this risk assessment, the target levels were based on the *2001 The Water Supply (Water Quality) Regulations.* The detailed data sheets are presented in Appendix I. Table 4 below compares the *EA* Level 1 remediation targets for the contaminants included in the risk assessments with the mean and maximum concentrations detected on site.

Table 4: Comparison of Contaminants Identified in Soils on Site with Calculated Site-Specific Environment Agency Level 2 Remediation Targets (all in mg/kg)

Contaminant	*EA* Level 1 Remediation Target Level	Site Maximum	Site Mean
Arsenic	34	112	30.8
Lead (inorganic)	428	78	32.5
Chromium	745	53	29.9
Nickel	336	68	17.6
Copper	8000	30	15.7
Zinc	210	102	58

With the exception of arsenic, even the maximum detected concentration of any of the analytes listed on Table 4 did not exceed the *EA* Level 1 Remediation Target Level. Five samples were found to exceed 34 mg/kg arsenic: sample TL14 from WS3 at 2.00 – 3.00 mbgl contained 90 mg/kg arsenic; sample TL17 from WS4 at 1.00 – 2.00 mbgl contained 35 mg/kg arsenic; sample TL19 from WS5 at 0.50 – 2.30 mbgl contained 51 mg/kg arsenic; sample TL22 from WS6 at 0.30 – 1.50 mbgl contained 41 mg/kg arsenic; and sample TL35 from WS10 at 1.00 – 2.00 mbgl contained 112 mg/kg arsenic. However, no leachable arsenic was detected. This suggests that the arsenic present in the soils this site, which does not have an anthropogenic origin, is unlikely to be mobilised into the local groundwater. The new development will significantly reduce the catchment area on the site.

11.4 Combined Risk Assessment

Table 5: Combined Risk Assessment

Source	Pathway	Receptor	Risk Estimate
Arsenic	Inhalation, dermal contact	Human health	Low: localised elevated results due to natural causes, with the greatest concentration below 1.00 mbgl
Arsenic	Lateral and downward migration	Groundwater	Low: localised elevated results due to natural causes, no soluble arsenic detected
Other Metals	Inhalation, dermal contact, ingestion	Human Health	Very Low: only low concentrations detected
Other Metals	Lateral and downward migration	Groundwater	Very Low: only low total and no/very low soluble concentrations detected
Hydrocarbons	Inhalation, dermal contact, ingestion	Human Health	None/Very Low: none detected
Hydrocarbons	Lateral and downward migration	Groundwater	None/Very Low: none detected
Ground Gas	Lateral migration, concentration in confined spaces	Human Health	Low risk from carbon dioxide due to presence of Chalk underlying the site
Asbestos	Inhalation	Human Health	None: no asbestos identified

12.0 GEOTECHNICAL EVALUATION

12.1 Engineering Properties

Introduction

This section presents a ground model for the site and describes the engineering properties of the key strata types based on field observations, engineering logs, in situ and geotechnical laboratory test results.

It is understood that the proposed development comprises the construction of twenty-six (26) residential properties and associated infrastructure. At present no loads have been provided for the structures associated with the development. Therefore typical loadings for similar developments have been assumed. For this assessment it is anticipated that potential structures and connecting infrastructure are settlement sensitive. The engineering properties of the various strata encountered are discussed in turn below, with a short summary of outline design considerations. Full factual records of the geotechnical laboratory testing results are presented in Appendix F.

Ground Model

The strata beneath the Site can be split into three main layers: Topsoil, Clay with Flint and Chalk with all three materials encountered or anticipated to be present across the Site. The engineering properties of the various soil strata are discussed below. Full factual records of geotechnical laboratory records are presented in Appendix F.
Design considerations derived from these figures and the in-situ testing data presented on pages 10 to 14 above are discussed in the Geotechnical Assessment in Section 12.2.

Topsoil

Topsoil was encountered across the site to a maximum depth of 1.00 mbgl, but generally to around 0.30 m, and comprised dark brown silty sandy clay with flint gravel and roots.
No geotechnical testing was carried out on this material.

Clay-with-Flints

Clay-with-Flints of variable thickness was encountered across the site beneath the Topsoil. Generally cohesive, locally it occurs with granular materials ranging from sand pockets and bands to more extensive granular deposits. Occasional bands of flint gravel and cobbles are noted locally across the site.
The cohesive Clay-with-Flints comprise stiff to very stiff, locally firm or soft orange brown silty sandy clay with flint and chalk gravel, traces of limonite, and locally with lenses of sand. The granular Clay-with-Flints fraction consists of orange brown clayey silty sand with lignitic and limonite staining, locally with clay lenses.

The thickness of the Clay-with-Flints is highly variable across the site, with the base of this material ranging from 1.50 mbgl to in excess of 10.00 mbgl. There is no apparent pattern to this distribution, suggesting the underlying Chalk surface is irregular and undulating. Significant variations in thickness of the Clay-with-Flints were observed over relatively small lateral distances during the ground investigation. It should be appreciated that substantial localised variability in thickness of this material will be encountered across the site, and may occur even within individual building plots. The engineering properties of the Clay-with-Flints, obtained from the limited geotechnical testing carried out, are presented in Table 6 on page 24 below.

The results of the geotechnical testing suggest the Clay with Flints to be variable in strength. Figure 7 presents the variation in SPT value for this material with depth. This appears to show no apparent increase in strength with depth. It should be noted that locally low SPT values were noted in this material, such as in WS4 and in WS11.

In-situ shear strengths of the cohesive Clay-with-Flints were not available However, the estimated shear strength of the clay ranges from 17 to 155kPa, corresponding to very low to very high strength clay and correlating with the field estimates of stiff to very stiff, locally soft to firm clay.

Table 6: Summary of Engineering Properties, Clay-with-Flints

		No of Results	Range		Average (mean)	Suggested Characteristic Value
SPT 'N' value	Cohesive	44	4-36		16	14
	Granular	11	16-35		22	22
Undrained Shear Strength from SPT (cohesive material) (kPa) [b]		44	17-155		70	60
Phi (Ø from SPT (granular material)[a]		11	32-37		33	33
Modulus of Volume Compressibility Mv (cohesive material) (m^2/MN))[c]		44	0.015-0.60		0.15	0.16
Natural moisture content (%) (cohesive)		2	12-19		15	19
Liquid limit (LL) (cohesive)		2	43-71		57	71
Plastic Limit (PL) (cohesive)		2	17-25		21	25
Plastic Index (PI) (cohesive)		2	26-46		36	46
Particle Size Distribution (%) (Cohesive)		1	Cobbles	Gravel	Sand	Silt/Clay
			0	0.2	75.7	24.1

[a] Based on a correlation by Peck, Hanson and Thornburn, Foundation Engineering, 2nd ed., 1974, John Wiley and Sons.

[b] estimated from a correlation by Stroud and Butler (1975) using plasticity index of 44 and Cu/N = 4.3.

[c] estimated from a correlation by Stroud and Butler (1975) using plasticity index of 44 and 1/mv.N = 0.418.

The cohesive Clay-with-Flints is indicated to be of intermediate to very high plasticity with moisture contents dry of the plastic limit, also correlating with the field estimates of stiff to very stiff material.

Estimates of the modulus of compressibility indicate the cohesive Clay-with-Flints to be of low to medium compressibility.