



**Ground Investigation
Geotechnical Consulting Services
Laboratory Testing Services
Concrete Testing and Drilling
Services to the Construction Industry
Chemical Contamination Assessment**

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Date: **27th August 2013**
Our Reference: **JMT/L15465 270813-Plots 5-**

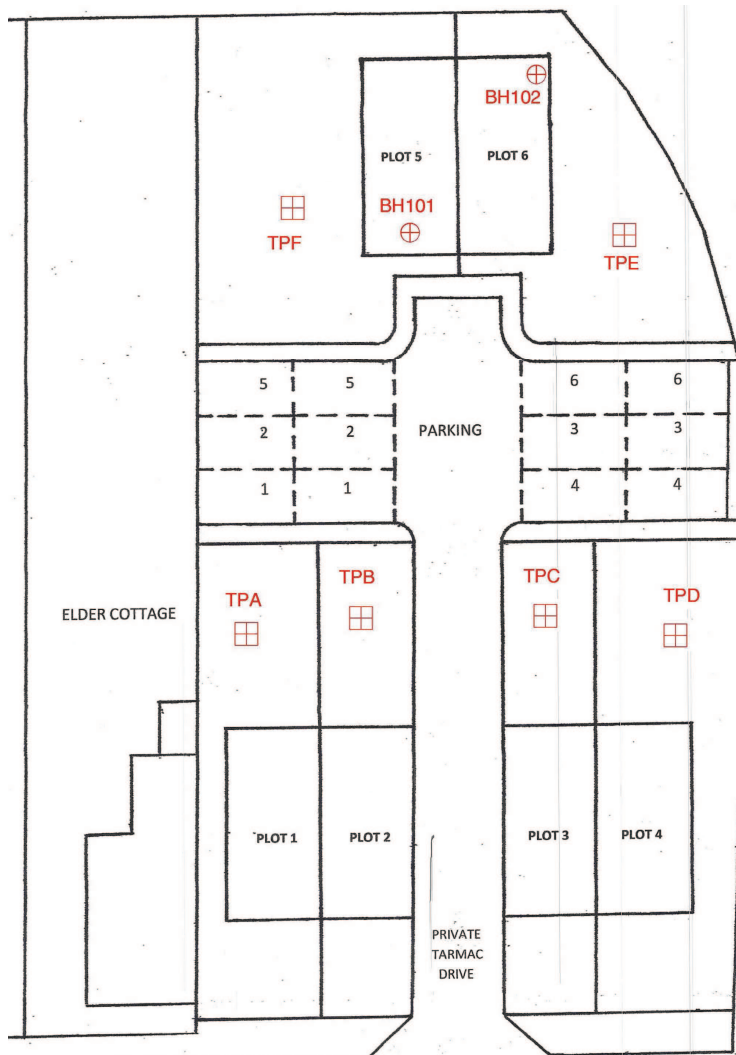
Your Reference:

Ventura Developments Limited
PO BOX 3632
The Courtyard
Chester
CH1 9NH
FAO: Andrew Kennerly

Re.: Plots 5-6 - Former St Paul's Church, King Street, Acrefair

The following report sets out the results of the fieldwork, contamination testing and proposed remedial protections measures for the proposed Plots 5-6 (Second development phase).

The site is located at the north western end of King Street in the central part of Acrefair. Plots 5 and 6 are located along the western boundary of the development site.



There are 6 building plots on the development site. Plots 1-4 have already been completed. Plots 5-6 are of the same design consisting of 2 x 2 bedroom semi-detached residential properties with associated car parking and gardens.



Member of the British Drilling Association



Prior to the start of the redevelopment, the previous owners had demolished St Paul's Church in 2007. At the start of the first phase of development in 2012 (Plots 1-4) the site was cleared of all the buildings and had a mudstone fill surfacing.

The area for plots 5-6 were initially used for storage, portable toilet and site office (caravan).



SITE GEOLOGY

The published British Geological Survey (BGS) Wrexham, Sheet Number 121 shows the site underlain by Drift comprising Glacial Till (boulder clay). The drift overlies bedrock consisting Carboniferous Pennine Lower Coal Measures.

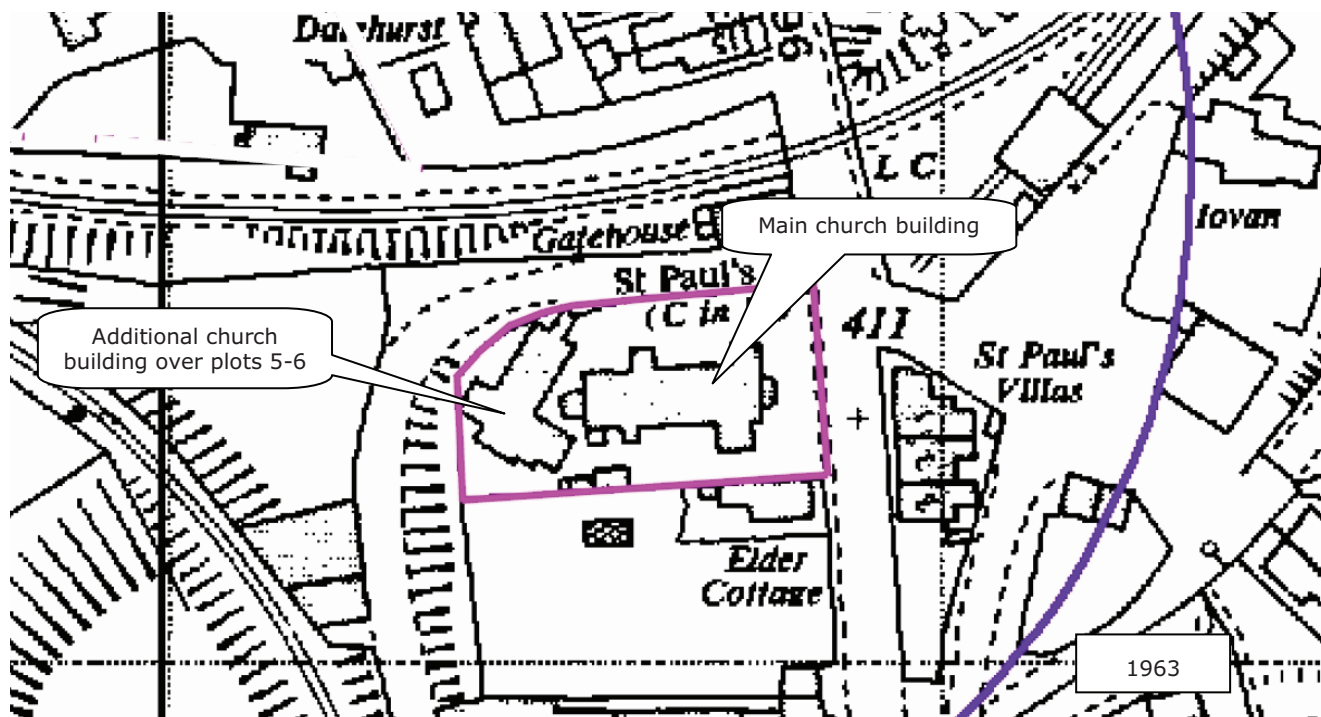
SUMMARY OF GROUND CONDITIONS

The boreholes and Trial Pits show the following sequence of strata.

Made Ground	Made Ground ranges in thickness from 1.2m to 4.0m and generally consists of loose to medium dense grey black mottled clayey sandy fine-coarse gravel sized mudstone with occasional coal/carbonaceous mudstone and ash fragments. The Made Ground generally is thickest at the western boundary as the natural topography slopes from east to west and the mudstone fill has been used to level the site.
Glacial Clay	Firm to stiff yellow brown grey orange mottled slightly sandy clay becoming stiff brown grey fissured slightly sandy slightly gravelly clay.
Mudstone	Grey mudstone interbedded with coal seams and occasional sandstone units.

ENVIRONMENTAL ISSUES

The site was previously occupied by open land in a mining area until it became the site of St Paul's Church built in 1895. The church had additional buildings added during its lifetime. The church was demolished in 2007.



One mine shaft has been located within Plots 1-2 but has been remediated. It appears that the site was levelled using mudstone material (mine waste) prior to the development of the church. The Mudstone Made Ground contains coal and ash inclusions. Therefore there is the potential for toxic metal and Poly-Aromatic Hydrocarbons (PAH) contamination within the shallow soils that may pose a risk to the end users of the site.

The site is not located within an area at risk from flooding from rivers with out or with defences.

The groundwater vulnerability map, Sheet 16 West Cheshire, shows the site to be underlain by Secondary – A. These aquifers can contribute to river base flow. *These are generally aquifers formerly classified as minor aquifers*

Low permeability drift deposits occurring at the surface and overlying Major and Minor Aquifers are head, clay-with-flints, brickearth, peat, river terrace deposits and marine and estuarine alluvium. Unproductive aquifer designation.

PLOTS 5-6 FIELDWORK

On the 8th April six (6no.) hand excavated trial pits (TPA-F) were carried out within the six rear gardens within all the proposed developments (plots1-6). The purpose of the trial pits was to collect samples from the material that would be underlying a proposed cover system within the soft landscaped areas of the developments. TPE and TPF were carried out in Plots 5 and 6.

The Trial pits encountered the following:

TP Location	Base Depth (m)	Stratum Description
TPE	0.6	Made Ground (Grey fine-coarse angular tabular mudstone gravel with slightly sandy clay matrix)
TPF	0.6	Made Ground (Grey slightly sandy Clay and fine-coarse flaky flat tabular mudstone gravel)

Plots 5-6 were not covered as part of the original investigation (Ashton Bennett), therefore geotechnical information was required for the foundation design for these plots. On the second May 2013, two continuously dynamic sampled boreholes (BH101-102) were carried out to 6.0m below existing ground level, followed by continuous dynamic sounding to 8.78m and 8.55m (stopped at assumed competent Rockhead).

The borehole encountered the following:

BH101	0.20	Made Ground (Dark grey/black fine-medium Sand, Gravel and coarse brick over terram)
	0.47	Made Ground (Black carbonaceous mudstone gravel Fill)
	3.50	Made Ground (Grey clayey sandy mudstone gravel Fill)
	5.91	Firm becoming stiff brown grey slightly sandy slightly gravelly clay
	6.45	Medium dense brown medium-coarse sand and fine gravel
BH102	0.14	Made Ground (Dark brown black sandy clay Fill with rootlets)
	4.00	Made Ground (Grey clayey sandy mudstone gravel Fill)
	6.45	Firm becoming stiff brown grey slightly sandy slightly gravelly clay

CONTAMINATION ANALYSIS – PLOTS 5-6

From the area within the second phase of development (Plots 5-6), three samples were selected consisting of Toxic metal, Poly-Aromatic Hydrocarbons and Total Petroleum Hydrocarbons.

Toxic Metal Analysis

Contaminants	BH101 1.0m	TPE - 0.5-0.6m	TPF - 0.5-0.6m	Site Screening Value (SSV) 2012 Residential (Plant uptake) Soil Guideline Values (Site Screening Value (SSV)) and Atkins Soil Screening Values (Site Screening Value (SSV))
Phase of Development	Phase 2 – Plots 5-6			
Arsenic	6	10	13	32mg/kg SGV
Cadmium	0.6	0.7	0.7	10mg/kg SGV
Chromium (total)	16	15	18	14.7 Based on Chromium VI
Chromium (VI)	<1	<1	<1	14.7 mg/kg
Copper	32	46	52	4020 mg/kg
Lead	20	42	43	322 mg/kg
Mercury	<0.5	<0.5	<0.5	16.9 mg/kg
Nickel	40	51	37	130 mg/kg
Selenium	<2	<2	<2	350 mg/kg
Vanadium	14	19	18	115 mg/kg
Zinc	117	182	567	17200 mg/kg
pH	8.4	7	5.8	5-9 *

The results of the toxic metal analysis have generally show low concentrations and there have been no exceedance of the relevant Soil Guidance Value or Site Screening Value (SSV).

Poly-Aromatic Hydrocarbons (PAH)

Contaminants	BH101 1.0m	TPE - 0.5- 0.6m	TPF - 0.5- 0.6m	GAC 2012 Residential (Plant uptake) Atkins Soil Screening Values (SSV)
Phase of Development	Phase 2 – Plots 5-6			
Acenaphthene	<0.1	<0.1	<0.1	2130
Acenaphthylene	<0.1	<0.1	<0.1	
Anthracene	<0.1	<0.1	<0.1	18300
Benz(a)anthracene	<0.1	<0.1	<0.1	8.54
Benzo(a)pyrene	<0.1	<0.1	<0.1	0.998
Benzo(b)fluoranthene	<0.1	<0.1	0.1	9.86
Benzo(ghi)perylene	<0.1	<0.1	<0.1	103
Benzo(k)fluoranthene	<0.1	<0.1	<0.1	100
Chrysene	<0.1	<0.1	<0.1	927
Dibenz(a,h)anthracene	<0.1	<0.1	<0.1	1
Fluoranthene	<0.1	0.2	0.1	2160
Fluorene	<0.1	<0.1	<0.1	1930
Indeno(1,2,3-cd)pyrene	<0.1	<0.1	<0.1	9.75
Naphthalene	<0.1	<0.1	<0.1	8.71
Phenanthrene	<0.1	<0.1	<0.1	
Pyrene	<0.1	0.1	<0.1	1550
PAH (total)	0.4	0.3	0.2	-

The results of Poly-Aromatic Hydrocarbons (PAH) analysis show consistently low concentrations and there is no exceedance of the Site Screening Values (SSV).

Total Petroleum Hydrocarbons

Contaminant	BH101 1.0m
TPH (GC)	46mg/kg

No odorous or visual fuel hydrocarbon contamination has been encountered during the latest fieldwork. The historical landuse on the site does not indicate a risk from hydrocarbon contamination. The Total Petroleum Hydrocarbons analysis has recorded very low concentrations and indicates no evidence of a hydrocarbon contamination issue.

CONTROLLED WATERS

Receptor - The nearest surface water feature is approximately 150m to the west of the site. It is understood that the watercourse is culverted towards Meredith Close (NE). Site underlain by Secondary A aquifer.

Pathway – the site is generally underlain by mudstone fill from mining spoil and the surrounding areas are also likely to be underlain by mudstone Fill. Underlying the mudstone Fill is glacial clay overlying carboniferous mudstone therefore the migration of potentially impacted groundwater is considered limited.

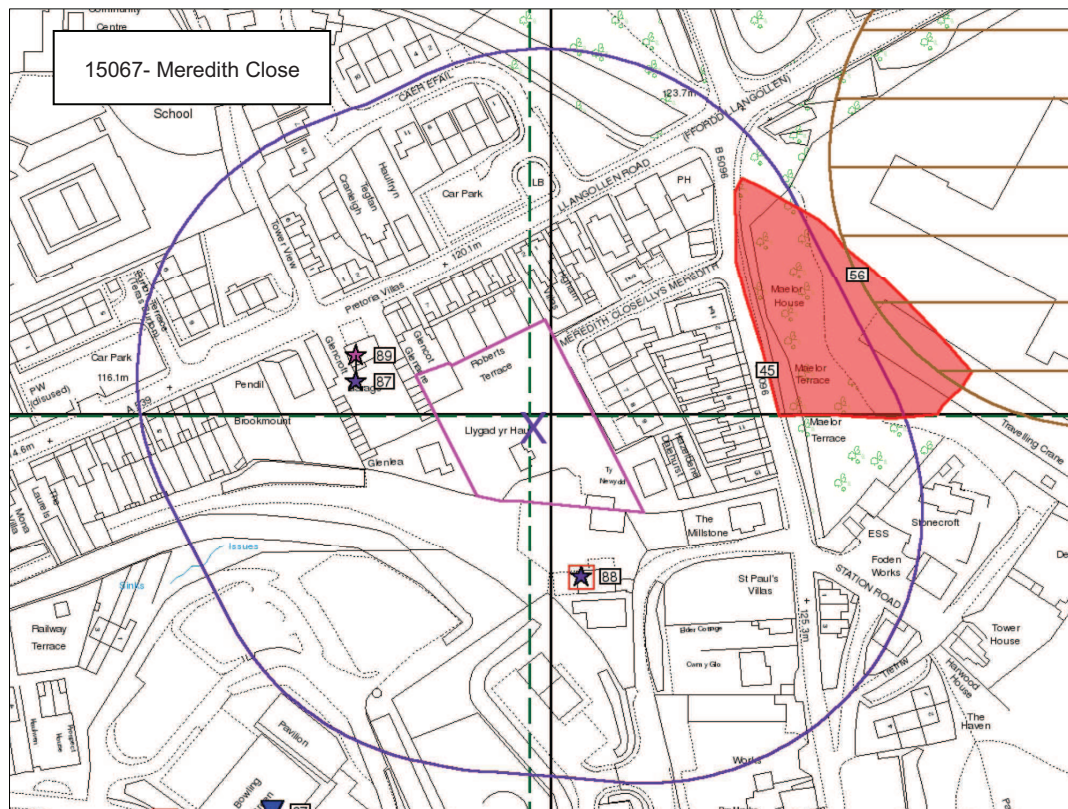
The groundwater vulnerability map, Sheet 16 West Cheshire, shows the site to be underlain by Secondary – A. These aquifers can contribute to river base flow. *These are generally aquifers formerly classified as minor aquifers.* Low permeability drift deposits occurring at the surface and overlying Major and Minor Aquifers are head, clay-with-flints, brickearth, peat, river terrace deposits and marine and estuarine alluvium. Unproductive aquifer designation.

Previous Investigation – SSL 15067 Meredith Close, Acrefair – 2011

The Meredith Close site lies to the rear of Roberts terrace (that front onto Llangollen Road) and to the north of Lygad yr Haul. The site formed the extended garden to the house Lygad yr Haul. The site gently slopes from the south to the north.

The development consisted of two pairs of semi detached houses and one detached house. The site as a whole was the rear garden to the Lygad yr Haul to the south of the development site.

The historical mapping showed that along the northern boundary of the site there was an open stream course that has since been culverted. The culverting appears to have made use of general fill of mine spoil mudstone/shale from the general area mixed with ash and cinders with some brick. Two samples from the mine spoil fill were selected for leachate testing. In summary, the results from the leachate analysis show very low concentrations with the exception of one result of Copper at 11ug/l, which slightly exceeds the EQS value of 10ug/l.



15465 – St Pauls Leachate results

2:1 Leachate Results (mg/l)	TPD 0.5-0.6m	EQS - All Freshwater - Hardness band 100-150mg/l	EQS - All Freshwater - Hardness band >150 - 200mg/l	EQS - All Freshwater - Hardness band >200-250mg/l
Arsenic	<1.0	50µg/l	50µg/l	50µg/l
Cadmium	<0.5	5µg/l	5µg/l	5µg/l
Chromium	2.1	20µg/l	200µg/l	250µg/l
Copper	2.2	10µg/l	10µg/l	10µg/l
Lead	<1.0	10µg/l	20µg/l	20µg/l
Mercury	<0.1	1µg/l	1µg/l	1µg/l
Molybdenum	2.0	-	-	-
Nickel	<1.0	150µg/l	150µg/l	200µg/l
Antimony	<1.0	-	-	-
Selenium	<1.0	-	-	-
Zinc	<1.0	75µg/l	75µg/l	75µg/l
pH (pH units)	8.1	-	-	-

The 2:1 leachate results which are part of the Waste Acceptance Criteria analysis have been compared against the Environmental Agency ESQ values. No hardness values are known for the site, therefore the results have been compared to a range of hardness levels. The results have shown very low concentrations of the toxic metals and there are no exceedance of the relevant EQS values.

Due to the low concentrations of toxic metals and the general cohesive nature of the Made Ground, the risk to controlled waters from the existing soils on the site is considered as very low to absent.

CONCRETE IN AGGRESSIVE GROUND

Contaminants	TP2 - AB	TP3 - AB	TP4 - AB	TP5 - AB	TP6 - AB	TPA – 0.5-0.6m
Soluble Sulphate 2:1 SO ₄	85	41	57	130	68	53.49
pH	6.73	6.7	5.79	7.08	7.66	7.1

With reference to BRE Special Digest 1 the site should be considered as brownfield with static groundwater.

The testing for sulphates shows low concentration of soluble sulphate in the Made Ground and low sulphate content in the ground water.

Therefore the Site Design Sulphate Class is DS1 and the Aggressive Chemical Environment for Concrete (ACEC) is AC1s.

RECOMMENDATIONS AND PROPOSED REMEDIAL MEASURES

1. The fieldwork carried out within Plots 5-6 of the development site has shown that the material to consist of weathered grey mudstone Fill.
2. The contamination testing has shown the mudstone fill does not contain elevated levels of toxic metals, Poly-Aromatic Hydrocarbons (PAH) or Total Petroleum Hydrocarbons that could be harmful to human health.
3. The fieldwork has shown the presence of sandy gravelly brick Fill material overlying Terram in the top 200mm. This material was brought onto site to stabilise the upper surface for site traffic. It is proposed that the top 300mm within garden areas of plots 5-6 is stripped and removed.
4. After the surface materials are stripped from the site, an inspection must be carried out by Strata Surveys to confirm the mudstone fill is a suitable sub-soil material.
5. The garden areas within plots 5-6 will have a minimum thickness of 300mm validated topsoil material as described below.
6. Topsoil. To be validated by appropriate testing to BS3882:2007. Contamination tests must include as a minimum heavy metals, speciated Poly-Aromatic Hydrocarbons (PAH), Total Petroleum Hydrocarbons. The number of tests should be one sample for every 200m³ from proven 'greenfield' sources and one sample every 50m³ from 'unknown', 'mixed' or 'brownfield' sources.
7. The correct installation of the cover systems described above will be confirmed within the Validation Report containing photographic evidence, which will be carried out by Strata Surveys and presented to the local authority.
8. If excess material is required to be removed from the site then the waste transfer notes will be presented within the validation report.

Ground Gas Assessment

The site has been assessed using the criteria given in BS8485 “Code of Practice for characterisation and remediation from ground gas in affected developments”, CIRIA Report 665 “Assessing risks posed by hazardous ground gases” and NHBC Report 04-2007 “Guidance on the evaluation of development proposals on sites where methane and carbon dioxide are present”.

The proposed development is for a mixture of semi-detached and terraced residential properties with associated gardens. The development is therefore assessed as high risk end use.

Ground Gases

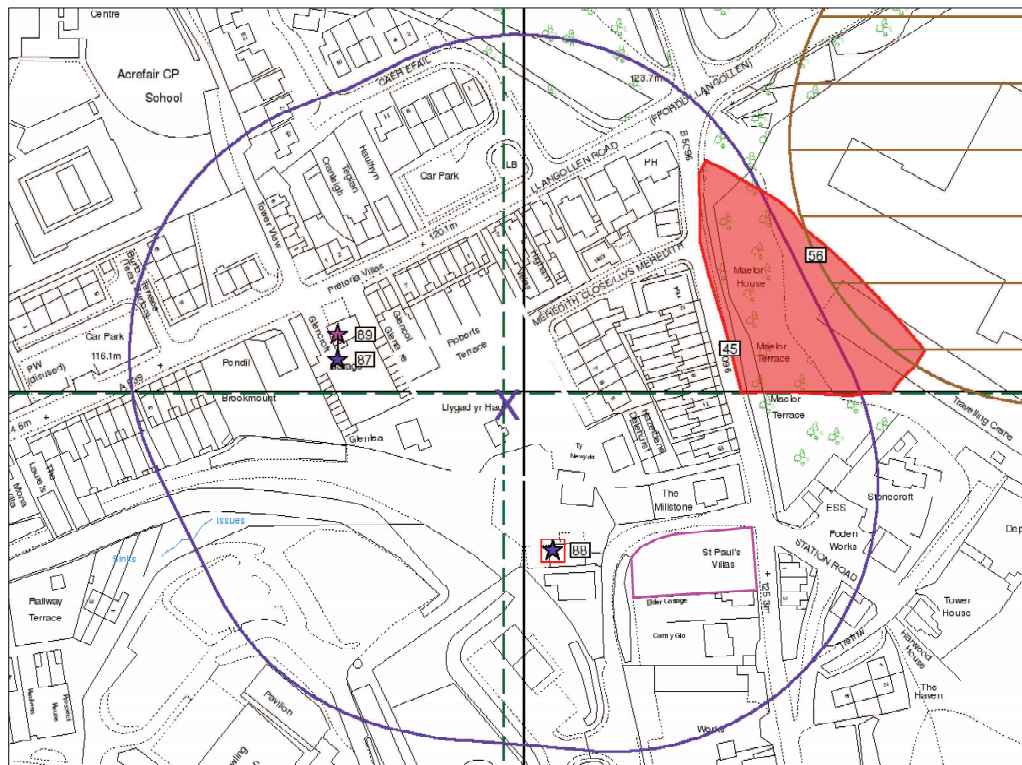
Principally Methane (CH₄) and Carbon Dioxide (CO₂) are the main ground gases that pose a potential hazard, however there are other trace gases such as carbon monoxide and hydrogen sulphide that may be present depending on the nature of the decomposing material.

Radon is a radioactive gas produced by radioactive decay of radium/uranium. Radon has no taste, smell or colour. Radionuclides (the decay products of radon) can damage lung tissues and ultimately lead to lung cancer. The variation in radon levels between different parts of the country is mainly controlled by the underlying geology.

CONCEPTUAL SITE MODEL

Potential ground gas sources have been identified as:

- 1) The property is in a radon affected area, as between 3 and 5% of homes are above the action level. The maximum reference level for dwellings is given as an annual mean radon concentration UK Action Level is 200 Bq m⁻³. The site is located in an area considered to be above this limit and thus basic Radon mitigation measures will be applicable. For the new developments a fully ventilated substructure and an appropriate membrane will need to be adopted.
- 2) Made Ground. The site has been shown to be generally underlain by black grey reworked clay and coal/mudstone with ash, coal, cinder inclusions. There is the possibility that the partially combusted material may react with groundwater to create Carbon Dioxide (CO₂) but not under high volumes or pressure. Methane (CH₄) is unlikely to be generated.
- 3) Bedrock from the underlying Lower Coal Measures (Mine Gas) – The Coal Authority report and Ashton Bennett SI report has shown that the site is underlain by a number of worked coal seams and there is one shaft on the site. The shaft has been fully grouted and capped. Details of the grouting are given in the AB phase 2 report. A theoretical risk of migrating ground gases from coal remains but is likely to be low volume and low pressure. The glacial clays will limit the pathway.
- 4) Registered landfill to NE of site. The plan below shows environmental data in the area around the site. The plan shows a historical landfill (No. 45) and registered landfill (No56) close to the site - details of the landfill are further below.



Licence Holder:	Air Products UK Limited	Licence Holder:	Air Products Ltd
Location:	Llangollen Road, Wrexham, Acrefair	Licence Reference:	L58
Name:	Air Products	Site Location:	Llangollen Road, Acrefair, Wrexham, Clwyd
Operator Location:	Not Supplied	Licence Easting:	328000
Boundary Accuracy:	As Supplied	Licence Northing:	343095
Provider Reference:	EAHLD14748	Operator Location:	As Site Address
First Input Date:	1st September 1977	Authority:	Environment Agency Wales, North Area
Last Input Date:	31st December 1991	Site Category:	Landfill
Specified Waste	Deposited Waste included Inert and Industrial Waste	Max Input Rate:	Small (Equal to or greater than 10,000 and less than 25,000 tonnes per year)
Type:	Not Supplied	Waste Source	No known restriction on source of waste
EA Waste Ref:	Not Supplied	Status	Licence lapsed/cancelled/defunct/not applicable/surrendered cancelled
Regis Ref:	6955/0002	Dated:	1st February 1992
WRC Ref:	Not Supplied	Preceded By	Not Given
BGS Ref:	WMBC L/8, WMBC L/58	Superseded	Not Given
		Positional Accuracy:	Manually positioned to the road within the address or location
		Boundary Accuracy:	Not Applicable
		Authorised Waste	Hardcore/Concrete

It should be noted that this landfill includes a portion of land that formed the railway embankment to the railway (GWR Llangollen Branch) that crossed the road on a north west – south west alignment. The land is at a higher elevation than the development site and thus migration of potentially harmful ground gases would escape through the embankment face and not through the existing ground below King Street.

It is considered that there is a low risk of harmful ground gases that may be attributed to the recorded landfill sites.

Anthropological Migration pathways

- Pile Foundations - The piling will consist of driven steel piles. The piles will penetrate through the glacial clays and into the Mudstone.

The piling method could introduce additional oxygen in to the Mudstone that could theoretically, over a short period of time, alter the ground gas conditions. However, as the ground conditions resumes to the state before piling, the alteration to the change in gas generation is expected to also return to the previous state. As the development proceeds and the ground gas mitigation measures are put in place, the pathway to the property is reduced. Properly designed, installed and validate gas protection measures will break the gas migration pathway.

Borehole location and monitoring well rationale

BH Location	Ashton Bennett Monitoring Well Details	As read monitoring Details	Presumed Rational	Comments
BH1	1.0-18.0m	Presumed to be 1.0-32.5m	Covers both coal seams at 16.5-16.65m and 31.5-31.75m	Underlies Plot 3 – located over northern set of semi pair
BH7	1.0-15.0m	Presumed to be 1.0-14.5m	Located just above coal seam met from 15.8-16.0m	Underlies Plot 2 - located over southern set of semi pair

Full details of the monitoring well installations for BH1 and BH7 carried out under the Ashton Bennett SI report have not been provided at the time of this report. The additional monitoring carried out by SSL has shown the base of the monitoring wells to be 32.5m in BH1 and 14.5m in BH7.

Gas Monitoring

Although BH1 and BH7 are not overlying plots 5-6, the ground conditions are very similar. Gas monitoring has been carried out over a five year period to monitor for ground gases including methane (CH₄), Carbon Dioxide (CO₂), Oxygen concentrations and flow readings. Two readings were carried out by Ashton Bennett Consultancy in 2007. Four additional readings have been carried out by Strata Surveys Ltd.

Monitoring was undertaken when possible at worst case conditions i.e. falling low atmospheric air pressure.

Well Number	Date / Time	Gases Balance %	Peak Methane (CH ₄) %	Peak CO ₂ %	Min O ₂ %	Atmospheric Pressure mBar		Flow l/hr
BH1	25/09/2007	-	0	0.0	19.4	999	-	Nil
BH1	03/10/2007	-	0	2.4	20.6	1002	-	Nil
BH1	24/08/2012 14:03	90.3	0	5.1	4.5	985	Falling	0.0
BH1	06/09/2012 14:38	87.1	0	9.0	4.0	1007	Static	0.0
BH1	27/09/2012 10:47	87.2	0	8.1	4.8	986	Rise	-0.3
BH1	03/10/2012 09:56	79.6	0	3.0	17.2	980	Static	0.0
BH7	25/09/2007	-	0	0.0	18.5	999	-	Nil
BH7	03/10/2007	-	0	5.1	20.6	1002	-	Nil

Well Number	Date / Time	Gases Balance %	Peak Methane (CH ₄) %	Peak CO ₂ %	Min O ₂ %	Atmospheric Pressure mBar		Flow l/hr
BH7	24/08/2012 14:18	79.1	0	14	6.7	984	Falling	0.1
BH7	06/09/2012 14:46	80.5	0	1.3	17.2	1007	Static	0.1
BH7	27/09/2012 11:02	80.5	0	0.1	17.4	986	Rise	0.0
BH7	03/10/2012 09:43	80.6	0	0.0	18.9	980	Static	0.0

No methane has been detected in any of the six visits. Carbon Dioxide (CO₂) has been recorded between 9.0% and zero percent in BH1 and 14.0% and zero in BH7. Depleted Oxygen (O₂) levels were detected in three of the readings in BH1 and in one of the readings in BH7. Flow and well pressures readings were zero or very low.

Gas Screening Value (GSV)

The Gas Screening Value (GSV) or Site Characteristic Hazardous Gas Flow (SCHGF) is calculated from the maximum flow rate and the maximum gas concentration.

No methane has been recorded.

The maximum CO₂ concentration is 14% and the maximum flow rate is 0.3litre.hour.

Thus the Gas Screening Value or Site Characteristic Hazardous Gas Flow is

$$0.14 (\text{CO}_2) \times 0.3 = 0.042 \text{ litre/hour}$$

Table 14.2 below shows the requirements of the NHBC report and Table1 of BS8485.

Traffic Light	Hazard Potential	Site characteristic hazardous gas flow litre/hour (Gas Screening Value)	Characteristic Gas Situation	Ground Gas Protection Measures Required
Green	Very Low	<0.07	1	Ground gas protection measures are not required.
Amber 1	Low	=> 0.07 - <0.7	2	Low-level ground gas protection measures are required, using a membrane and ventilated sub-floor void that creates a permeability contrast to limit the ingress of gas into buildings. Gas protection measures are to be installed as prescribed in BRE 414. Ventilation of the sub-floor void should be designed to provide a minimum of one complete volume change per 24 hours.
Amber 2	Moderate	=>0.7 - <3.5	3	High-level ground gas protection measures are required, creating a permeability contrast to prevent ingress of gas into buildings. Gas protection measures are to be installed as prescribed in BRE 414. Membranes used should always be fitted by a specialist contractor and should be fully certified (see Appendix E). As with Amber 1, ventilation of the sub-floor void should be designed to provide a minimum of one complete volume change per 24 hours.
Red	Moderate to high High Very High	=>3.5 - <15 =>15 - <70 =>70	4 5 6	Standard residential housing is not normally acceptable without further Ground Gas Risk Assessment and/or possible remedial mitigation measures to reduce/remove the source of the ground gases. In certain circumstances, active protection methods could be applied, but only when there is a legal agreement assuring the management and maintenance of the system for the life of the property.

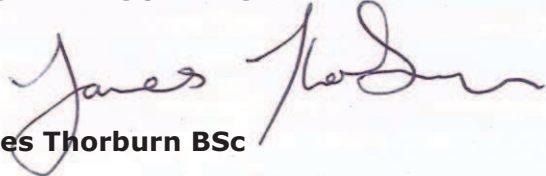
The calculated Gas Screening Value for Carbon Dioxide (CO₂) is 0.042 litres/hour, which gives a Characteristic Gas Situation of 1 (Green).

The proposed developments require radon gas protection measures due to the underlying geology. This would be in line with Characteristic Gas Situation of 2 (Amber1). The properties will have a ventilated sub-structure and gas membrane. The membrane will give protection against the ingress of radon and Carbon Dioxide (CO₂) gas. All joints will be overlapped and sealed with double sided tape and airtight seals will be formed around all service entry points.

The installation of the gas protection membrane will be verified by a qualified person who is able to recognise that the membrane has been laid and sealed to the required standard. A verification report will be submitted showing photographic evidence of the membrane once laid and evidence showing that the suitable proposed materials were used.

Yours faithfully

for STRATA SURVEYS LIMITED

A handwritten signature in dark ink, appearing to read 'James Thorburn', is written over a light blue rectangular background.

James Thorburn BSc