

CONSULTING ENGINEERS

CIVIL • STRUCTURAL
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**PROPOSED RESIDENTIAL DEVELOPMENT
GRESFORD ROAD,
LLAY, WREXHAM
FOR
ANWYL CONSTRUCTION & BELLWAY HOMES LTD**

FINAL ISSUE

JULY 2017

**GEO-ENVIRONMENTAL INVESTIGATION REPORT
17040/GEIR**

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EXECUTIVE SUMMARY

Site	The site is irregular in shape and extends to an area of approximately 15.63 hectares. It is situated upon the northern eastern side of Gresford Rd, Llay approximately 6.0km north of Wrexham town centre.
NGR	SJ 33697 562657
Site History	The site has remained in agricultural usage throughout its history. Former ponds located within the central area of the site have been infilled. A review of the surrounding areas has identified infilled features to the east and west of the site.
Investigations	The investigations have extended to:- • Walkover survey • Desk study • Extensive intrusive investigations by window sample, cable percussion boreholes and trial pits • Chemical analyses of soil samples • Ground gas monitoring
Ground Conditions	Topsoil has been identified over the whole site area present at varying thicknesses between 0.2 – 0.6m. Localised deposits of made ground has been identified within positions TP17, TP35, TP44 – TP47, WS7, BH3 at depths between 0.0 – 2.0m bgl comprising of intermixed soils with anthropogenic materials. Underlying the topsoil and made ground strata the majority of the natural strata within the site comprises of firm to stiff clays which have been identified at depths between 0.2 – 6.45m bgl. Within the eastern half of the site medium dense sand units are more prominent and have been identified at depths between 0.2 – 7.45m bgl. Within position WS6 brown clayey gravel is present at depths between 1.8 – 2.1m bgl. At position WS8 a brown sandy silt is present at depths between 1.8 – 2.1m bgl.
Groundwater	Ground water ingress has been identified within positions TP7, TP9, TP17, TP22, TP24, TP27, and TP30. TP32 – TP33, TP35, TP44, BH3, BH4, BH8 at depths between 0.5 – 3.5m bgl which is considered to represent the perched water within the made ground and natural strata.
Environmental	Chemical analysis has not identified any harmful concentrations of the determinands considered and the topsoil material is considered suitable for reuse within the site. Chemical analysis of the made ground material has confirmed that it is suitable for retention within the site and asbestos screening has confirmed the absence of asbestos fibres.
Trees	The site contains a number of trees located around all site boundaries and along field boundaries. The cohesive strata identified on site is classified as having a low volume change potential. A full arboriculturist report is required.
Foundations	Strip footings formed on natural clay strata with a safe bearing capacity of 100kN/m ² at a minimum depth of 0.9m below finished ground level and 0.6m below finished floor level within granular deposits. Foundation depths expected to be in the range of 0.9 - 1.5m below ground level except in areas of tree root effects where foundations may extend to depths up to 2.5m. There will be a requirement for nominal reinforcement within foundations due to variable ground conditions. Within the localities of made ground deposits associated within infilled ponds, ground works and animal burial, piled foundations may be required.
Slabs	Reinforced suspended ground floor slabs are recommended for the proposed dwelling. A full programme of ground gas monitoring has identified CS1 (NHBC Green) ground gas conditions. However, there will be a requirement to incorporate basic radon ground gas precautions within all properties of this development.
Remediation	No specific program of remediation required. The topsoil within the site is considered to be suitable for reuse within a residential environment.
Animal Burials	Targeted investigation has identified animal carcasses within positions TP32 – TP33 at depths between 0.8 – 2.0m bgl. The APHA should be notified of these so appropriate disposal should be carried out. The remaining two locations identified by the landowner have not identified animal carcasses and there will be a requirement for further investigation at these locations.
Further Works	Further investigation is required into the remaining areas where animal carcasses have not been confirmed. Investigation will be required within the locality of the existing concrete slab adjacent to Home Farm to confirm ground conditions.

This brief summary should not be assumed to represent a complete account of all the potential geo-environmental issues that may exist at the site. As such it is strongly recommended that the report be read in its entirety.

GEO-ENVIRONMENTAL INVESTIGATION WORKS**GRESFORD ROAD, LLAY, WREXHAM.****1.0 INTRODUCTION****1.1 Instructions**

1.1.1 We are instructed by Anwyl Construction, Anwyl House, Clos Dewi Sant, St David's Park, Ewloe, Deeside, CH5 3DT and Bellway Homes Ltd, 2 Alderman Road, Speke, Liverpool, L24 9LR to undertake a program of ground investigation works at a site located north east of Gresford Road, Llay, Wrexham which they intend to re-develop in a residential manner.

1.2 Object

1.2.1 The object of these investigations are as follows:

- To determine the engineering properties of the soils present within the site to form a basis upon which foundation and general infrastructure recommendations and design may be based;
- To enable sufficient information regarding ground conditions to be obtained from which risks to end users and the environment can be assessed;
- To utilise the information obtained from the investigations to provide recommendations for remediation measures where required.

1.3 Scope

1.3.1 The investigations considered within this report have comprised of the following elements:

- An initial environmental and engineering desk study based upon existing reports, services location information, geological, hydrogeology and hydrological information, a commercially available database and old Ordnance Survey maps;
- An initial walkover survey of the site has been undertaken prior to any intrusive investigations being commenced to determine the presence of any visible hazards or features which may affect the design of the ground investigation works;
- Undertake ground investigation works by trial pitting, cable percussion and window sample boreholes;
- Determine the presence, nature and extent of any soil and groundwater contamination at the site;
- Determine the presence of any toxic or explosive gasses from areas of infilling within or adjacent to the site;
- Determination of the engineering properties of the soils present within the site to form a basis upon which recommendations for foundations and infrastructure construction may be based;
- Identify the potential requirements for any remedial action, where required.

1.4 Development Proposals

- 1.4.1 *We understand that it is our client's intention that the site will be developed by the construction of three hundred and sixty two (362 No.) residential units with associated road access, garden areas and areas of POS.*
- 1.4.2 *At the time of undertaking these ground investigation works a site layout drawing, drawing reference SK01P4 has been appended to this report for reference. It is however recognised that the development proposals may be amended as a result of the planning process. If the general principles of the development proposals vary from the assumptions made within this report, than any subsequent recommendations may become inappropriate and require reassessment in the light of further information.*

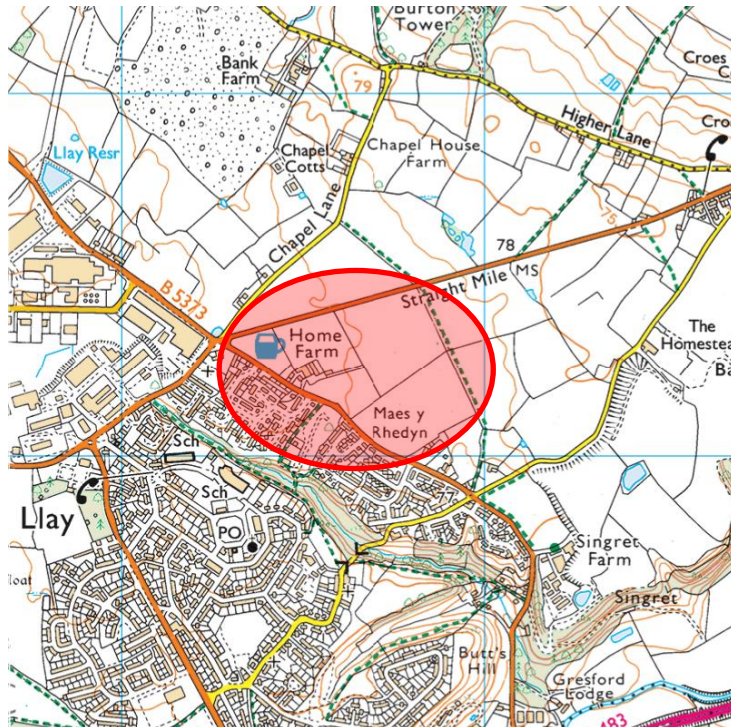
1.5 Services

- 1.5.1 *Information regarding the possible presence of live public services has been provided by our client and a drainage survey has identified the presence of a sewer located centrally within the site. It enters the site from the north west and trends in a south easterly direction towards the centre of the site where it then splits and travels in a general east to west direction and also continues south east. The drainage survey has also identified the presence of surface water outfall located within the southern corner of the site which trends in a north east to south west direction and then turns 90 degrees and travels in a south easterly direction. All remaining service drawings indicate utilities located outside of the site boundary mainly within pavement and road areas.*
- 1.5.2 *Although service information has been provided we are aware that private services may also be present thus due regard to potential live services was undertaken prior to investigation with a cable avoidance tool (CAT) and to an appropriate depth.*

2.0 THE SITE

2.1 Location

- 2.1.1 *The site is irregular in shape and extends to an area of approximately 15.63 hectares. It is located upon the north eastern side of Gresford Road, Llay approximately 6.0km north of Wrexham town centre. The site is located at an approximate National Grid Reference SJ 33697 562657 and comprises of multiple parchments of agricultural land. The site location is also shown in figure 1 overleaf.*

Figure 1 - Site Location

2.2 Boundaries

2.2.1 The northern boundary of the site is formed by Straight Mile (B5102) and the north eastern boundary is formed by a hedgerow that leads on to further agricultural fields. The south eastern boundary is formed by further agricultural fields and residential property Fernyfield. The south western boundary is formed by Home Farm and Gresford Road (B5373).

2.3 Access

2.3.1 Access to the site is gained via a private access road located at Home Farm, however it is anticipated that multiple new accesses will be created prior to development and will be agreed with the local authority.

2.4 Topography

2.4.1 The general topography of the site slopes towards the east at a general gradient of 1 : 90 however general topography across the site undulates and topographical lows are located within the most southern part of the site where seasonal ponds form. These gradients are not considered to pose potential issues in relation to this development but may need to be considered locally where they may impact upon roads and other infrastructure.

2.5 Site Conditions

2.5.1 At the time of the investigation the site was utilised as agricultural land mainly for the purpose of grazing with the presence of two seasonal ponds located within the southern area of the site.

2.6 Trees

- 2.6.1 *There are a numerous trees and shrubs located along the majority of the site boundaries as well as internal field boundaries.*
- 2.6.2 *It is strongly recommended that all trees within the proposed development area should be subject to a detailed arboriculturist report prior to any trees being removed. It is also recommended that the arboriculturist report should extend to all trees which lie outside the site area but which may lie within potentially influencing distance of any proposed buildings.*

2.7 Walkover Survey

- 2.7.1 *Prior to commencing the ground investigation works we have undertaken an initial walkover survey of the site to identify any areas which may impact upon the proposed site redevelopment works. These features are identified upon the appended walkover survey plan which is appended to this report for reference along with site walkover photographs and the Site Walkover Photograph Plan. However the main features of the site are as follows:-*

- *The whole site is utilised as agricultural land mainly for the purpose of grazing and crops;*
- *Two topographical lows have been identified within the southern part of the land which also contain standing water following a period of inclement weather;*
- *The general gradient of the site slopes towards the east where there are numerous local variations in topography;*
- *Manholes have been identified within the central area of the site which are considered to relate to the existing drainage sewer;*
- *Manholes have also been identified within the southern area of the site catered in areas of topographical low;*
- *A concrete yard area has been identified which is utilised for the storage of farming equipment and consumables;*
- *A former vehicle repair shop has been identified across Gresford Road adjacent to the western corner of the site which appears to be no longer in operation.*

2.8 Animal Burials

- 2.8.1 *During the site walkover the landowner indicated that he has previously buried farm animals that died of natural causes within the site. These locations are marked on the walkover survey plan. The landowner has indicated that within each location potentially three to four animals have been buried comprising of sheep and cattle. It is indicated that these have been buried at depths in excess of 2.5m below ground level. There will be a requirement for targeted investigations within these locations to identify any potential animal carcasses.*
- 2.8.2 *After receiving this information we have contact the Animal and Plant Health Agency (APHA) for any further information on potential animal burials within the site. The APHA have indicated no records of burials or outbreaks were identified within the site, however prior 2001 on farm burials were common place and may be present within the site itself. We have appended their response to this report for reference and a Code of Practice to prevent the spread of animal and poultry disease. They have confirmed that if animal carcasses are identified during the intrusive investigation, then these will remain in position and backfilled immediately upon identification and the positions of these carcasses will be recorded and provided to the APHA for further guidance.*

3.0 DESK STUDY

3.0.1 As part of our environmental desk studies we have commissioned an Enviro-Insight report by Groundsure which gives details of all recorded environmental features relating to the site and its immediately surrounding area. We have also obtained copies of all available old Ordnance Survey maps for the area and these give some historical guidance regarding the former usage of the site area and its immediate vicinity. A Geo-Insight report has also been commissioned which assesses the geological structures within the general area of the site.

2.1 Historical Land Uses

2.1.1 The Enviro-Insight report has identified forty (40 No.) records of potentially contaminative past land uses within 500m of the search boundary. The first record is located 8m south and relates to earth works. This is located upon the south western side of Gresford Road which has now been redeveloped in the form of Oakfield Park Home Estate. All remaining records are located in excess of 30m from the site boundary and relate to wind pump, railway siding, colliery, industrial estate, sand pit, unspecified pit, gravel pit, nursery and police station. These potentially contaminated past land uses are not considered to pose a potential source of contamination to this development.

3.1.2 The Enviro-Insight report has identified nine (9 No.) records of historical tanks within 500m of the search boundary however these are all located in excess of 385m from the site boundary.

3.1.3 The Enviro-Insight report has identified nineteen (19 No.) records of historical energy features within 500m of the search boundary however these are all located in excess of 104m from the site boundary and relate to electricity sub stations.

3.1.4 The Enviro-Insight report has identified sixteen (16 No.) records of historical garage and motor vehicle repair sites within 500m of the site boundary. Of these, five records are located 7 – 9m south west which relate to a garage. This garage has been identified during the site walkover and is considered to represent a vehicle repair site which is no longer in operation. This site is not considered to pose a potential off site source of hydrocarbon contamination to this development. All remaining records are located within excess of 320m from the site boundary.

3.1.5 The Enviro-Insight report has identified sixty (60 No.) potentially infilled features within 500m of the study site. The first four records are located on site and relate to a pond which is located south of Home Farm, this infilled pond may indicate localised deposits of made ground and may pose a source of explosive and toxic gases within the site. Therefore there would be a requirement for ground gas monitoring that will be incorporated into the intrusive investigation within the site. Numerous potentially infilled features have been identified to the west and the south east relating to sand pits, unspecified pits and collieries. These off site infilled features pose potential sources of explosive and toxic gases to this development therefore a programme of ground gas monitoring will be required.

3.2 Environmental Permits, Incidents and Registers

3.2.1 The Enviro-Insight report has identified two (2 No.) records of historic IPC authorisation within 500m of the study site. Both records are located 409m north west which relate to Magellan Aerospace and relate to the pre-organic chemical processes.

Due to its remote locality this IPC authorisation is not considered to pose a potential source of contamination to this development.

- 3.2.2 *The Enviro-Insight report has identified two (2 No.) records of Part A (2) and Part B activities within 500m of the study site. Both records are located in excess of 380m from the site boundary and are noted to be Part B type permits. Due to the remote locality they are not considered to pose a potential source of contamination to this development.*
- 3.2.3 *The Enviro-Insight report has identified eight (8 No.) records of Licensed Discharge Consents within 500m of the study site. All records are located in excess of 238m from the site boundary and are not considered to pose a potential contaminative hazard to this development.*
- 3.2.4 *The Enviro-Insight report has identified thirty eight (38 No.) records of National Incidents Recording System (NIRS) List 2. All records are located within excess of 65m from the site boundary and have recorded impacts to land, water and air between Category 4 (no impact) and Category 3 (minor).*
- 3.2.5 *The Enviro-Insight report has identified a National Incidents Recording System (NIRS) List 1 record located 230m south west where a significant impact to water is noted, no impact to land and air. This incident is not considered to pose a potential source of contamination to this development.*

3.3 Landfill Sites

- 3.3.1 *The environmental report has identified one (1 No.) records of Environment Agency landfills located 376m north and the landfill type is noted to be household, commercial & industrial waste, due to its remote locality this landfill is not considered to pose a potential off site source of explosive and toxic gases to this development.*
- 3.3.2 *The Enviro-Insight report has identified six (6 No.) records of Environment Agency historical landfill sites within 1500m of the study site. The first record is located 197m south east and relates to Singret Quarry which is noted to receive inert industrial waste. Due to its close proximity to the site this historical landfill may pose a potential source of explosive and toxic gases to this development therefore there would be a requirement for a programme of ground gas monitoring within the intrusive investigations. All remaining historical landfill records are located in excess of 625m from the site boundary.*
- 3.3.3 *The Enviro-Insight report has identified one (1 No.) record of Local Authority landfill located 700m north west. This is not considered to pose a ground gas hazard to this development.*
- 3.3.4 *The Enviro-Insight report has identified thirty five (35 No.) records of Environment Agency waste sites within 1500m of the study site boundary. All records are located in excess of 535m of the site boundary and are considered to remote to have any potential environmental impact upon the development of the site.*

3.4 Current Land Uses

- 3.4.1 *The Enviro-Insight report has identified seven (7 No.) records of potentially contaminative industrial sites within 250m of the study site.*

The first record is located 25m to the south west and relates to Blackbrook Motors which was identified during the site walkover. The remaining records are all located in excess of 30m from the site boundary. All potentially contaminative industrial sites are not considered to pose a potential hazard to the development of this site.

- 3.4.2 The Enviro-Insight report has identified a petrol or fuel site located 108m south west however this is now noted to be obsolete. Aerial photographs confirm that this area has now been redeveloped in the form of Oakfield Park Home Estate.*
- 3.4.3 The environmental report has not identified any National Grid high voltage underground electricity transmission cables or high pressure gas transmission pipelines within 500m of the study site boundary.*

3.5 Hydrogeology & Hydrology

- 3.5.1 The superficial deposits within the vicinity of the site are designated as Secondary A and unproductive. Within the eastern half of the site superficial deposits are designated as unproductive which relates to layers of drift deposits with low permeability that have negligible significance of water supply or river base flow. The eastern half of the site comprises of secondary A aquifer which contains permeable layers capable of supporting water supplies at local rather than strategic scale and in some cases forming an important source of base flow to rivers.*
- 3.5.2 The site is located above Secondary (A) aquifer rocks which contain permeable layers capable of supporting water supplies at local rather than strategic scale and in some cases forming an important source of base flow to rivers. The development of this site in a residential manner is not considered to pose a potential hazard to the underlying aquifers within the superficial deposits and bedrock.*
- 3.5.3 The Enviro-Insight report has not identified any abstraction license within 870m of the site boundary, however records do exist beyond this distance.*
- 3.5.4 The environmental report has provided Environment Agency information on groundwater vulnerability and soil leaching potential and is classified as minor aquifer/low leaching potential with a Soil Vulnerability Category HU – L.*
- 3.5.5 The environmental report has identified four (4 No.) records of detailed river networks within 500m of the study site however these are located in excess of 210m from the site boundary. Development of the site is not considered to pose a potential hazard to these river networks.*
- 3.5.6 The environmental report has identified seven (7 No.) records of surface water features within 250m of the study site however these are located in excess of 170m of the site boundary. Development of this site is not considered to pose a hazard to these surface water features.*

3.6 Flooding

- 3.6.1 The environmental report does not indicate that the site lies within an Environment Agency flood plain area and the risk of flooding from rivers and the sea (RoFRaS) flood rating of very low. The environmental report however does identify groundwater flooding susceptibility areas within 50m of the boundary of the site and relates to superficial deposits flooding with limited potential.*

Where limited potential for groundwater flooding to occur is indicated, this means that although given the geological conditions there may be a groundwater flooding hazard, unless other relevant information e.g. records of previous flooding, suggests groundwater flooding has occurred before in this area. You need to take no further action in relation to ground water flooding hazard. A high confidence is given to this flooding susceptibility.

3.7 Environmentally Sensitive Areas

- 3.7.1 *The environmental report has not identified any environmentally sensitive areas within 170m of the site boundary although records do exist beyond this distance.*

3.8 Geology

- 3.8.1 *The Geo-Insight report has not identified any made ground deposits within the site however large deposits of made ground have been identified 77m to the west which therefore may pose a potential off site source of explosive or toxic gases to this development.*
- 3.8.2 *The superficial deposits within this site are divided into two equal formations. The eastern half of the site comprises of glaciofluvial sheet deposits which are considered to comprise of sand and gravels with alternating clay and silt units. The western half of the site comprises of glacial till considered to comprise mainly of cohesive clays, minor granular units.*
- 3.8.3 *The solid geology below the site comprises of the Salop Formation which is Westphalian D and is considered to comprise of mudstone with minor units of sandstone and conglomerates.*
- 3.8.4 *The geological report has identified one geological fault located 439m north. This geological fault is not considered to pose a potential hazard to the development in terms of minor ground movements.*
- 3.8.5 *The site is located within an area where between 5 – 10% of properties are above the action level for radon gas and therefore there is a requirement for basic radon protective measures within the development.*
- 3.8.6 *The geological report has identified numerous historical surface ground working features within 250m. The first four records are located on site and relate to a pond which is located south of Home Farm. This surface ground working feature may represent localised deposits of made ground within the development and will require targeted investigation. The remaining records are all located outside of the site boundary and are not considered to pose a potential hazard in relation to this development.*
- 3.8.7 *The geological report has identified seven (7 No.) historical underground working features. All records are located in excess of 50m from the site boundary and relate to a colliery, unspecified mine and disused shafts.*
- 3.8.8 *The Geo-Insight report has identified twelve (12 No.) records of BGS current ground workings within 1000m of the study site. All records are located in excess of 89m from the site boundary and relate to sand quarries, clay pits and collieries. These current ground workings are not considered to pose a potential hazard to the development of this site.*

3.8.9 The site has been identified within a coal mining area and a Coal Authority report has been obtained. The Coal Authority report has indicated that the site is in a surface area that could be effected by underground mining and five seams of coal at depths between 660 – 1000m depth and were last worked in 1966. Any movement in the ground due to coal mining activity should have stopped. Considering the depth of coal seams are in excess of 660m below the site any potential future collapses would choke themselves out for transmitting to the surface of the site and therefore the site is not considered to be at risk from minor ground movements associated with the collapse of coal workings. Therefore there is no requirement for intrusive investigations in relation to shallow coal mine workings.

3.8.10 The geological report has identified one non coal mining site located 706m north west relating to a vein mineral. The assessment of likelihood is that its sporadic underground mining of restricted extent may have occurred. The site is not considered to be at risk of collapse of vein mineral iron workings.

3.9 Boreholes

3.9.1 The Geological report has identified four (4 No) BGS borehole records within 250m of the study site boundary. These borehole records indicate varying glacial till and glaciofluvial sand deposits identified within the desk study information.

3.10 Background Soil Chemistry

3.10.1 The Geo-Insight report includes an estimated geometric mean soil concentration of various elements. Assessment of this information suggests that the majority of soil concentrations are anticipated to be below tier 1 assessment criteria in relation to human health effects.

3.11 Site History

3.11.1 Table 1 – Review of Historical Maps

Date	Site	Adjacent Land
1872	The site comprises of two parchments of agricultural land. A pond is located centrally within the site and also two ponds located just south of Home Farm adjacent to the south western boundary.	The majority of the surrounding land comprises of further agricultural fields with sporadic ponds. The site is bounded to the north and the south east by roadways. Home Farm is located adjacent to the south east boundary.
1900	The site is now split in five parchments of land similar to its current layout.	Adjacent to the south east boundary earth works are shown and a sand pit is located approximately 100m to the south east adjacent to Oak Cottage and Vaddock Cottage.
1909	No significant change.	No significant changes.
1938	No significant change.	No significant change.
1949	No significant change.	A large gravel pit has been identified approximately 750m to the east. Large ground workings have also been identified to the west approximately 150m. These ground workings also have railway sidings associated with Llay main colliery.
1964	No significant change.	Gravel pit to the east has now extended to approximately 500m from the site boundary. Ground working railway sidings to the west have also expanded.
1981	Both ponds located within the site are no longer represented on mapping they are assumed to be infilled.	The large gravel pit to the east is noted to be disused. Partial development has taken place to the west of the former railway sidings. Earth works adjacent to the south eastern boundary are now shown to be a caravan park.
1992	A roadway is now shown to extend from Home Farm to the centre of the site.	No significant changes.
2002	No significant change.	Land to the west has now been redeveloped into a Llay industrial estate.
2010 - 2014	No significant change.	No significant change.

3.11.2 Careful appraisal of the historical maps has identified that the site remained as agricultural land throughout its entire history however ponds located within the central area of the site have now been infilled. Assessment of the surrounding land has identified ground workings located to the east and west in relation to gravel pits and railway sidings and also identified adjacent to the south eastern boundary.

3.12 Anticipated Ground Conditions

3.12.1 Based upon the information obtained during the initial desk study phase, the anticipated ground conditions are expected to comprise of strata as detailed in table 2 below.

Table 2 – Anticipated Ground Conditions

Ground Material	Anticipated Condition
Topsoil	Topsoil is assumed to be present over the majority of the site area.
Made Ground	Possible localised deposits of made ground within the areas of infilled ponds.
Glacial Till Deposits	Where present, it is anticipated that it will consist of firm to stiff sandy boulder clay with silt and sand lenses.
Glacial Fluvial Deposits	Where present, these are anticipated to consist of sands and gravels with minor clay units.
Bedrock	The underlying geology comprises of Salop formation which is considered to be at a significant depth below the site.
Ground Water	Expected to lie at depth within the bedrock aquifer and localised areas of perched water within the superficial deposits.

3.12.2 Based upon the data available within the desk study and tables 1 and 2 above, potential ground related issues associated with the proposed redevelopment of this site are likely to include the elements noted in table 3 overleaf.

Table 3 – Potential Ground Related Issues

Type of Issue	Site Specific issue	Remarks (refer to walk over survey plan)
Potential on Site Contamination Sources	1. Localised areas of made ground associated with the previously infilled pond. 2. Naturally occurring contaminates within the topsoil.	1. Refer to the desk study.
Potential off Site Contamination Sources	1. Potential ground gas migration from the former infilled gravel pit ground workings.	1. Refer to desk study.
Potential Geotechnical Hazards	1. Soft / loose ground.	1. Potential loose made ground.

3.13 Preliminary Conceptual Model

3.13.1 The information presented within this Desk Study section of this report has been used to compile a preliminary conceptual model for the site. The identified potential contaminant and receptors have been considered along with any possible pathways that may link them. The resulting pollution linkages are considered in Table 4 below. The risk classification has been estimated in accordance with the terms and definitions based upon CIRIA C552 Contaminated Land Risk Assessment, A Guide to Good Practice.

Table 4 – Preliminary Conceptual Site Model

Potential Source	Potential Receptor	Possible Pathway	Probability	Consequence	Risk	Mitigation / Investigation
Contaminated Soils	Site personnel during construction	Direct contact of soils Inhalation or ingestion of soil / dust	Lw	Md	Moderate / Low	Soil sampling during intrusive investigations. Laboratory analysis of samples
	Future site users	Direct contact of soils Inhalation or ingestion of soil / dust	Li	Md	Moderate	
	Surface water in the vicinity of the site	Leaching of contaminants through drainage system	Lw	Mi	Low	
	Ground water in aquifer	Leaching of contaminants to ground water	Lw	Sv	Moderate	
	Future site users	Vapour migration from soils	Li	Md	Moderate	
	Proposed buildings and services	Direct contact with contaminated soils	Lw	Mi	Low	
	Plants in gardens and soft landscaping	Direct contact	Lw	Mi	Low	
Contaminated ground water	Site personnel during construction	Water entering excavations	Lw	Mi	Low	Sampling of ground water (where encountered)
	Future site Users	Retained surface water	Lw	Mi	Low	
Toxic and explosive gases	Proposed buildings and occupiers	Ground gas migration into buildings	Li	Md	Moderate	Program of ground gas monitoring to be conducted
Radon gases	Proposed buildings and occupiers	Ground gas migration into buildings	Lw	Md	Moderate/Low	Basic radon gas precautions required
Key: Probability: Sv = Severe, Md = Medium, Mi = Mild, Mr = Minor Consequence: Hi = High, Li = Likely, Lw = Low Likelihood, UI = Unlikely						

4.0 SITE WORKS

4.1 Intrusive Works

4.1.1 The ground conditions at this site have been investigated by the excavation of forty seven (47 No.) trial pits along with eleven (11 No.) window sample boreholes. These trial pits and boreholes have been intended to investigate the shallow ground conditions present within the site and the window sample boreholes have been utilised to facilitate the installation of ground gas monitoring wells within the superficial deposits. These ground investigation works have also been supplemented by the drilling of eight (8 No.) cable percussion boreholes we utilised to identify deeper ground conditions and to also facilitate the installation of ground gas monitoring wells. Trial pit excavations were supervised by a REFA engineer and the boreholes conducted by Geo-Ventures (UK) Ltd., who are a specialist ground investigation contractor.

- 4.1.2 *During the excavations and drilling works representative samples of soils encountered have been obtained for laboratory analysis and testing where considered to be appropriate.*

4.2 Locations

- 4.2.1 *The locations of the trial pits and boreholes have been chosen by ourselves in conjunction with the proposed site layout in an effort to identify the representative ground conditions present across the site area.*
- 4.2.2 *The locations of the boreholes and trial pits are indicated upon the appended exploratory hole location plan in relation to the site features present at the time of the investigation.*
- 4.2.3 *At the time of the intrusive investigation, investigations were unable to be carried out within the yard area located immediately south of Hope Farm at the request of the land owner. There will be a requirement of further investigation within this area following the removal of the concrete slab.*

4.3 Records

- 4.3.1 *During the investigations records of the strata types, water entries, ground conditions and levels within each borehole and trial pit have been maintained. This information has been collated into a series of borehole and trial pit journals which are appended to this report for reference. Representative samples of the strata encountered have been retained for laboratory testing as required and where appropriate.*

4.4 Targeting

- 4.4.1 *It has been considered that the whole of this site has been in agricultural usage throughout its recorded history. Generally a non-targeted sampling regime has been adopted for these investigations in accordance with the recommendations laid down in BS10175 : 2011 : "Investigation Of Potentially Contaminated Sites". However, some specific areas have been targeted as outlined below. Representative samples of the strata at this location have been retained for chemical analyses.*
- 4.4.2 *The window sample and cable percussion boreholes have been utilised to allow the installation of gas monitoring equipment to assess potential ground gas migration from the infilled features.*
- 4.4.3 *Trial pits TP15, TP16, TP22, TP23, TP32 and TP33 have all been targeted within the potential burial site area as indicated by the farmer to investigate the potential presence of animal remains.*
- 4.4.4 *Positions TP 17, BH 3 and WS 7 have been targeted within areas of infilled pond to identify any potential made ground and to facilitate the installation of ground gas monitoring pipes.*
- 4.4.5 *During the intrusive investigation the landowner indicated an area located centrally within the site adjacent to the infilled pond that he utilised to dispose of demolition rubble and therefore position TP 35, TP 43 – TP 47 have been targeted within these areas to identify any potential made ground deposits.*

Table 5 - Initial Ground Investigation Strategy

Exploratory Hole No.	Target	Purpose
TP 1 – TP14, TP18 – TP21, TP24 – TP31, TP34, TP36 – TP42 WS2 – WS6, WS9 – WS11 BH2, BH4 – BH6 & BH8	General ground conditions	To determine the general nature of underlying soils and geology including: 1. Nature, distribution and thickness of made ground 2. Nature, degree and extent of potential contamination 3. Content of unacceptable material eg biodegradable matter etc. 4. Suitability of the ground for the founding of structures 5. Engineering properties of the ground 6. Monitor ground gases to assess potential risk
TP 17, BH3 & WS7	Infilled pond areas	
TP35, TP43 – TP47	Infilled groundworks	
TP15, TP16, TP22, TP23, TP32, TP33	Burial Sites	1. Identify any potential animal carcasses
BH1, BH7, WS1, WS8	Shallow ground conditions and possible ground gases	1. Monitor ground gases to assess potential risk

5.0 **GROUND CONDITIONS**

5.0.1 These intrusive investigations have identified variable ground conditions across the whole site and therefore table 6 below provides a geological summary of the ground conditions identified during the intrusive investigations.

5.1 **Topsoil**

5.1.1 These investigations have located the presence of surface topsoil across the majority of the site at varying thicknesses between 0.2 – 0.6m bgl. This has identified a significant volume of topsoil for potential reuse on site following chemical assessment.

Table 6 – Geological Summary							
Stratum	Description	SPT ‘N’ Value	Typical Depth: (m bgl)				Location
			TOP:		BASE:		
			MIN	MAX	MIN	MAX	
TOPSOIL	Brown silty sandy clay with rootlets	N/A	0.0	0.0	0.1	0.6	TP1 – TP4, BH1 – BH8, WS1 – WS11
MADE GROUND	Intermixed soils with anthropogenic materials	10 - 11	0.0	0.8	0.7	2.0	TP17, TP35, TP44 – TP47, WS7, BH3
ANIMAL REMAINS	Intermixed soils with animal remains	N/A	0.3	0.3	2.0	2.0	TP32 – TP33
Firm to Stiff CLAY	Firm to stiff slightly sandy slightly gravelly CLAY	9 - 33	0.2	5.0	0.5	6.45	TP1 – TP6, TP8 –TP26, TP29 – TP31, TP33 – TP47, WS1 – WS2, WS4 – WS10, BH1 – BH8
Medium dense SAND	Brown silty clayey gravelly fine to coarse SAND	7 -31	0.2	6.10	0.6	7.45	TP1 – TP4, TP7 – TP9, TP22, TP24, TP26 – TP28, WS1 – WS5, WS7, WS11, BH4 – BH7
SILT	Brown slightly sandy SILT	N/A	1.8	1.8	2.1	2.1	WS8
GRAVEL	Brown clayey fine to coarse surrounded GRAVEL	N/A	1.8	1.8	2.1	2.1	WS6

5.2 Made Ground

5.2.1 Within positions TP17, TP32 – TP33, TP35, TP44 – TP46, WS7 and BH3 made ground deposits have been identified comprising of intermixed soils with anthropogenic materials. This made ground strata has been proven to a maximum depth of 2.0m bgl. No visual or olfactory evidence of contamination was identified within the made ground strata however the presence of anthropogenic materials indicates the potential for non-visible contaminants.

5.2.2 The made ground strata is to be variable in consistency and therefore is considered unsuitable of offering a uniform safe bearing capacity.

5.2.3 Within position TP32 and TP33 evidence of animal remains were identified within the made ground material. Upon the identification of these remains trial pits were terminated and back filled immediately. These remains will require reporting to the APHA who will then in turn contact the duty vet for the appropriate disposal of animal remains prior to development proceeding.

5.3 Natural Strata

- 5.3.1 Majority of exploratory holes within this site have identified firm to stiff clays which have been proven to a maximum depth of 6.45m bgl. During the field work insitu hand shear vane testing were conducted within the cohesive materials and recorded hand shear values between 31 – 129 kPa. Within the boreholes standard penetration tests (SPT's) recorded "N" values between 9 – 33 blows/300mm. Assessment of these results indicates that the natural clay strata within this site is capable of offering a safe bearing capacity of at least 100kN/m² at a minimum depth of 0.9m bgl. Greater bearing capacities may be achieved with depth in agreement with the Building Inspector and foundations engineer.
- 5.3.2 Within the eastern half of the site sand units become more prominent have been identified at depths varying between 0.2m – 7.45m bgl. The presence of these sand units within the eastern half of the site confirm the desk study information indicating glaciofluvial deposits within this half of the site. SPT's generated within the sand deposits recorded "N" values between 7 – 31 blows/300mm and therefore sand within the clays is considered capable of offering a safe bearing capacity of at least 100kN/m² at a minimum depth of 0.6m bgl.
- 5.3.3 Within position WS 8 brown slightly sandy silt was identified at depths between 1.8m - 2.1m and a brown clay fine to coarse gravel was identified within position WS 6 at depths between 1.8m – 2.1m.

5.4 Bedrock

- 5.4.1 These investigations have not identified the presence of bedrock within the site and it is anticipated that bedrock lies at a significant depth below the site.

5.5 Groundwater

- 5.5.1 During these investigations groundwater ingress has been identified within positions BH 3, BH 4, BH 8, TP 7, TP 9, TP 17, TP 22, TP 24, TP 27, TP 30, TP 32, TP 33, TP 35 and TP 44 at depths between 0.5m – 3.0m. This groundwater ingress is considered to represent perched water within the made ground and natural strata and groundwater table was considered to lie at significant depth below the site.
- 5.5.2 Although no significant evidence of water ingress has been identified across the site, it can be considered that the groundwater table is present at significant depth within the bedrock and within areas where cohesive natural strata is present, perched water may be present during inclement weather but may be remediated with simple sump pumping techniques, though more extensive management may be required in more extreme cases.

5.6 Excavations

- 5.6.1 The majority of natural strata within this site comprises of firm to stiff clays and expectations are considered capable of remaining open for significant periods of time. However within the eastern half of the site sand deposits are more prominent and these are anticipated to suffer instability over periods of time and are considered incapable open for significant periods of time. The sudden catastrophic collapse of any excavation made within this site is considered to represent a high risk.

- 5.6.2 *It is essential that personnel should not be allowed to approach or enter any excavation made upon this site unless appropriate precautions have been adopted to ensure that hazardous side instability has been prevented. This is particularly important in relation to foundation and drainage construction where operatives may be specifically required to enter excavations. Reference should be made to HSE Publication HSG 150 "Health and Safety in Construction" for guidance.*

5.7 Contamination

- 5.7.1 *These investigations have identified the presence of localised deposits of made ground within the site however no visual or olfactory evidence of contamination has been identified. However the presence of anthropogenic materials within the made ground indicate the potential for contaminants.*

5.8 Sampling

- 5.8.1 *Based upon the previous usage of the site representative samples of the strata encountered during these investigations have been retained for chemical analyses. This analysis has been intended to determine the potential presence of any contaminants which may represent a hazard to site operatives or end users of the site. This section of the work is considered in more detail in section 7 and 8 of this report.*

5.9 Index Testing

- 5.9.1 *Where cohesive deposits have been identified they have been considered to be potentially subject to volumetric change as a result of variation in moisture content. Accordingly a series of twenty (20 No.) samples of clay strata have been submitted to a civil engineering laboratory to determine the index properties of the clays present. Index testing undertaken upon these samples have confirmed that the soils within this site have a plasticity index in the range of 12% - 22%. Sample TP27 at 1.0m has been recorded as non-plastic and confirms that the strata within this location comprises of very clayey fine to coarse sand.*
- 5.9.2 *Nineteen of the twenty samples have recorded plasticity indices <20% and therefore the cohesive strata within this site can be considered to have a low volume change potential in relation to tree root effects in accordance with NHBC Handbook Chapter 4.2.*

5.10 Ground Gases

- 5.10.1 *The desk study information has identified infilled features within the site and to the east and west of the site and therefore there is a potential for ground gas migration to the site.*
- 5.10.2 *Six (6 No.) boreholes have been utilised for the installation of ground gas monitoring standpipes to assess the potential risk of ground gas migration from the identified infilled areas within the desk study.*

5.11 SUDS

- 5.11.1 *Assessment of the ground conditions present within this site in terms of sustainable urban drainage suggests that the majority of the site is effectively impermeable natural deposits at shallow depth will not allow the dissipation of surface water within the site area. Even where granular deposits are more prominent within the eastern half of the site there appears to be no lateral continuity and therefore variable permeability rates are assumed.*

It is our opinion based upon the results of these investigations that the ground conditions within this site are not conducive to the adoption of a soakaway or other ground infiltration system of drainage for surface water disposal.

6.0 GAS MONITORING

6.1 General

6.1.1 *The initial desk study for this site has identified the potential for migration of toxic and explosive gasses from previously infilled areas located to the east and west of the site. Accordingly a program of ground gas monitoring has been included within these investigations to determine the extent of any potential hazard.*

6.2 Installation

6.2.1 *To identify the presence of possible ground gases six (6 No.) boreholes have been completed as permanent gas monitoring points. These boreholes and standpipes have been targeted to the east and west of the site and identify migrating gases off site. A standpipe has been installed within position BH03 to identify any potential ground gas generated from the infilled pond area. The response zones within the stand pipes have been constructed at depths varying between 0.5 – 7m bgl.*

6.2.2 *The installations have included for the insertion of high density polyethylene 50mm diameter plain and slotted standpipes. The annulus space around the standpipe has been filled with non-calcareous pea gravel in the range of 2mm – 5mm. The upper 1.0m of the borehole (upper 0.5m BH3) has been sealed with bentonite clay and both positions have been finished with a gas tap and lockable steel cover. Full details of the installations are appended to this report for reference.*

6.3 Dates

6.3.1 *A complete programme of ground gas monitoring has now been completed which commenced on the 27th March 2017 and continued until 6th July 2017.*

6.3.2 *During the monitoring programme position WS07 was not monitored on the final monitoring visit on the 6th July as this was damaged and lost due to farming activity. Position WS8 was not monitored on the final visit on the 27th May and 6th July due to agricultural activity and damaged covers. However at least three (3 No.) standpipes have been monitored six times over a period of 3 months in accordance with the guidance CIRIA C665.*

6.4 Procedure

6.4.1 *The installation of the gas wells and gas monitoring procedures have been based upon the recommendations laid in CIRIA C665 "Assessing Risks Posed by Hazardous Ground Gasses to Buildings". In accordance with that documentation, it is intended that the period of monitoring will be up to 3 months with at least six gas monitoring visits being undertaken during that period. This assessment is based upon tables 5.5a and 5.5b and relates to a residential development with a very low potential source of gas.*

6.5 Range

6.5.1 *The installed wells are to be monitored for flammable gas (calibrated to methane, carbon dioxide, oxygen and gas flow) using a portable infrared gas analyser. Full details of the analysis program and assessment are presented within the appendix of this report.*

6.6 Monitoring

6.6.1 The recommendations require that gas monitoring rounds should encompass various climatic conditions particularly in relation to atmospheric pressure but including at least one period of falling pressure with one during and after heavy rainfall.

6.7 Results

6.7.1 A full programme of ground gas monitoring has been conducted and this is presented within the appendix of this report. However a summary of the monitoring results are detailed in table 7 below.

Table 7: Summary Of Gas Monitoring Results (complete)

Location	No Of Monitoring Occasions	Methane % v/v	Carbon Dioxide % v/v	Oxygen %	Flow l/hr	W.L. Depth	Base of Installation (m)	Atmospheric Pressure (mB)
BH1	6	0.0 - 0.1	0.2 - 0.4	17.4 - 20.3	0.0	Dry - 5.52	6.0	1013 - 1022
BH3	6	0.0	0.6 - 1.9	19.7 - 20.2	0.0	0.26 - 0.73	2.5	1013 - 1022
BH7	6	0.0 - 0.1	0.0 - 1.2	19.3 - 20.6	0.0	0.67 - 6.6	7.0	1013 - 1022
WS1	6	0.0 - 0.1	0.0 - 0.4	19.9 - 20.6	0.0	DRY	4.0	1013 - 1022
WS7	5	0.0	0.0 - 0.1	20.4 - 20.6	0.0	0.7 - 0.78	4.0	1013 - 1022
WS8	4	0.0	0.0 - 0.1	20.4 - 20.6	0.0	0.82 - 1.02	4.0	1013 - 1022

Note ND - none detected

6.7.2 Based upon the monitoring data calculations we have confirmed that the maximum gsv for methane is 0.0001l/hr and 0.0019l/hr for carbon dioxide. Reference to table 8.5 of CIRIA C665 confirms that based upon these gsv values this site should be classified as Characteristic Situation 1 (NHBC Green). There are no recorded incidences of methane above 1.5% or carbon dioxide above 5% and therefore there is no requirement to raise the Characteristic Situation by one level. Although the ground gas monitoring indicates no requirement for ground gas precautions within the development, the site is located within an area where **basic radon ground gas precautions** are required within all properties within this development.

7.0 CONTAMINATION ANALYSIS & ASSESSMENT CRITERIA

7.1 Sampling

7.1.1 A total of twenty five (25 No.) samples of topsoil and made ground encountered during these investigations have been retained for chemical analyses. Generally these samples relate to the topsoil and made ground conditions located within the site. These samples are considered to be representative of the shallow ground conditions within the site and form a basis for assessment of their potential for reuse within a residential environment.

7.1.2 All samples obtained from this site were considered to be subject to a program of PAH analyses. Accordingly, all samples have been placed into a 250ml wide necked brown glass jar. All soil samples have been stored in cool boxes at temperatures of approximately 4° (+/- 2° centigrade) until delivery in the selected laboratory. All sample containers were marked with the site address, trial pit and borehole number, depth and date of sampling.

All samples have been tested within the specified handling period to accord with the sampling protocol presented by Exova Laboratories.

7.2 Range

These investigations have identified the presence of three distinct strata types within this site.

- 7.2.1 The site contains a layer of topsoil over all areas of the site and varies in thickness from 0.2 – 0.6m. The topsoil strata is considered to represent material that can be potentially reused on site following chemical analysis.*
- 7.2.2 Localised areas of made ground have been identified and may hold the potential for contaminants. Accordingly a sampling and testing program has been undertaken upon these made ground materials and the samples have been obtained from varying depths to determine any variation in contaminant content and vertical profile.*
- 7.2.3 The natural strata identified within this site comprises mainly of slightly sandy clays, more prominent sand units are present within the eastern half of the site. This material is normally considered free from any potential contaminative influences and reference to the initial desk study has confirmed no evidence to suggest naturally arising elevated concentrations of contaminants within the natural strata.*

7.3 Laboratory

- 7.3.1 All samples selected for chemical analyses have been returned to Exova (UK) Laboratories who are an MCERTS and UKAS accredited laboratory facility. Each sample has been subject to a range of chemical analyses to determine the concentrations of a wide range of common contaminants and confirmation of the UKAS and MCERTS accreditation for each test is indicated within the results.*

7.4 Development Proposals

- 7.4.1 We are aware that the site is to be re-developed on a private residential basis and that the proposals include for the preparation of private garden areas. The majority of the site will be covered by buildings, hard standing and access road ways. Clearly however it is essential to ensure that the materials present within the sensitive garden areas are suitable for retention within a residential environment.*

7.5 Analysis Range

- 7.5.1 The initial desk study and preliminary conceptual model confirm that this site is unlikely to have been affected by contamination based upon its history. However a number of issues relating to the site may have generated potentially hazardous contamination and these are as follows:-*
 - Possible contamination within localised deposits of made ground;*
 - Naturally occurring contaminants within the topsoil.*
- 7.5.2 Table 8 below confirms the range of analyses undertaken upon the samples of soil obtained from this site.*

Table 8 – Table of Chemical Testing

Analysis Suite	Determinands	No. of Samples
<i>Metals</i>	<i>Arsenic, Cadmium, Chromium (total), Copper, Lead, Mercury, Nickel, Selenium, Zinc</i>	<i>25</i>
<i>Organics 1</i>	<i>PAH – USEPA 16 suite, Phenol</i>	<i>25</i>
<i>Organics 2</i>	<i>TPH (CWG), BTEX</i>	<i>3</i>
<i>Inorganics</i>	<i>Cyanide, Soluble sulphates, Sulphide, pH, Organic matter</i>	<i>25</i>
<i>Asbestos</i>	<i>Asbestos Screen</i>	<i>5</i>

7.6 Results

7.6.1 *The full results of the testing program are appended to this report and should be read in conjunction with the comments and recommendations regarding risk assessments.*

7.7 Approach

7.7.1 *The current UK approach to the consideration of contaminated land is based upon the principles of risk assessment. This in turn is founded upon the use of a source-pathway-target principle in order to establish the presence of a potential pollutant linkage. Our approach to the risk assessment is consistent with UK guidance and best practice. As advocated in the EA Policy Statement : Guidelines For Environmental Risk Assessment And Management a tiered approach has been adopted. This tiered approach is central to Part IIA of the Environmental Protection Act 1990 and the Town and Country Planning Act 1990.*

7.8 Site Classification

7.8.1 *The current development proposals for this site confirm that the site will be developed on a private residential basis utilising large areas of private gardens. Accordingly the site usage has been considered on the basis of an end land use of residential as defined by EA Science Report SC050021/SR3 2009 in relation to the most recent soil guideline values.*

7.9 Criteria

7.9.1 *The concentrations of contaminants within the ground have been compared to a range of generic soil guideline values that have been prepared by DEFRA and the Environment Agency. Where published, soil guideline values (sgv) have been utilised as intervention values for the purpose of an initial tier 1 assessment.*

7.9.2 *At the time of the preparation of this report soil guideline values were available only for a limited number of contaminants and the development of both the CLEA model and additional soil guideline values is on-going.*

Where published soil guideline values are available they have been utilised as intervention values for the purposes of an initial tier 1 assessment. A number of sgv's have recently been updated to reflect a modern approach to the protection of human health.

7.9.3 *In March 2014 the Department for Environment Food & Rural Affairs published SP1010 : Development of Category 4 Screening Levels for Assessment of Land Affected by*

Contamination Policy Companion Document. This document provides a series of Category 4 screening levels based upon differing land uses. Reference has been made to the values presented within this report in relation to the appropriate land usage.

- 7.9.4 *Where soil guideline values were not published at the time of preparing this report, generic assessment criteria (GAC) published by Land Quality Management Ltd., in conjunction with the Chartered Institute Of Environmental Health have been adopted. The values published in the LQM/CIEH S4UL's for Human Health Risk Assessment" Registration No. S4UL3265.*
- 7.9.5 *Reference has also been made to published soil screening values presented by Atkins Ltd., under their Atrisk Subscription Service. The SSVs have been adopted where SGVs or GACs are not available. The remaining contaminants have been considered based upon information that was the best available at the time of the study.*

8.0 RESULTS OF ANALYSIS & QUALITATIVE RISK ASSESSMENT

8.1 *Model*

- 8.1.1 *As discussed above, assessment of contaminated land is based upon a simple assessment of pollutant linkages referred to as the source-pathway-target model. This assessment considers the current or proposed usage of the site in terms of suitability for use. This implies the use of risk assessment in principle in order to evaluate the potential effects and concerns of contamination on a site-specific basis.*
- 8.1.2 *Initial assessment of the chemical analyses results has been undertaken to assess the concentrations of determinands in relation to tier 1 assessment criteria. The summary of these test results is detailed overleaf.*

8.2 *Results Summary*

- 8.2.1 *The following tables 9 - 12 have been prepared as a summary of the laboratory analyses depending upon the class of analyses undertaken. The test results have been compared to the adopted assessment criteria, relating to a proposed residential land usage.*
- 8.2.2 *All samples obtained during these investigations have been considered in each table. Principally the tables below relate to topsoil and made ground strata and assess its suitability for reuse.*

Table 9: Summary of Contamination Analysis: Metals & Inorganics

	No. of Samples	Range of Values (mg/kg)	Assessment Criteria (mg/kg)	No. of Samples Failing	Locations
Arsenic	25	<2.0 – 43.0	37 ³	1	TP44 – 0.4m
Cadmium	25	<1.0 – 2.0	11.0 ³	0	-
Chromium (total)	25	9.0 – 29.0	910 ³	0	-
Copper	25	11.0 – 200.0	2400 ³	0	-
Lead	25	28.0 – 233.0	200 ¹	1	TP46 – 0.2m
Mercury	25	<1.0	40 ³	0	-
Nickel	25	9.0 – 47.0	180 ³	0	-
Selenium	25	<1.0	250 ³	0	-
Zinc	25	42.0 – 490.0	3700 ³	0	-
Total Cyanide	25	<1.0 – 2.0	34.0 ²	0	-
Phenol	25	<1.0 – 3.0	200 ³	0	-
pH	25	5.86 – 7.49	-	0	-
SOM %	25	2.4 – 11.1	-	0	-
SO ₄ (2:1)	25	0.01 – 0.07	0.5 ⁴	0	-
Asbestos	5	ND	Absent/Present	0	-

¹ DEFRA : SP1010 : Category 4 Screening Levels
² Atkins Atrisk SSV residential with home grown produce (1% SOM)
³ LQM and CIEH S4UL's for Human Health Risk Assessment (Registration No. S4UL 3265)
Residential with home grown produce (2.5% SOM)
⁴ BRE Special Digest 1:2005 DS-1 (units in g/l) ND – None Detected

8.3 Metals & Inorganics

- 8.3.1 Reference to table 9 above confirms the range of contaminants considered within this series. One exceedance of arsenic has been identified within sample TP44 at 0.4m which relates to made ground material. The adopted assessment criteria for arsenic is 37mg/kg and the exceedance has recorded 43mg/kg which is considered only to be a marginal exceedance and does not pose a potential hazard to long term end users of the site.
- 8.3.2 An exceedance of lead has been identified within sample TP46 at 0.2m which also relates to made ground material. The assessment criteria for lead is 200mg/kg and the exceedance has recorded 233mg/kg. This again is considered to be a marginal exceedance of the assessment criteria and no further elevated lead concentrations were identified. Therefore this lead concentration is not considered to pose a potential hazard to long term end users of the site.
- 8.3.3 Where made ground has been accounted containing demolition material samples have been screened for the presence of asbestos. Five (5 No.) samples of made ground confirmed the absence of asbestos fibres within the made ground. Therefore there is no requirement for remediation due to asbestos fibres within the site.

Table 10: Summary of Contamination Analysis: Organics: PAH USEPA 16 Suite

	No. of Samples	Range of Values (mg/kg)	Assessment Criteria ¹ (mg/kg)	No. of Samples Failing	Locations
Acenaphthene	25	<0.1	510	0	-
Acenaphthylene	25	<0.1	420	0	-
Anthracene	25	0.1	5400	0	-
Benzo[a]anthracene	25	<0.1 – 0.6	11.0	0	-
Benzo[a]pyrene	25	<0.1 – 0.8	5.0 ²	0	-
Benzo[b]fluoranthene	25	<0.1 – 1.2	3.3	0	--
Benzo[ghi]perylene	25	<0.1 – 0.6	340	0	-
Benzo[k]fluoranthene	25	<0.1 – 0.5	93	0	-
Chrysene	25	<0.1 – 0.9	22.0	0	-
Dibenz[ah]anthracene	25	<0.1 – 0.2	0.28	0	-
Fluoranthene	25	<0.1 – 0.9	560	0	-
Fluorene	25	<0.1	400	0	-
Indeno[123-cd]pyrene	25	<0.1 – 0.5	36.0	0	-
Naphthalene	25	<0.1	5.6	0	-
Phenanthrene	25	<0.1 – 0.4	220	0	-
Pyrene	25	<0.1 – 0.9	1200	0	-

¹ LQM & CIEH S4UL's for human health risk assessment (Registration No. S4UL 3265) – Residential with home grown produce (2.5% SOM)

² DEFRA : SP1010 : Category 4 Screening Levels

8.4 Speciated PAH

8.4.1 The soil samples retained from these investigations have been subject to a programme of analyses which have assessed the concentrations of the individual constituents of the polycyclic aromatic hydrocarbon series. A summary of the topsoil and made ground samples are shown in tables 10 above. The assessment criteria utilised are based upon the presence of 2.5% soil organic matter within the samples generally. Reference to the tests results does however show variable soil organic matter content.

8.4.2 Assessment of table 10 above confirms that the topsoil and made ground samples show no exceedances of various PAH compounds in relation to the adopted assessment criteria. No specific remediation is required in terms of PAH compounds.

Table 11: Summary of Contamination Analysis: Organics: TPH (CWG) Suite

	No. of Samples	Range of Values mg/kg	Assessment* Criteria mg/kg	No. of Samples Failing	Notes
Aliphatic EC> 5 – 6	3	<0.01	78.0	0	
Aliphatic EC> 6 – 8	3	<0.01	230	0	
Aliphatic EC> 8 - 10	3	<1.0	65.0	0	
Aliphatic EC> 10 - 12	3	<1.0	330	0	
Aliphatic EC> 12 - 16	3	<1.0	2400	0	
Aliphatic EC> 16 - 35	3	2.2 – 9.0	92000	0	
Aliphatic EC> 35 - 44	3	<1.0	92000	0	
Aromatic EC> 5 - 7	3	<0.01	140	0	
Aromatic EC> 7 - 8	3	<0.01	290	0	
Aromatic EC> 8 - 10	3	<1.0	83.0	0	
Aromatic EC> 10 - 12	3	<1.0	180	0	
Aromatic EC> 12 - 16	3	<1.0	330	0	
Aromatic EC> 16 - 21	3	<1.0 – 1.6	540	0	
Aromatic EC> 21 - 35	3	2.0 – 5.0	1500	0	
Aromatic EC> 35 - 44	3	<1.0	1500	0	

*Criteria values based upon LQM and CIEH S4UL's for human health risk assessment (Registration No. S4UL 3265) – Residential with home grown produce (2.5% SOM)

8.5 Speciated TPH (CWG)

- 8.5.1 The presence of made ground has raised the potential for hydrocarbon contamination being present. All samples of the made obtained from this site has been subject to detailed analysis to determine the presence of petroleum hydrocarbons. The results of this testing program are summarised in table 11 above.
- 8.5.2 The summaries clearly demonstrate that hydrocarbons are not present at elevated concentrations in any of the made ground samples selected for testing. These results indicate that the soil samples tested do contain hydrocarbons, although they are below the detectable limit. This site does not require any specific remediation in terms of hydrocarbon contamination.

Table 12: Summary of Contamination Analysis: Organics: BTEX Suite

	No. of Samples	Range of Values (mg/kg)	Assessment* Criteria (mg/kg)	No. of Samples Failing	Notes
Benzene	3	<0.01	0.17	0	
Toluene	3	<0.01	290	0	
EthylBenzene	3	<0.01	110	0	
M/P Xylenes	3	<0.01	140	0	
O Xylene	3	<0.01	140	0	
Methyl tert-Butyl Ether	3	<0.01	20 ¹	0	
* Criteria values based upon LQM & CIEH S4UL's for human health risk assessment (Registration No. S4UL 3265) – Residential with home grown produce (2.5% SOM)					
¹ Atkins Atrisk SSV residential with home grown produce (1% SOM)					

8.6 BTEX

- 8.6.1 As part of the analysis for petroleum hydrocarbons the BTEX fractions have also been assessed. Reference to table 12 above confirms no elevated concentrations of any of the BTEX fractions within samples representative of the made ground strata. Widespread hydrocarbon contamination is therefore not considered to represent a hazard at this site.

8.7 Sulphates

- 8.7.1 Within the program of laboratory testing each sample has also been analysed to determine the concentration of water soluble sulphates within the ground. Reference to the laboratory results presented by Exova confirms that soluble sulphates are present at concentrations are between 0.01 – 0.07g/l. Reference to BRE Special Publication 1 : 2005 “Concrete in Aggressive Ground” confirms that at <0.5g/l, the design sulphate class for this site is DS-1. Accordingly the ACEC class for the site is assessed to be AC-1s on the basis that the site does not have mobile groundwater and the pH value is >5.5. Reference to Table D of BRE Special Publication 1 indicates that the DC class for this site should be considered to be DC-1.

9.0 DISCUSSIONS

9.1 General

- 9.1.1 *The initial desk study of this site has identified a history which has been consistent with agricultural usage although infilling works have taken place adjacent to the south western boundary in relation to a historic pond.*

A review of the surrounding land has also indicated numerous infilled features located to the east and west that may pose a potential ground gas source. The initial walkover survey of the site has identified the presence of agricultural fields used for grazing and our initial appraisal of the site has not identified any direct visible evidence of any potentially hazardous contamination but nevertheless consideration of possible non-visible contamination has been considered within this report.

- 9.1.2 *The results of the chemical analyses undertaken upon representative samples of the strata obtained from this site have been assessed in section 7 above and are subject to further discussion below.*

- 9.1.3 *Prior to the intrusive investigation the land owner indicated to us the presence of buried farm animals within the site, these have been identified and targeted within the investigations. Of the three locations one location has proven to contain animal remains and will require consultation with the APHA and appropriate disposal. Further investigation is required in the remaining two locations.*

9.2 Metals & Inorganics

- 9.2.1 *The analysis undertaken upon this suite of determinands has identified one marginally elevated concentration of arsenic and one marginally elevated concentration of lead. Consideration of these concentrations is not considered to pose a potential hazard to the long term end users of the site. Therefore topsoil material and made ground is suitable for retention within the proposed development.*

9.3 PAH Suite

- 9.3.1 *The analysis has confirmed that no elevated concentrations of PAH compounds are present within the samples of topsoil and made ground. No specific remediation is required in terms of PAH contamination.*

9.4 Petroleum Hydrocarbons

- 9.4.1 *A program of analysis to determine the presence of the speciated fractions of the TPH (CWG) grouping have been undertaken on all of soil obtained from this site. The chemical analyses results demonstrate that the soils within this site are not affected by any significant hydrocarbon contamination. Accordingly no specific remediation measures are proposed.*

- 9.4.2 *It is important to recognise that the investigations have been limited to the sampling of trial pits and boreholes. Where any visual or olfactory evidence of hydrocarbon contamination becomes apparent during the subsequent development activities, it is strongly recommended that the attention of the appropriate authorities should be drawn to these materials to ensure that appropriate assessments are undertaken.*

9.5 BTEX

9.5.1 As part of the TPH analyses an assessment of the presence of the BTEX compounds has also been undertaken. The results demonstrate that the soils within this site are again effectively uncontaminated in respect of BTEX compounds and no remediation is considered to be necessary.

9.6 Asbestos

9.6.1 Samples of made ground screened for asbestos fibres have not identified any presence of asbestos fibres and therefore no remediation is required in terms of asbestos.

9.7 Ground Gases

9.7.1 The initial desk study has identified an infilled pond within the site and two significant infilled areas located to the east and west of the site. Therefore there is a requirement for a programme of ground gas monitoring as part of the intrusive investigation.

9.7.2 A full programme of ground gas monitoring has been conducted and identified CS1 (NHBC Green) ground gas conditions. Based upon this information there is no requirement for ground gas precautions to be incorporated within the proposed development, however the desk study in formation has identified that the site is in an area where 5 – 10% of properties are above the action level for radon gases and therefore **basic radon protective measures** are required in all properties within the site.

9.8 Conceptual Site Model

9.8.1 As a result of these intrusive ground investigations and subsequent program of chemical analyses, it has been possible to revise the preliminary conceptual site model presented in section 3. The revised conceptual site model is now shown in table 13 below.

Table 13 – Revised Conceptual Site Model

Potential Source	Potential Receptor	Possible Pathway	Probability	Consequence	Risk	Mitigation / Investigation
Contaminated Soils	Site personnel during construction	Direct contact of soils Inhalation or ingestion of soil / dust	Ul	Md	low	No specific remediation required. Topsoil considered suitable for reuse.
	Future site users	Direct contact of soils Inhalation or ingestion of soil / dust	Li	Mi	Low	
	Surface water in the vicinity of the site	Leaching of contaminants through drainage system	Lw	Mi	Low	
	Ground water in aquifer	Leaching of contaminants to ground water	Ul	Md	Low	
	Future site users	Vapour migration from soils	Ul	Mi	Very Low	
	Proposed buildings and services	Direct contact with contaminated soils	Lw	Mr	Very Low	
	Plants in gardens and soft landscaping	Direct contact	Lw	Mi	Low	
Contaminated ground water	Site personnel during construction	Water entering excavations	Lw	Mr	Very Low	No significant ground water presence
	Future site Users	Retained surface water	Ul	Mr	Very Low	
Toxic and explosive gasses	Proposed buildings and occupiers	Ground gas migration into buildings	Ul	Md	Low	CS 1 (NHBC Green)

Radon gases	Proposed buildings and occupiers	Ground gas migration into buildings	Lw	Md	Moderate/Low	Basic radon gas precautions required
Key: Probability: Sv = Severe, Md = Medium, Mi = Mild, Mr = Minor Consequence: Hi = High, Li = Likely, Lw = Low Likelihood, Ul = Unlikely						

9.9 Preliminary Remediation Proposals

- 9.9.1 Chemical analysis has confirmed that the topsoil within the site is suitable for reuse within the proposed development. The analysis has also confirmed that the made ground present within this site is also suitable for retention within the proposed development however any large physical hazards should be removed from this made ground material and placed under areas of hard standing.
- 9.9.2 It is important to note that should any visual or olfactory evidence of potential contamination become apparent during the development works, then these areas must be drawn to the attention of the appropriate authorities to allow inspection, sampling, testing and assessment to be carried out to ensure that these materials do not represent a hazard to site operatives or end users. It is important that site staff are aware that any suspicious ground conditions should be reported to the site supervisor and works suspended until investigations have been completed.
- 9.9.3 A full programme of ground gas monitoring has been completed and has identified a CS1 (NHBC Green) ground gas conditions. However there will be a requirement for basic radon ground gas precautions to be incorporated within the proposed development.
- 9.9.4 These investigations have targeted areas indicated by the land owner, where farm animals have been buried. Targeted investigations have confirmed the presence of buried animals within one location and there will be a requirement for further more extensive investigation within the two remaining areas to confirm the presence of animal bodies. Where remains have been identified there will be a requirement to consult the APHA and to carry out appropriate disposal. Based upon the results of this investigation there is a high likelihood of animal carcasses being present in the identified locations.
- 9.9.5 Copies of this ground investigation should be presented to the regulatory authorities for confirmation of their acceptance of these recommendations.

9.10 Foundations

- 9.10.1 The ground investigations have identified superficial deposits consisting of sandy clays over the majority of the site and this natural strata is considered to offer a safe bearing capacity of at least 100kN/m² at a minimum depth of 0.9m in cohesive material and 0.6m within granular strata. Due to the variance of ground conditions within the eastern half of the site it is anticipated that there will be a requirement for reinforced concrete spread strip foundation to protect against possible residual differential settlements. With close proximity to trees, tree roots may influence foundation depths which may mean they may have to extend to depths of 2.5m. Cohesive material within the site is considered to have a low volume change potential as defined by NHBC Handbook Chapter 4.2.
- 9.10.2 This ground investigation has targeted areas indicated by the land owner containing animal burial. The site investigation has confirmed one location of buried animals which will need to be dealt with by the APHA and the duty vet. During ground works if animal carcasses are identified then works should stop and the appropriate authorities should be notified.

9.10.3 This investigation has identified deposits of made ground associated with the infilling of ponds and previous ground works. Within these areas it is anticipated that deep foundations may be required and it may require piled foundations due to the instability of the made ground. A constraints plan has been appended to this report for reference.

9.11 Ground Floor Construction

9.11.1 It is recommended that all properties within this site should be provided with a suspended ground floor construction. This may be of a specialist manufactured precast concrete beam and block type arrangement, or of a designed cast insitu construction. In areas where tree root effects are critical, it will be necessary for the foundations to be designed in accordance with the requirements of the NHBC Handbook Chapter 4.2 in conjunction with the arboriculturist report. The clay soils within this site are considered to have a low volume change potential for design purposes.

9.11.2 The site is located within an area where 5 % - 10% of properties are above the action level for radon gas and therefore basic radon ground gas precautions are required within the ground floor construction of all properties on this site in accordance with BR211 : Radon "Guidance on Protective Measures for new Dwellings".

10.0 CONCLUSIONS & RECOMMENDATIONS

10.1 Remediation

10.1.1 This program of intrusive ground investigations and laboratory analyses has not identified any elevated concentrations above the adopted assessment criteria within any samples collected from topsoil or made ground. No specific program of remediation is required within this site and the topsoil material is considered suitable for reuse within the garden and soft landscaped areas of this development.

10.1.2 This investigation targeted localities where the landowner has indicated previously buried farm animals. This investigation has confirmed the location of one burial site however two burial sites have not been identified and there will be a requirement for further investigation within these locations to identify animal burials and to contact the APHA for the appropriate removal of these carcasses.

10.2 Foundations

10.2.1 The ground investigations have identified superficial deposits consisting of sandy clays over the majority of the site and this natural strata is considered to offer a safe bearing capacity of at least 100kN/m² at a minimum depth of 0.9m in cohesive material and 0.6m within granular strata. Due to the variance of ground conditions within the eastern half of the site it is anticipated that there will be a requirement for reinforced concrete spread strip foundation to protect against possible residual differential settlements. With close proximity to trees, tree roots may influence foundation depths which may mean they may have to extend to depths of 2.5m. Cohesive material within the site is considered to have a low volume change potential.

10.2.2 This ground investigation has targeted areas indicated by the land owner containing animal burial. The site investigation has confirmed one location of buried animals which will need to be dealt with by the APHA and the duty vet. During ground works if animal carcasses are identified then works should stop and the appropriate authorities should be notified.

10.2.3 This investigation has identified deposits of made ground associated with the infilling of ponds and previous ground works. Within these areas it is anticipated that deep foundations may be required and it may require piled foundations due to the instability of the made ground. A constraints plan has been appended to this report for reference.

10.3 Ground Floor Construction

10.3.1 It is recommended that all properties within this site should be provided with a suspended ground floor construction. This may be of a specialist manufactured precast concrete beam and block type arrangement, or of a designed cast insitu construction. In areas where tree root effects are critical, it will be necessary for the foundations to be designed in accordance with the requirements of the NHBC Handbook Chapter 4.2 in conjunction with the arboriculturist report. The clay soils within this site are considered to have a low volume change potential for design purposes.

10.3.2 The site is located within an area where 5 % - 10% of properties are above the action level for radon gas and therefore basic radon ground gas precautions are required within the ground floor construction of all properties on this site in accordance with BR211 : Radon "Guidance on Protective Measures for new Dwellings".

10.4 SUDS

10.4.1 Assessment of the ground conditions present within this site comprise mainly of effectively impermeable clay. Permeable sand deposits are more prominent within the eastern half of the site although there appears to be little lateral continuity of these granular units. It is therefore unlikely that surface water falling onto the site will percolate readily through the shallow strata and localised ponding with run off will occur.

10.4.2 It is our opinion based upon the results of these investigations that this site is not conducive to the adoption of a soakaway or other ground infiltration system of drainage for surface water disposal. It will be necessary for surface water to be disposed utilising an adjacent existing drainage system.

10.5 Precautions

10.5.1 Excavations within the cohesive strata on this site are considered likely to stay open for significant periods of time, although granular sand and gravel deposits have also been identified in this site and these are considered to be capable of sudden and catastrophic collapse without warning. Suitable precautions should be adopted to all excavations to ensure the health and safety of all site operatives and visitors regardless of ground conditions.

10.5.2 Ground workers should be made aware of the previous coal mining activities within the site and if they identify areas of irregular ground condition or the presence of colliery spoil, then they must stop and seek the advice of an experienced engineer to determine the possible presence of any unrecorded coal mining features.

10.5.3 If during ground works animal carcasses are identified within the ground then works must stop and the APHA must be notified.

10.6 Further Works

10.6.1 If any unusual or suspicious strata or ground conditions are encountered during the subsequent site stripping and preparation works it will be necessary for these areas to be brought to the attention of the appropriate authorities so that all necessary inspection, sampling and testing may be undertaken to determine whether these materials represent a hazard to human health. It is incumbent upon the site contractors to advise a responsible authority of any unusual findings within the site which may then be further investigated.

10.6.2 This investigation has targeted three animal burial sites but has only confirmed one location containing animal carcasses. Two remaining sites will require further investigation to identify the presence of animal carcasses within the site.

10.6.3 Further investigation will be required below the footprint of the existing concrete slab utilised as a storage area.

11.0 NOTES

11.1 *All reports are for advisory purposes only and all design decisions are the ultimate responsibility of others.*

11.2 *Unless stated otherwise the investigation has been undertaken in general accordance with the recommendations given in BS 5930 : 1999 "A Code of Practice for site Investigations" and the laboratory testing has been carried out in accordance with BS 1377 : 1990 "Methods of Test for Civil Engineering Purposes".*

11.3 *Soil and rock descriptions are generally based on the scales of strength and relative density within BS 5930 although it should be noted that in certain circumstances descriptions are based on site records or a qualitative assessment without the benefit of in-situ or laboratory test results.*

11.4 *The assessment of ground conditions given in this report is based on the results of the fieldwork and laboratory testing carried out and there may be other conditions at the site not encountered by these works, which have not been taken into account.*

11.5 *The scope of the investigation and information provided may not necessarily reflect all the geotechnical and environmental aspects related to the site, and the omission of certain items does not mean that the site is unaffected by such problems.*

11.6 *It should be noted that groundwater levels can vary and may at times be significantly different to those recorded during the investigation and attention is drawn to BS 5930 which indicates that measurements may be necessary over an extended period of time to investigate changes in groundwater pressures due to seasonal, tidal and other causes.*

11.7 *Any recommendations on construction methods within this report are for initial guidance only and all design proposals remain the responsibility of the appropriate contractor/consultant.*

11.8 *Further assessment, investigation, construction activities or time may reveal conditions that were not found during the period of investigation and, therefore, could not have been taken into account in the preparation of the report and where such information might impact upon the stated opinion R. E. Fry & Associates Ltd request the opportunity to review such information and modify the report if necessary.*

- 11.9** Where information has been obtained from sources other than the direct findings of the investigation, R. E. Fry & Associates Ltd cannot and does not guarantee the authenticity or reliability of this information.
- 11.10** Where opinions expressed in this report are based on current available guidelines and legislation, no liability can be accepted by R. E. Fry & Associates Ltd for the effects of any future changes to such guidelines and legislation.
- 11.11** This report has been prepared on the instructions and to the requirements of the named client and any unauthorised party using this information for any purpose does so at his own risk and any duty of care to that party is excluded.

Signed for and on behalf of
R E FRY & ASSOCIATES LIMITED



Mark Davies B Sc (Hons)

Signed for and on behalf of
R E FRY & ASSOCIATES LIMITED



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