BETTS GEO
CONSULTING ENGINEERS

David Wilson Homes

Ground Investigation Report

for

Whalley Road, Barrow, Clitheroe,

Lancashire

May 2018

REPORT NO: 18DWH018/GI

- *Desk Studies and Site Walkovers*
- *Intrusive Contaminated Land Investigations*
- *Geotechnical Appraisals and Ground Investigations*
- *Landfill Gas Assessments and Remedial Design*
- *Remediation Design and Implementation*
- *Remediation Project Management and Supervision*
- *Site Abnormal Assessments (Foundations and Contaminated Land)*

GEOTECHNICAL - CONTAMINATED LAND - FLOOD RISK

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1 EXECUTIVE SUMMARY

***Note** – The following summary is not exhaustive and is to be used for guidance purposes only. The full report should be consulted for full details.*

1. Site Location

The site is located west of Whalley Road, Barrow, Clitheroe, Lancashire, BB7 9BN. The coordinates for the centre of the site on National Grid are: 373355, 437929. The site area is approximately 7.96 hectares in size.

2. Site Description

On Site

The site is currently undeveloped apart from two small paths which run along the central hedgerow and southern site boundary. The site comprises of four (4 No) fields used for agricultural uses. The field boundaries are outlined by fences, trees or hedgerows.

A ditch is present in the western third of site, running north to south. The ditch area was noted as boggy during the time of the walkover.

Surrounding Area

Immediately N is a newly built residential development, E is Whalley Road and residential development and south and west are agricultural fields.

3. Proposed Development

The proposed construction of residential dwellings and associated gardens, public open spaces, new road and associated infrastructure.

4. Site History

On Site

The earliest map is the 1848 1:10,560 map which shows the site as undeveloped apart from a pond which is located in the western third of site. This pond is no longer shown circa 1895.

No further changes are shown to occur on site until circa 1970, where two drains are shown on site (one along the southern site boundary, and another down the western third of site in a north to west direction).

No further significant changes occur post circa 1970 – present day.

Surrounding Area

The majority of the surrounding area remains predominantly undeveloped. A railway line is present 5m SW since historic maps began. Barrow Bridge Print Works and associated reservoirs are shown 320m NE between 1848 – 1970 before being shown as an Engraving works. The works is no longer shown circa 2001 and is shown as residential/commercial circa 2011. Residential development begins in an easterly direction circa 2001.

5. Published Geology

The BGS map shows the geology (1:50,000 Sheet 68 Clitheroe) beneath the following:

- **Drift – Glacial Till** – Sandy gravelly CLAY.
- **Bedrock – Clitheroe Limestone Formation and Hodder Mudstone Formation (Undifferentiated) –** Mudstone.

6. Hydrogeology and Hydrology

- The Glacial Till Deposits are classed as a Secondary Undifferentiated Aquifer (Low - Negligible Permeability).
- The bedrock deposits of the Mudstone are classed as a Secondary A Aquifer (Moderate Permeability).
- The site does not lie within a Groundwater Source Protection Zone as defined by the Environment Agency.
- The nearest water feature (other than the drains on site) is the Barrow Brook which is located 320m N of site.

7. Previously Undertaken Site Investigation

Johnson Poole undertook a Site Investigation on site in August 2014. The fieldwork comprised of three cable tool boreholes, twenty four trial pits and soil chemical sampling.

Ground Conditions

"The site comprised of TOPSOIL typically 200mm thick overlying a sequence of principally cohesive "glacial till" comprising essentially firm/firm to stiff silty gravelly clays and moderately compacted gravelly clayey silts. Locally softer clays were encountered between depths of 0.60mbgl and 1.00mbgl."

Groundwater

"In the vast majority of trial pits, groundwater was either absent during excavation or limited to minor seepages at depths of 0.90mbgl – 1.20mbgl. Secondary seepages occurred in the minority of pits at depths of 2.00mbgl – 2.70mbgl.
During cable tool boring, initial groundwater strikes were recorded at depths of between 5.00mbgl – 7.70mbgl."

Contamination Encountered

"All determinants tested for came under the residential with homegrown produce guidance."

Johnson Pool Conclusion

"The natural glacial soils are considered compatible with the use of conventional shallow foundations, net bearing pressures in the range of 100kN/m2 - 150kN/m2.

No mitigation measures are generally considered necessary in the context of the risk to human health across the site in garden/soft landscaped areas.

No general mitigation measures are necessary for the protection of controlled waters.
Laboratory testing classifies the near surface glacial soils as clays of low to very high plasticity (but most commonly intermediate and high plasticity)."

8. Summary of Environmental Data

Possible Contamination Sources

- Current Land Use on Site – **No.**
- Historical Land Use –On Site – **Possible but localised to former ponds.**
- Railway Line 5m SW – **No.**
- Former Filter Beds – 250m N – **Yes.**
- Former Barrow Bridge Print Works – 320m NE - **Unlikely.**

Pathways and Receptors

- Springs on Site – **Possible.**
- Aquifer below site – **Unlikely.**
- Barrow Brook 320m N – **No.**

In this qualitative risk assessment, a **Low - Low/Moderate** risk of contamination and ground gas exists. Remedial action is unlikely to be necessary however, the extent of the remedial action cannot be confirmed until the additional ground investigation is carried out.

9. Scope of Investigation

The fieldwork was carried out on the 6th April 2018 and comprised of the following;

- Eleven (11 No) machine excavated trial holes to between 2.50mbgl (TP210) and 3.00mbgl (TP201).
- Six (6 no) window sampling small diameter boreholes drilled to between 1.80mbgl (WS202) and 3.00mbgl (WS201) and installed with gas and groundwater monitoring wells, followed by six (6 No) ground gas monitoring visits over a period of at least three months during varying barometric pressures.
- Chemical analysis (Metals, PAH's, TPH's) of eighteen (18 No) samples.
- Screening of fifteen (15 No) samples for asbestos.

- Screening of eighteen (18 No) samples for cyanides and speciated phenols.
- Collection and analysis of seven (7 No) soil samples for geotechnical and concrete classification.

10. Ground Conditions Encountered

Ground conditions generally consisted of TOPSOIL (to a maximum depth of 0.30mbgl) over firm to stiff CLAY.

11. Contamination Encountered

No elevated determinants were encountered within the Topsoil or Natural Strata when compared against residential with home grown produce guidance.

12. Remedial Actions

Soils

No elevated concentrations of determinants analysed were identified above the residential with home grown produce guidance, therefore no further risk assessment is required.

Groundwater and Aquifer Risk

No significant contamination sources have been identified within the soils onsite and given the presence of low permeability soils, the risk to groundwaters and the aquifer from site is considered very low.

13. Off-Site Disposal of Surplus Soil

It is recommended that the results of the contamination testing (including the history of the site) be presented to the proposed landfills, to obtain their acceptance of the information to date and to determine the actual WAC limits used by them.

Segregation of made ground and natural should be possible given the chemical analysis and very different visual identification.

14. Specialist Ground Gas Measures

BRE211 (2007) Radon: guidance on protective measures for new buildings shows it is in a lower probability area, as between 1-3% of homes are above the action level. Therefore no Radon protective measures are necessary in the construction of new dwellings or extensions.

The ground gas monitoring is ongoing. For the purposes of pricing it would be prudent to allow for Amber 1 ground gas protection/full radon measures until further ground gas monitoring is completed.

15. Foundations

It is recommended that conventional strip/trench foundations can be adopted across the site founded within the firm to stiff CLAY at a minimum depth of 0.75mbgl. The following allowable bearing capacities can be assumed for foundation design;

- Firm to stiff gravelly sandy CLAY with an allowable bearing pressure of 100 kN/m2 - 125kN/m2.

Localised deepening of foundations and/or piled foundations are likely to be required in the vicinity of trees.

Foundations should be excavated wholly on one stratum. Should proposed foundations span different strata, trenching and stepping of foundations and/or nominal reinforcement will be required. A foundation zoning plan should be undertaken when proposed levels are made available.

Calculations on the allowable bearing capacity indicate settlements of less than 25mm for a square pad using the above allowable bearing capacity.

16. Highway

According to the criteria of Highways Agency HD 25/95 Volume 7 Section 2 Part 2 HD 25/94, a CBR value of 3-5% on the

firm to stiff clay is anticipated, however in-situ CBR's should be undertaken during construction to confirm. Placement of geotextiles within the areas of roads / parking could also be designed to minimise the subgrade thickness.

17. Heave / Shrinkage Potential

LOW plasticity has generally been determined from geotechnical lab testing. Foundation design for tree heave protection could be designed accordingly following discussion with the NHBC.

18. Ground Floor Construction

Shrinkable soils are present at shallow depth across the site and it is therefore recommended that suspended floor construction (e.g. either in-situ RC slabs or block and beam flooring) is adopted in accordance with NHBC guidance.

19. Control of Groundwater

Limited groundwater was encountered on site, however a number of the exploratory holes encountered damp CLAY. It is likely that provision of pumping/shuttering will be necessary during excavation of foundation trenches during wet weather and to deeper excavations for sewers etc. It is good practice to have such equipment on standby in case of seasonal / abnormal weather conditions.

20. Concrete Design

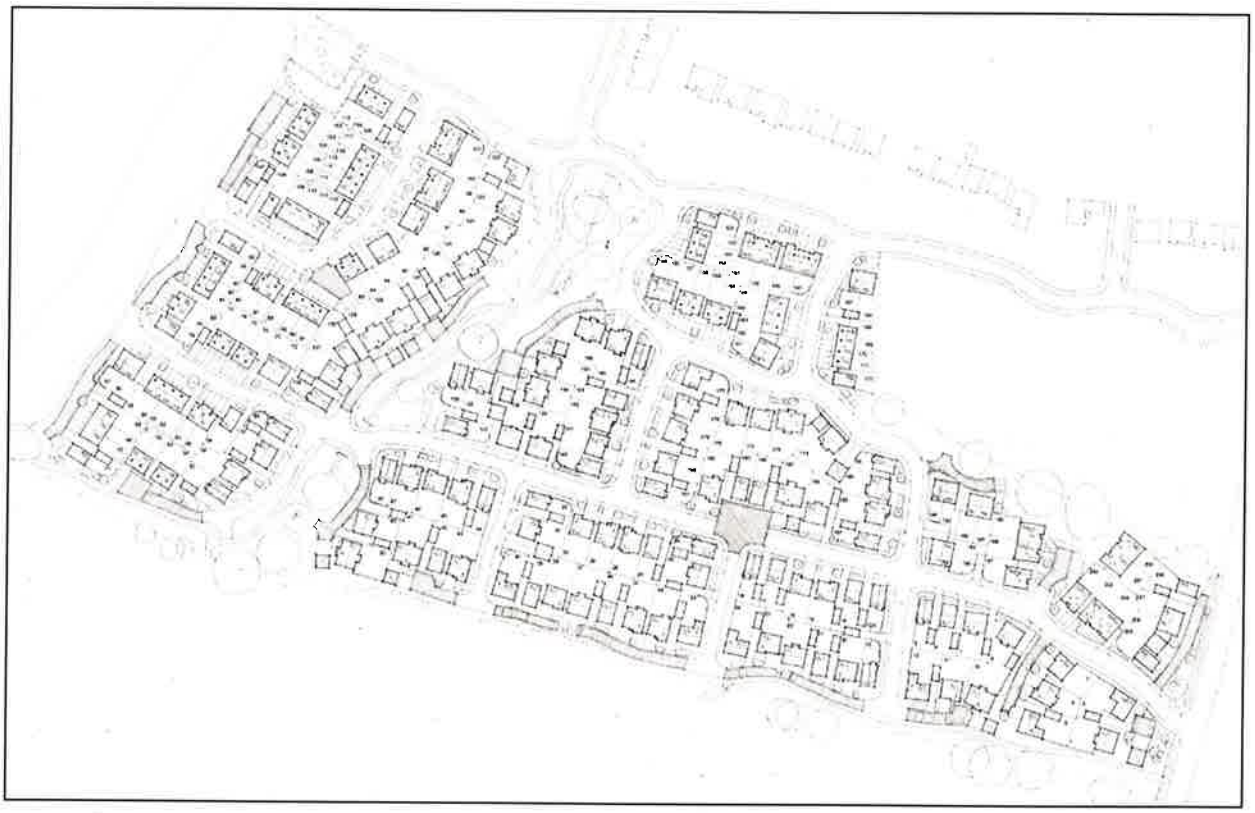
It is considered for concrete design purposes that a greenfield site and static groundwater conditions are applicable and the results are summarised below:

Concrete Classification	
Design Sulphate Class	DS-1
ACEC Class	AC-1
Design Chemical Class	DC-1

2 SITE DESCRIPTION

2.1 Introduction

This investigation was carried out on the instruction of David Wilson Homes. The purpose of the work was to review a previous Desk Study and Site Investigation Report and undertake additional Ground Investigation works to provide further geotechnical and contamination risk information for the proposed construction of residential dwellings and associated gardens, public open spaces, new road and associated infrastructure. A Detailed Site Layout can be seen below;



Sketch Layout – Barrowlands, Southern Parcel – David Wilson Homes – 20.09.2017 (Drawing No: DWH/BP2/SK/01)

2.2 Site Location

The site is located west of Whalley Road, Barrow, Clitheroe, Lancashire (nearest postcode: BB7 9BN). The coordinates for the centre of the site on National Grid are: 373355, 437929. The site area is approximately 7.96 hectares in size. See Site Location Plan in Appendix A.

2.3 Site Description

2.3.1 On Site

The site is rectangular in shape and can be accessed from Whalley Road to the east of site.

The site is currently undeveloped apart from two small paths which run along the central hedgerow and southern site boundary. The site comprises of four (4 No) fields used for agricultural uses. The field boundaries are outlined by fences, trees or hedgerows.

A ditch is present in the western third of site, running north to south. The ditch area was noted as boggy during the time of the walkover.

The topography of the site comprises of a gentle slope down from the eastern boundary (76m AOD) to the western boundary (64m AOD).

2.3.2 Surrounding Area

The area surrounding the site comprises of the following;

- **North –** Immediately N is a newly developed housing site to 250m N with agricultural fields and Clitheroe golf course beyond to 500m N. 320m N is Barrow Brook.
- **East –** Immediately east is Whalley Road followed by a mixture of residential dwellings and agricultural fields to 500m E.
- **South –** 0m – 500m S are agricultural/grassed open fields.
- **South West –** Immediately SW of site is a railway line running north to south. Beyond the railway line are agricultural/grassed open fields to 500m SW. A cemetery is located approximately 360m SW.
- **West –** Immediately west are agricultural/grassed open fields. 140m W is a railway line followed by further grassed open fields to >500m W.

3 ENVIRONMENTAL SETTING AND DATA

3.1 Previously Undertaken Reports/Investigation

David Wilson Homes provided Betts Geo with two (2 No) previously undertaken reports for the site. These reports are as follows;

- Phase 1 Geo-Environmental Desk Study for the Proposed Development of Land to the West of Whalley Road, Barrow, Lancashire by Capita Symonds – January 2012 (Doc reference: 18394-DS02).
- Phase 2 Site Investigations Report for the Barrows Lands, Barrow, Clitheroe by Johnson Poole and Bloomer Land Consultants – August 2014 (Doc reference: OC515-75/NJW).

Where necessary the above report has been used throughout this report and referenced accordingly. The following 'Site History Summary', 'Geology' and 'Environmental Data' has been summarised from the Capita Phase 1 Geo-Environmental Desk Study (Doc reference: 18394-DS02).

Whilst Betts Geo Environmental Ltd cannot be held liable for the third party, client furnished, results/data, it is suggested that it is reasonable to assume that the data provided in these reports have been undertaken with suitable care and due diligence by suitably experience consultants. As such the data is regarded as being of an appropriate standard to utilise within this report.

3.2 Summary of Site History

3.2.1 On Site

The earliest map is the 1848 1:10,560 map which shows the site as undeveloped apart from a pond which is located in the western third of site. This pond is no longer shown circa 1895.

No further changes are shown to occur on site until circa 1970, where two drains are shown on site (one along the southern site boundary, and another down the western third of site in a north to west direction).

No further significant changes occur post circa 1970 – present day.

3.2.2 Surrounding Area

The following table below shows the changes in historical use surrounding the site:

Date First Shown	Land Uses
1848	**5m SW –** Railway Line (still present). **320m NE** – Barrow Bridge Print Works and associated reservoirs (shown as Whalley Abbey Print Works circa 1895 and Whalley Abbey Engraving Works circa 1970. No longer shown circa 2001. Shown as residential/commercial circa 2011). **320m N** – Barrow Brook (still present).
1895	No significant changes.
1913 - 1914	**185m N –** Sewage Tank (no longer shown circa 1932). **250m N –** Filter Beds (no longer shown circa 1983). **210m SW** – Tank (no longer shown circa 1970).
1932 - 1933	**185m N –** Allotments (still present). **360m SW** – Cemetery (still present).
1955	**120m SE** – Whiteacre School (shown as residential circa 2001. Still present). **330m NW** – Clitheroe Golf Course (still present)
1970	**170m SSW** – Corn Mill (shown as Industrial Park circa 2001. Still present). **350m – 500m W** – Residential development (still present). **470m NNE** – Warehouse (shown as residential circa 2001. Still present).
2001	**5m – 230m E** – Residential development (still present). **270m SSW** – Nursery (still present). **500m E –** A671 Road (still present).
2006 - 2016	No significant changes.

4 GEOLOGY

The following section details the published and available geological data available for the site and the surrounding area. This summary is taken from the reports referenced in Section 3.1 above. For full details, please refer to this report.

It is important to note that when the dataset was ordered, the site boundary was much larger. Since the publishing of the third part reports, the site boundary has decreased in size therefore all figures given for distances N/NW and NE of site need to have 300m added to them i.e. what was previously 50m N should now be read as 350m N.

4.1 Published Geology

The documented geology of the site is summarised on the British Geological Survey map principally, with further site specific details detailed below.

Geology	Drift	Solid
1:50,000 Sheet 68 Clitheroe	**Till, Devensian** – Sandy Gravelly CLAY.	**Clitheroe Limestone Formation and Hodder Mudstone Formation (Undifferentiated)** – Mudstone.

4.1.1 Fault Lines

No fault lines are shown within 250m of site.

4.2 Geological Features

The table below summarises the presence/absence of recorded mining, extraction and natural cavities records within 500m of site. If entries are present within 250m, further details are provided in the relevant section below.

Data Type	On Site	0 – 250m	250 – 500m
Geological			
BGS Recorded Mineral Sites	-	-	-
Man Made Mining Cavities	-	-	-
Natural Cavities	-	-	-

4.2.1 Coal Mining

The site does not lie within an area affected by Coal Mining.

4.2.2 Radon

The site boundary is in a low probability area, as between 1% - 3% of properties are above the action level. Therefore, no radon protective measures are necessary in the construction of new dwellings or extensions.

4.3 Hydrogeological and Hydrological Features

The table below summarises the presence/absence of any hydrological licences and incidents within 500m of the proposed site. If entries are present within 250m, further details are provided in the relevant subsection below;

Data Type	On Site	0 – 250m	250 – 500m
Hydrological			
Discharge Consents	-	5	5
Pollution Incidents to Controlled Waters	2	4	3
Source Protection Zones	-	-	-
Water Abstractions	-	1	2

4.3.1 Discharge Consents

There are five (5 No) Discharge Consents within 250m of site, only one (1 No) of which has now been revoked and is detailed below;

Map ID	Details	Quadrant Reference (Compass Direction)	Estimated Distance From Site	Contact	NGR
1	**Discharge Consents** Operator: North West Water Limited Property Type: Not Given Location: Barrow Et Works Humu Authority: Environment Agency, North West Region Catchment Area: Ribble (Ex Calder) Reference: 17160031 Permit Version: Not Supplied Effective Date: Not Supplied Issued Date: 1st April 1991 Revocation Date: Not Supplied Discharge Type: Sewage Effluent Discharge-Storm Effluent Discharge Environment: Coastal Receiving Water: Barrow Brook **Status:** Not Supplied Positional Accuracy: Located by supplier to within 100m	A11SW (N)	44	1	373380 438330

It is important to note that due to the change in site boundary, this consent is now 344m N.

4.3.2 Pollution Incidents to Controlled Waters

There are two (2 No) Pollution Incidents to Controlled Waters recorded on site as detailed below;

Map ID	Details	Quadrant Reference (Compass Direction)	Estimated Distance From Site	Contact	NGR
8	**Pollution Incidents to Controlled Waters** Property Type: Not Given Location: Location Description Not Available Authority: Environment Agency, North West Region Pollutant: Rubble/Litter Or Solids Note: Barrow Brook Incident Date: 12th May 1993 Incident Reference: 93340033 Catchment Area: Ribble - Non-Tidal Receiving Water: Not Given Cause of Incident: Unknown Incident Severity: Category 3 - Minor Incident Positional Accuracy: Located by supplier to within 100m	A11SW (N)	0	1	373400 438200
9	**Pollution Incidents to Controlled Waters** Property Type: Not Given Location: Location Description Not Available Authority: Environment Agency, North West Region Pollutant: Rubble/Litter Or Solids Note: Barrow Brook; Waste Plastic Cont. Incident Date: 28th November 1991 Incident Reference: 91340113 Catchment Area: Ribble - Non-Tidal Receiving Water: Not Given Cause of Incident: Unknown Incident Severity: Category 3 - Minor Incident Positional Accuracy: Located by supplier to within 100m	A11SW (N)	0	1	373500 438300

It is important to note that due to the change in site boundary, these incidents are now 300m N.

4.3.3 Water Abstractions

There is one (1 No) Water Abstraction within 250m of site as detailed below;

Map ID	Details	Quadrant Reference (Compass Direction)	Estimated Distance From Site	Contact	NGR
28	**Water Abstractions** Operator: Clitheroe Golf Club Ltd Licence Number: 2671309036 Permit Version: Not Supplied Location: Barrow Brook, Pendleton, CLITHEROE Authority: Environment Agency, North West Region Abstraction: Industrial & Transfer Abstraction Type: Not Supplied Source: Surface Daily Rate (m3): 11 Yearly Rate (m3): 3404 Details: Additional Purpose: Transfer of water; Licence Status: Revoked Authorised Start: Not Supplied Authorised End: Not Supplied Permit Start Date: Not Supplied Permit End Date: Not Supplied Positional Accuracy: Located by supplier to within 100m	A11SW (N)	19	1	373400 438300

It is important to note that due to the change in site boundary, this abstraction is now 319m N.

4.3.4 Hydrogeology:

- The superficial deposits of the Glacial Till are classed as a Secondary Undifferentiated Aquifer (Low Permeability).
- The bedrock deposits of Mudstone are classed as a Secondary A Aquifer (Moderate Permeability).

- The site does not lie within a Groundwater Source Protection Zone as defined by the Environment Agency.
- The nearest surface water feature (other than the drains on site) is the Barrow Brook which is located 320m N of site.

4.3.5 Flood Risk and Drainage Management Strategy

A Flood Risk Assessment has been undertaken for the site by Rutter Johnson in January 2013 (Report reference: RJ-BL-FRA2-190). This report should be consulted for further details.

5 ENVIRONMENTAL DATA

The following section details environmental data available for the site and the surrounding area. Full details can be found in the Desk Study undertaken by Capita Symonds – January 2012 (Doc reference: 18394-DS02). It is important to note that the Envirocheck data set used within the Capita report was ordered in 2012, therefore some records may vary slightly and care should be taken with data interpretation.

It is also important to note that when the dataset was ordered, the site boundary was much larger. Since the publishing of the third party reports, the site boundary has decreased in size therefore all figures given for distances N/NW and NE of site need to have 300m added to them i.e. what was previously 50m N should now be read as 350m N.

The table below summarises the presence/absence of any pollution controls/registers, waste, hazardous substance sites of industrial land uses within 500m of the proposed site. If entries are present within 250m, further details are provided in the relevant section below.

Data Type	On Site	0 – 250m	250 – 500m
Pollution Controls/Registers			
Integrated Pollution Controls	-	-	-
Integrated/Local Authority Pollution Prevention and Controls	-	-	-
Prosecutions Relating to Authorised Processes	-	-	-
Registered Radioactive Substances	-	-	-
Substantiated Pollution Incident Register	-	-	-
Waste			
BGS Recorded Landfill Sites	-	-	-
Historic Landfill Sites	-	-	1
Integrated Pollution Control Registered Waste Sites	-	-	-
Licensed Waste Management Facilities (Landfill Boundaries and Locations)	-	-	-
Local Authority Recorded Landfill Sites	-	-	-
Registered Landfill Sites	-	-	-
Registered Waste Transfer Sites	-	-	-
Registered Waste Treatment or Disposal Sites	-	-	-
Hazardous Sites			
COMAH/Explosive sites/NIHHS/Planning Hazardous Substances	-	-	-
Industrial Land Uses			
Contemporary Trade Directory Entries	-	22	-
Fuel Station Entries	-	1	-

5.1 Industrial Land Uses

5.1.1 Contemporary Trade Directory Entries

There are twenty two (22 No) Contemporary Trade Directory Entries with 250m of site, none of which are within 100m of site. For full details please refer to the Desk Study undertaken by Capita Symonds – January 2012 (Doc reference: 18394-DS02).

5.1.2 Fuel Station Entries

There is one (1 No) Fuel Station Entry within 250m of site, as detailed below;

Map ID	Details	Quadrant Reference (Compass Direction)	Estimated Distance From Site	Contact	NGR
49	**Fuel Station Entries** Name: Pendle Garage Location: Clitheroe Road, Barrow, Clitheroe, Lancashire, BB7 9AQ Brand: Gulf Premises Type: Petrol Station Status: Open Positional Accuracy: Automatically positioned to the address	A7SW (S)	196	-	373559 437575

6 PREVIOUSLY UNDERTAKEN SITE INVESTIGATION

6.1 Introduction

Johnson Poole undertook a Site Investigation on site in August 2014. A summary of the Site Investigation can be found below. Full details can be found in their report (Doc reference: OC515-75/NJW).

It should be noted that the investigation area within the above report was much larger than the current site boundary. Therefore, only the investigation within the current site area has been detailed below.

6.2 Fieldwork Scope

The fieldwork was undertaken over the period of 13th May 2014 – 18th June 2014 and included the following:

- Three (3 No) cable tool boreholes extending to maximum depths of between 6.80mbgl (BH5) and 15.45mbgl (BH4).
- Twenty four (24 No) machine excavated trial pits to depths of between 2.00mbgl and 4.00mbgl:
- Five (5 No) in situ CBR tests at nominal depths of 450mm below ground level.
- Samples tested for moisture content and liquid and plasticity (Atterberg) limits.
- Chemical analysis (Metals, PAH's, TPH's) of a number of samples.

6.3 Ground Conditions Encountered

"The site comprised of TOPSOIL typically 200mm thick overlying a sequence of principally cohesive "glacial till" comprising essentially firm/firm to stiff silty gravelly clays and moderately compacted gravelly clayey silts. Locally softer clays were encountered between depths of 0.60mbgl and 1.00mbgl."

6.4 Groundwater

"In the vast majority of trial pits, groundwater was either absent during excavation or limited to minor seepages at depths of 0.90mbgl – 1.20mbgl. Secondary seepages occurred in the minority of pits at depths of 2.00mbgl – 2.70mbgl.

During cable tool boring, initial groundwater strikes were recorded at depths of between 5.00mbgl – 7.70mbgl."

6.5 Soil Contamination Encountered

For the majority of contaminants, the site was classed against 'residential with home grown produce'.

"All determinants tested for came under the residential with homegrown produce guidance."

6.6 Johnson Poole Conclusion

"The natural glacial soils are considered compatible with the use of conventional shallow foundations, net bearing pressures in the range of 100kN/m^2 - 150kN/m^2.

No mitigation measures are generally considered necessary in the context of the risk to human health across the site in garden/soft landscaped areas.

No general mitigation measures are necessary for the protection of controlled waters.

Laboratory testing classifies the near surface glacial soils as clays of low to very high plasticity (but most commonly intermediate and high plasticity)."

7 SUMMARY OF ENVIRONMENTAL SENSITIVITY

The following section is a review of the environmentally sensitivity of the site as discussed in Sections 2-6. Significant potential risks are discussed in the following subsections and will then be evaluated as part of the Site Conceptual Model in Section 8.

Sources are defined as where pollution comes from, pathways are a route in which the pollution travels and receptors are anything affected by a pollutant. Further details on Source-Pathway-Receptor methodology can be found in Appendix F.

The table below focuses on significant site specific sources, pathways and receptors. More 'generic' pathways and receptors (such as site end uses) will be covered as part of the full Site Conceptual Model in Section 16.

7.1 Sources

Source	Distance/ Direction	Details	Significant Risk
Current Land Use	On Site	Site is currently undeveloped and is used for agricultural purposes. Possible contamination from animals wastes and pesticides although these are short lived when released into the environment. Anticipated cohesive superficial geology across site lowering any migration risk.	**No**
Historical Land Use	On Site	Majority of site has remained undeveloped since historic maps began apart from an infilled pond shown circa 1848 – 1895. Due to age of infilling, the likelihood of ground gas production is low however it may be a source of localised contamination (heavy metals, PTH's, PAH's and asbestos). Previous SI found no elevated determinants. Ground investigation to confirm.	**Possible – localised**
Railway Line	5m SW	Railway line is present 5m SW and has been present since historic maps began circa 1848. Possible contaminants from this source include heavy metals, TPH's, PAH's and asbestos. Railway line is located within an area of cutting and is anticipated to be surrounded by cohesive superficial deposits. Previous SI didn't find any elevated determinants on the land adjacent to the railway line.	**No**
Former Filter Beds	250m N	Filter beds shown 250m N circa 1912 – 1983. Post circa 1983 the site has remained undeveloped. A number of structures are known to remain below ground level with a number of elevated determinants above then 'current' guidance for residential without homegrown produce/public open space. Ground gas issues also highlighted. Potential for the ground gas/contamination to migrate onto the proposed development site although the Previous SI found no elevated determinants on the site. Additional ground investigation and ground gas monitoring to confirm.	**Yes**

Former Barrow Bridge Print Works	320m NE	Barrow Bridge Print Works present 320m NE of site between 1848 and 1970. Shown as an engraving works between circa 1970 – 2001). Shown as residential and commercial development circa 2011. Due to recent redevelopment, it is likely that remediation has occurred if contamination was present from this source. Previous SI found no evidence of raised determinants within the local area on site. Additional ground investigation to confirm.	**Unlikely**

7.2 Pathways

Source	Distance/ Direction	Details	Significant Risk
Springs	On Site	A spring is located on site showing that permeable horizons exist on site. Possible pathway for any contamination located from the former filter bed area 250m N of site. Site anticipated to be surrounded by cohesive superficial geology. Groundwater testing required	**Possible**

7.3 Receptors

Receptor	Distance/ Direction	Details	Significant Impact
Aquifer	Below Site	Superficial deposits anticipated to be cohesive glacial till. Bedrock deposits classed as a Secondary A Aquifer. Previous SI found no elevated determinants on site. Additional SI to confirm.	**Unlikely**
Barrow Brook	320m N	Barrow Brook located 320m N. No elevated determinants identified in the Brook during previous SI. Superficial deposits anticipated to be cohesive glacial till lowering the risk of any migration off site. Brook significant distance from site.	**No**

8 INITIAL CONCEPTUAL SITE MODEL

For details on how the conceptual model is evaluated please refer to Appendix F

This section of the report aims to identify land which could potentially be affected by contamination, such that it could affect the value or re-use of the land, or such that mitigation would be required for certain proposed end uses of the land.

Potential contamination sources and environmentally sensitive receptors have been discussed in Section 7. Potentially significant risks are evaluated as part of the subsequent sub-sections.

8.1 Source-Pathway-Receptor Linkages

The risk assessment uses a 'Source-Pathway-Receptor' methodology for assessing whether a source of contamination could potentially lead to harmful consequences. This means that there needs to be a pollutant linkage from source to receptor for harm to be caused, this linkage consisting of: a source of pollution; a pathway for the pollutant to move along; a receptor that is affected by the pollutant.

The current potential risks to site arising from various source-pathway-receptor linkages are assessed below. A risk may be considered significant if all three of the stages are present and therefore providing a pollution linkage. The various sources, pathways and receptors are considered separately. The assessment is based on the future use, which is understood to be residential with garden areas.

Type of Contamination	Potential Sources	Potential Pathway	Potential Receptors	Pollution Linkage	Comment	Estimated Level of Risk
Ground Gas	Historic Land Use On Site Former Filter Beds 250m N	Inhalation of Vapours	Construction/ Maintenance Workers	**Potentially Active**	Ground gas production unlikely from infilled pond due to age of infilling. Greatest risk from former filter beds 250m N. Previous SI identified elevated carbon dioxide in filter bed area which has the potential to migrate on site although anticipated cohesive superficial deposits lower the risk. Additional SI and ground gas monitoring to confirm. PPE to protect.	**Low**
		Vapours Penetrating Unprotected Buildings	Future Site Users	**Potentially Active**	Ground gas production unlikely from infilled pond due to age of infilling. Greatest risk from former filter beds 250m N. Previous SI identified elevated carbon dioxide in filter bed area which has the potential to migrate on site although anticipated cohesive superficial deposits lower the risk. Additional SI and ground gas monitoring to confirm. Future site use to be residential.	**Low – Low/ Moderate**
Near Surface Contaminants Within Soils	Historic Land Use On Site Former Filter Beds 250m N	Ingestion, Inhalation, Dermal Contact	Current Site Users	**Potentially Active**	Potential for contaminants within the localised Made Ground (metals, TPH's, PAH's and asbestos) in the vicinity of the former pond located on site – although previous SI confirmed there are no elevated determinants in this area. Potential for contamination from the former filter bed area to migrate on site, however anticipated cohesive superficial deposits lowers the risk. Current site use is open fields used for agricultural grazing. Additional SI to confirm.	**Low**
			Construction/ Maintenance Workers	**Potentially Active**	Potential for contaminants within the localised Made Ground (metals, TPH's, PAH's and asbestos) in the vicinity of the former pond located on site – although previous SI confirmed there are no elevated determinants in this area. Potential for contamination from the former filter bed area to migrate on site, however anticipated cohesive superficial deposits lowers the risk. Additional SI to confirm. PPE to protect.	**Low**
			Future Site Users	**Potentially Active**	Potential for contaminants within the localised Made Ground (metals, TPH's, PAH's and asbestos) in the vicinity of the former pond located on site – although previous SI confirmed there are no elevated determinants in this area. Potential for contamination from the former filter bed area to migrate on site, however anticipated cohesive superficial deposits lowers the risk. Future site use to be residential with homegrown produce. Additional SI to confirm.	**Low – Low/ Moderate**
			Adjacent Land Users	**Potentially Active**	Majority of adjacent land use is agricultural land. Residential area to the north and east of site. Site anticipated to be surrounded by cohesive superficial deposits lowering the risk of migration off site.	**Low – Low/ Moderate**
		Direct Contact	Structures	**Potentially Active**	Possible TPH and high sulphates within the localised Made Ground on site and within the former filter bed area off site.	**Low – Low/ Moderate**
		Absorption in Root Zone	Plants	**Potentially Active**	Potential for contaminants within the localised Made Ground (metals, TPH's, PAH's and asbestos) in the vicinity of the former pond located on site – although previous SI confirmed there are no elevated determinants in this area. Potential for contamination from the former filter bed area to migrate on site, however anticipated cohesive superficial deposits lowers the risk. Future site use to be residential with	**Low – Low/ Moderate**

Type of Contamination	Potential Sources	Potential Pathway	Potential Receptors	Pollution Linkage	Comment	Estimated Level of Risk
					homegrown produce. Additional SI to confirm.	
Mobile Contaminants, Leachables e.g. from Pollution Sources on Site/Off Site	Historic Land Use On Site Former Filter Beds 250m N	Leaching into Groundwater	Groundwater	**Potentially Active**	Previous SI identified some leachable contaminants on site – mainly located in the northern area of site. Groundwater sampling however showed no traces of these determinants. Site anticipated to be surrounded by cohesive superficial deposits lowering any risk of migration. Further water testing to be undertaken.	**Low**
		Offsite Migration in Groundwater	Abstractions	**Potentially Active**	The closest groundwater abstraction is 597m E. Site is anticipated to be surrounded by cohesive superficial deposits. No groundwater contamination identified during previous SI.	**Low**
			Controlled Waters	**Potentially Active**	Barrow Brook is 320m N of site. Site anticipated to be surrounded by cohesive superficial deposits lowering any risk of migration.	**Low**
Organic and Inorganic Contaminants Within Soils / Groundwater	Historic Land Use On Site Former Filter Beds 250m N	Potable Water Supply Pipes	Utilities Workers	**Potentially Active**	Potential for TPH and PAH contamination due to infilled pond on site and former filter beds 250m N. Risk assess once water pipelines are known and final layout. Ground investigation to confirm, then liaise with local water authority supplier.	**Low**

8.2 Summary

In this qualitative risk assessment, a **Low - Low/Moderate** risk of contamination and ground gas exists. Remedial action is unlikely to be necessary, however, the extent of the remedial action cannot be confirmed until the additional ground investigation is carried out.

8.3 Betts Conclusion on Desk Based/Previous Investigation

No elevated contamination concentrations were recorded on the subject site, however, insufficient samples have been taken to adequately assess the soils for reuse. The off-site filter beds are also classed as a potential ground gas source, however, no gas monitoring has been undertaken on the subject site.

Betts Geo therefore recommends that the following investigation is undertaken to allow for a more robust risk assessment, and as a result of this, any significant risks to site end users be successfully mitigated:

- Further topsoil testing for possible reuse on site.
- Ground gas monitoring to benchmark ground gas migration risk (unlikely due to the clay on site, however requires confirmation).

8.4 Geotechnical Risk

It should be highlighted that the following geotechnical constraints exist at the site and should also be considered when undertaking the ground investigation to allow foundation design:

- Unknown made ground depth in the vicinity of the former pond.
- Spring lines.
- Potential unknown services.

9 FIELDWORK

9.1 Fieldwork Objectives

The objectives of the intrusive ground investigation will be to:

- Clarify the ground conditions encountered within the Third Party Reports provided by the client.
- Provide additional contamination and ground gas information for the site.
- Provide additional data for the design of any remedial works that may be required.
- Provide additional geotechnical information to be used for the design and specification of foundations and substructure requirements.

9.2 Fieldwork Scope

The fieldwork was carried out on the 6th April 2018 and comprised of the following;

- Eleven (11 No) machine excavated trial holes to between 2.50mbgl (TP210) and 3.00mbgl (TP201).
- Six (6 no) window sampling small diameter boreholes drilled to between 1.80mbgl (WS202) and 3.00mbgl (WS201) and installed with gas and groundwater monitoring wells, followed by six (6 No) ground gas monitoring visits over a period of at least three months during varying barometric pressures.
- Chemical analysis (Metals, PAH's, TPH's) of eighteen (18 No) samples.
- Screening of fifteen (15 No) samples for asbestos.
- Screening of eighteen (18 No) samples for cyanides and speciated phenols.
- Collection and analysis of seven (7 No) soil samples for geotechnical and concrete classification.

10 GROUND CONDITIONS

10.1 General

The exploratory holes were logged by a Betts Engineer in general accordance with the recommendations of BS5930:1999+A2:2010 Detailed descriptions, together with relevant comments, are given in the exploratory hole logs included in Appendix C.

Ground conditions generally consisted of TOPSOIL (to a maximum depth of 0.30mbgl) over firm to stiff CLAY.

10.2 Ground Conditions Summary

Strata	General Description	Thickness m		No of Holes Located
		Top	Base	
TOPSOIL	Brown sandy CLAY. Occasional rootlets. Rare coal fragment.	0.00	0.30	TP201, TP202, TP203, TP204, TP205, TP206, TP207, TP208, TP209, TP210, TP211, WS201, WS202, WS203, WS204, WS205, WS206
CLAY	Soft to firm orangish brown sandy CLAY.	0.25 (TP211)	1.80 (TP209)	TP209, TP211
CLAY (2)	Firm yellowish/orangish/greyish brown slightly gravelly slightly silty sandy CLAY.	0.20 (TP202)	2.00 (TP201)	TP201, TP202, TP203, TP204, TP205, TP206, TP207, TP208, TP210, TP211, WS201, WS202, WS203, WS205, WS206
CLAY (3)	Firm to stiff grey sandy CLAY. Laminated. Occasional gravel.	0.25 (WS204)	2.00 (TP207)	TP207, WS204
CLAY (4)	Stiff dark brown gravelly cobbley very sandy CLAY. Rare boulder.	0.60 (TP202)	3.00 (TP201)	TP201, TP202, TP203, TP204, TP205, TP206, TP207, TP208, TP209, TP210, TP211, WS201, WS202, WS203, WS204, WS206

10.3 Visual and Olfactory Contamination

No visual or olfactory evidence of contamination was encountered during the fieldwork.

10.4 Obstructions

No obstructions were encountered within the exploratory holes during the fieldwork apart from two (2 No) boulders within WS202 (terminated at 1.80mbgl – boulder caused refusal) and WS206 (terminated at 1.80mbgl – boulder caused refusal).

10.5 Groundwater – Fieldwork

The following exploratory holes encountered groundwater during the fieldwork:

Exploratory Hole	Depth (mbgl)	Strata	Remark
TP202	0.60	CLAY	Land drain – fast inflow of water.
TP204	0.80	CLAY	Moderate inflow of water
TP209	0.35 – 1.80	CLAY	Damp
TP211	0.50 – 1.90	CLAY	Damp
WS202	1.2	CLAY	Land drain – moderate inflow of water.
WS206	0.80 – 1.80	CLAY	Damp.

10.6 Groundwater – Post-Field Work Monitoring (Ongoing)

The table below indicates groundwater encountered during the monitoring post fieldwork (2/6 visits have been undertaken to date);

Exploratory Hole	Depth to Water (mbgl)		Borehole Depth (mbgl)	
	Min	Max	Min	Max
WS1	0.88	1.02	2.98	3.01
WS2	1.10	1.17	1.95	2.04
WS3	0.25	0.53	2.52	2.53
WS4	0.79	0.79	1.94	1.94
WS5	0.75	0.75	3.07	3.07
WS6	2.47	2.47	3.05	3.05

11 LABORATORY TESTING

11.1 General

An assessment of potential determinands associated with the former land uses and those identified during previous investigations has been undertaken.

Determinands originating from the current/former site uses include metals, polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPHs), phenols, cyanide and asbestos.

11.2 Scheduled Chemical Testing: Soils

Soil was sent to a UKAS accredited laboratory, and were generally analysed in accordance with ISO 17025 and/or MCERTS accreditation. The results are summarised in tabular and/or graphical form in Appendix D.

Chemical Test	No. of Samples	Comment/Method
pH Values	22	Determination of pH (using Cyberscan pH meter).
Sulphate - Soluble 2:1 Extract	22	Dionex.
Arsenic, Cadmium, Chromium VI, Chromium III, Total Chromium, Lead, Mercury, Selenium, Copper, Nickel, Complex and Free Cyanide and Zinc.	18	Soil samples were analysed in accordance with UKAS/MCERTS standards Inductively coupled plasma atomic emission spectroscopy (ICP-OES)
Speciated Polycyclic Aromatic Hydrocarbons (PAH),	18	Determination of Polycyclic Aromatic Hydrocarbons by GC-MS. End/end extraction using DCM on as received sample. In house method modified USEPA 8270. Include coronene if required.
TPH CWG	18	TPH CWG (Aliphatics C5-6,>6-8,>8-10,>10-12,>12-16,>16-21,>2-35) (aromatics >C5-7,>7-8,>8-10,>10-12,>12-16,>16-21,>21-35) C5-8 fractions by Headspace GC-MS (003S). C8-35 fractions on as received sample extracted with hexane/acetone, aliphatic/aromatic splits run by GC-FID (005S), banded as listed above.
GRO/BTEX/MTBE by GC-FID (C5-10; C10-C12)	18	Determination of Gasoline Range Hydrocarbons (GRO) and BTEX (MTBE) compounds by Headspace GC-FID (C4-C12).
Organic Matter	18	Determination of Organic Matter by combustion.
Asbestos Screen	15	Visual Screening for Fibres and PLM
Atterburg Limits	5	BS1377 Part 2. 1990, 4.3,5.3,5.4
Cyanide (total, free and complex)	18	Colorimetry
Phenols (speciated HPLC)	18	HPLC-ECD

12 CONTAMINATION ASSESSMENT

12.1 General

Contaminants of concern recorded at concentrations above relevant screening values are summarised below. For ease of description, the identification of contaminant sources and possible re-use of material, Topsoil, Made Ground, Natural Strata and Groundwater will be dealt with in separate sub-headings in this section of the report where required.

Our assessment is based on the following assumptions:

- The proposed site end use is of a high risk rating (residential dwellings with proposed gardens). For analysis purposes, 'residential with home grown produce' is deemed the most appropriate end use.
- The superficial deposits of the Glacial Till are classed as a Secondary Undifferentiated Aquifer (Negligible/Low Permeability). The bedrock deposits of Mudstone are classed as a Secondary A Aquifer (Moderate Permeability).
- It is deemed that some statistical analysis is appropriate. Where sample data numbers are low and/or targeted, each determinant result is however reviewed further as an individual result as opposed to an average across the site.
- Site history has indicated a **Low – Low/Moderate** risk of contamination and ground gas.
- Statistical analysis of the chemical test results has been undertaken in general accordance with Environment Agency 2009 SGV Guidance and AtRisk 2017 using the combined assessment criterion given by CLEA (Note: all SSVs for EA derivation are for a SOM of 6% in line with Environment Agency Report SC050021/SR4 – this figure is deemed representative as an average value for sandy loam soil). AtRisk 2017 are used to the nearest SOM percentage deemed appropriate.
- No free product, visual or olfactory evidence of contamination was noted in the exploratory holes.
- Following the withdrawal of CLR7-10 Guidance documents by the Environment Agency, statistical analysis has been undertaken in accordance with the CIEH/CL:AIRE 'Guidance on Comparing Soil Contamination Data with a Critical Concentration' (May 2008). As such, the use of the mean value test alone is not considered.

A full risk assessment is detailed within Section 13 of this report.

12.2 Soils Contamination Summary

Topsoil

All determinants for TPH's, PAH's and Metals fall below the residential home grown produce guidance levels within the Topsoil.

Made Ground

No Made Ground was encountered on site.

Natural Strata

All determinants for TPH's, PAH's and Metals fall below the residential home grown produce guidance levels within the Natural Strata.

Asbestos

No asbestos was identified in the samples analysed.

Phenols and Cyanides

No significantly elevated concentrations of Phenols or Cyanides were identified during the ground investigation.

13 ENVIRONMENTAL RISK ASSESSMENT

13.1 General

This section assesses likely risks to the identified receptors, arising from potential contamination sources. It provides a final qualitative assessment of the risks involved, indicating whether (where appropriate) any immediate action is required to mitigate certain risks.

In assessing the risk qualitatively, it is appropriate to use the methods outlined in the CIRIA document C552, "Contaminated Land Risk Assessment a Guide to Good Practice". It uses a classification of risk based on the magnitude of the potential consequence or severity or risk occurring, compared with the magnitude of the probability or likelihood of the risk occurring. These are indicated on the attached tables in Appendix F.

The superficial deposits are classed as a Secondary Undifferentiated Aquifer (Low/Negligible Permeability) and the bedrock deposits classed as a Secondary A Aquifer (Moderate Permeability). With respect to human health, the proposed end use (residential with home grown produce) is of high sensitivity. Therefore the site's environmental setting is considered to be a moderate to high environmental sensitivity. Transient risks to construction workers can be addressed by the adoption of appropriate health and safety measures (see Section 14.2), therefore, the primary residual risks that require assessment are Site End Users. The following sections are split into soils and groundwater for clarity.

13.2 Assessment of Contamination Analytical Results

Soils

No elevated concentrations of determinants analysed were identified above the residential with home grown produce guidance, therefore no further risk assessment is required.

Groundwater and Aquifer Risk

No significant contamination sources have been identified within the soils onsite and given the presence of low permeability soils, the risk to groundwaters and the aquifer from site is considered very low.

14 GROUND GAS ASSESSMENT

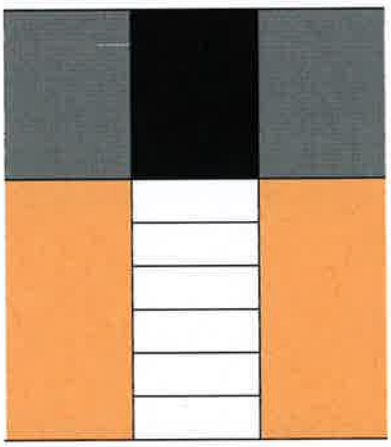
14.1 Ground Gas Requirements – Radon

BRE211 (2007) Radon: guidance on protective measures for new buildings shows it is in a lower probability area, as between 1-3% of homes are above the action level. Therefore no Radon protective measures are necessary in the construction of new dwellings or extensions.

14.2 Ground Gas Assessment

14.2.1 Ground Gas Boreholes Installations

The six (6 No) boreholes were installed to between 1.80mbgl and 3.00mbgl with 1.00m of plain pipe and between 0.80m – 2.00m of slotted pipe into the Natural Strata below. A typical installation is shown below;



14.2.2 Summary of Results (Ongoing)

Two out of six (2/6) ground gas visits have been completed to date and the provisional details are summarised below (see Appendix E for full results);

Borehole Number	Methane (%)	Carbon Dioxide (%)	Oxygen (%)	Baro Pressure (mB)	Peak Flow (l/hr)	Other Gases - CO	GSV CH_4	GSV CO_2	No. of Visits
WS1	0.0	0.2 – 0.6	20.7 – 21.0	1010 - 1020	0.3	-	0.000	0.002	2
WS2	0.0	1.6 - 3.3	16.9 – 20.4	1010 - 1020	0.1	-	0.000	0.000	2
WS3	0.0	0.2	21.1	1010 - 1020	0.1	-			2
WS4	0.0	0.0 – 0.2	20.0 – 20.7	1010 - 1020	0.0	-	0.000	0.000	2
WS5	0.0	0.4 – 0.5	20.7 – 20.9	1010 - 1020	0.1	1	0.000	0.001	2
WS6	0.1	0.8 – 0.9	20.0	1010 - 1020	0.0	1	0.000	0.000	2

Barometric air pressure was stable on visit 1 and 2.

14.2.3 Guidance

Three recent publications are used for ground gas risk assessment:

- 'Guidance on Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide are Present', Report Edition No.04 March 2007 NHBC – designed for use with low rise residential properties.
- CIRIA C665 'Assessing risks posed by hazardous ground gases for buildings' 2007 - for high rise residential / flats.
- BS8485:2015 'Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings'.

Further details / accompanying notes for the following gas risk assessment are enclosed in Appendix G. The proposed development at the site is private residential two-storey houses, therefore assessments using the NHBC Guidance are deemed most appropriate.

14.2.4 Gas Recommendations

No elevated gases have been identified on site after 2 visits. Based on gas results to date, the site has been assessed as green and it is anticipated that no ground gas protection measures will be required.

Site Area	Site Classification	Recommended Ground Gas Protection Measures
Whole Site	Green	No specialist ground gas protection is required.

For the purposes of pricing it would be prudent to allow for Amber 1 ground gas protection/full radon measures until further ground gas monitoring is completed.

15 REVISED CONCEPTUAL SITE MODEL

15.1 General

The Initial Conceptual Site Model has been amended in light of data obtained during the ground investigation, most notably the absence of any significantly contaminated soil in relation to the screening criteria for the proposed end use.

15.2 Final Conceptual Site Model

This section reassesses likely risks to the identified receptors, arising from potential contamination sources. It provides a final qualitative assessment of the risks involved, indicating whether (where appropriate) any immediate action is required to mitigate certain risks. It also discusses (where appropriate) what longer term measures or remedial works may be required in the future if the site were to be developed. It is considered that the site has not been assessed by the Local Authority as a contaminated site under the terms of the Environmental Protection Act 1990 Part IIa.

Target (Receptor)	Potential Source-Pathway Linkage	Remedial Action Required (where appropriate)	Est. Degree of Risk to Target Following Remedial Action Where Necessary
Site End Users	Inhalation of soil gases, odours or dust.	Ground gas monitoring ongoing – Amber 1 assumed across site until monitoring has been completed.	Low
Site End Users	Ingestion of, and skin contact with, contaminated soil.	300mm growing medium across site.	Low
Site End Users	Ingestion of contaminants in vegetables etc. or in soils adhering to vegetables, etc	300mm growing medium across site.	Low
Construction/ Maintenance Workers	Inhalation of soil gases, odours or dust.	PPE	Low (assumed basic PPE is used)
Construction/ Maintenance Workers	Ingestion of, and skin contact with, contaminated soil	PPE	Low (assumed basic PPE is used)
Plants	Adverse effects on growth caused by presence of contaminants in soil	300mm growing medium across site.	Low
Buildings and Structures	Flow of ground gas into buildings. Asphyxiation, toxicity, explosion and fire hazards	Ground gas monitoring ongoing – Amber 1 assumed across site until monitoring has been completed.	Low
Foundations	Sulphate attack of foundations	Foundations to be designed as per section 16.4.	Low
Water Supplies	Hydrocarbons penetrating plastic water supply pipes.	United Utilities pipeline risk assessment required.	Low
Groundwater	Migration of soluble contaminants into groundwater on or off site	No remedial action required.	Low
Surface Water	Migration of soluble contaminants and/or direct run-off of contaminants	No remedial action required.	Low

16 OUTLINE STRATEGY FOR RISK REDUCTION/REMEDIATION STRATEGY

16.1 General

The following section details any recommendations and to reduce risk on site and recommended remedial actions (as per the previous sections of this report). For clarity, the section is split into sub-sections as per the conceptual site model (Section 15).

16.2 Construction/Maintenance Workers

Although no significant contamination was encountered on site, the following recommendations should be adhered to during site works:

- Site workers should wear gloves, boots and overalls and wash their hands before eating, drinking and smoking. Excessive dust generation should be avoided.
- It is recommended that during all excavations adequate ventilation should be maintained. If man entry is required, gas monitoring should be carried out as a precaution.
- If areas of suspected contamination are found then a suitably qualified person should undertake appropriate sampling, testing and further risk assessment.
- Although asbestos was not encountered on site, vigilance should be adhered, and any suspected asbestos should be notified and a suitably qualified person appointed to inspect.

16.3 Site-End Users

No contamination was encountered on site, therefore no specialist remedial action is required. A minimum thickness of 300mm of debris-free soil within garden areas to provide a growing medium will be required as per NHBC guidance; this is likely to be made up of site-won subsoil and topsoil.

16.4 Ground Gas Protection Measures

BRE211 (2007) Radon: guidance on protective measures for new buildings shows between 1 - 3% of properties are above the action level, therefore no radon protection measures are necessary.

Ground gas monitoring is ongoing. For the purposes of pricing it would be prudent to allow for Amber 1 ground gas protection measures until further ground gas monitoring is completed.

16.5 Piped Drinking Water Supplies

The use of Protect-a-Line is not anticipated, however a pipeline assessment should be undertaken and confirmed with United Utilities.

16.6 Off-Site Disposal of Surplus Soil

If there is the need to remove soil/Made Ground off-site, it is recommended that the results of the contamination testing (including the history of the site) be presented to the proposed landfills to obtain their acceptance of the information to date and to determine the actual WAC limits used by them (see Appendix L for further guidance).

Segregation of Made Ground and Natural Strata should be possible given the chemical analysis and very different visual identification. If moved to other sites for use, it is proposed to use the results of the contamination testing to determine if it is deemed suitable for re-use as topsoil or subsoil.

17 GEOTECHNICAL ASSESSMENT

17.1 Introduction

It is understood that the proposed development will comprise two – three storey residential dwellings with associated gardens, public open spaces, new road and associated infrastructure. Associated foundation loadings are anticipated to be low.

17.2 Site Preparation and Excavation

All excavations should be planned and due consideration should be given to providing temporary support or suitable battering. Excavations should be regularly inspected by a competent person to ensure continued safety. Further advice on the safety of excavations is given *in Health and Safety in Construction.* Shallow (<1.20mbgl) excavations for service trenches could be complicated by collapsing sands, silts/clays, and care should be taken.

17.3 Control of Groundwater

Limited groundwater was encountered on site, however a number of the exploratory holes encountered damp CLAY. It is likely that provision of pumping/shuttering will be necessary during excavation of foundation trenches during wet weather and to deeper excavations for sewers etc. It is good practice to have such equipment on standby in case of seasonal / abnormal weather conditions.

17.4 Foundations

It is recommended that conventional strip/trench foundations can be adopted across the site founded within the firm to stiff CLAY at a minimum depth of 0.75mbgl. The following allowable bearing capacities can be assumed for foundation design;

- Firm to stiff gravelly sandy CLAY with an allowable bearing pressure of 100 kN/m^2 - 125kN/m^2.

Localised deepening of foundations and/or piled foundations are likely to be required in the vicinity of trees.

Foundations should be excavated wholly on one stratum. Should proposed foundations span different strata, trenching and stepping of foundations and/or nominal reinforcement will be required. A foundation zoning plan should be undertaken when proposed levels are made available.

Calculations on the allowable bearing capacity indicate settlements of less than 25mm for a square pad using the above allowable bearing capacity.

17.5 Ground Floor Construction

Shrinkable soils are present at shallow depth across the site and it is therefore recommended that suspended floor construction (e.g. either in-situ RC slabs or block and beam flooring) is adopted in

accordance with NHBC guidance.

17.6 Soakaways

Soakway tests were not undertaken during the fieldwork due to the cohesive (low permeability) strata encountered on site.

17.7 Heave / Shrinkage Potential

A summary of Atterburg limit tests is shown below. Full results are located in Appendix D.

Exploratory Position ID	Depth (m)	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	% <425um	% Plasticity Index	NHBC Modified Plasticity Level
TP1	1.50	18	39	26	77	13	LOW
TP3	1.20	11	32	15	64	17	LOW
TP6	1.30	11	31	15	60	16	LOW
TP9	1.00	14	42	19	70	23	LOW
TP11	1.70	10	29	14	69	15	LOW

LOW plasticity has generally been determined from geotechnical lab testing. Foundation design for tree heave protection could be designed accordingly following discussion with the NHBC.

17.8 Highway

According to the criteria of Highways Agency HD 25/95 Volume 7 Section 2 Part 2 HD 25/94, a CBR value of 3-5% on the firm to stiff clay is anticipated, however in-situ CBR's should be undertaken during construction to confirm. Placement of geotextiles within the areas of roads / parking could also be designed to minimise the subgrade thickness.

17.9 Protection of Buried Concrete

It is considered for concrete design purposes that a greenfield site and static groundwater conditions are applicable and the results are summarised below:

Concrete Classification	
Design Sulphate Class	DS-1
ACEC Class	AC-1
Design Chemical Class	DC-1

18 REFERENCES

18.1 *BS 5930:2015 Code of Practice for Site Investigation.*

18.2 *BS1377: 2016 Methods of Test for Soils for Civil Engineering Purposes.*

18.3 Assessment of risks to human health from land contamination: an overview of the development of guideline values and related research. EA, 2002.

18.4 *Contaminated Land Risk Assessment; A Guide to Good Practice; CIRIA C552: 2001.*

18.5 *Health and Safety in Construction, HSG150, HSE, 1996.*

18.6 *Hazardous Waste: Interpretation of the Definition and Classification of Hazardous Waste, Environment Agency, WM2 Version 1.0, June 2003.*

18.7 *DoE (1991), The Building Regulations Approved Document C, Site Preparation and Resistance to Moisture, HMSO.*

18.8 *Baker W (1987), Investigation Strategy - lecture at City of Birmingham Development Department Symposium on Methane Generating Sites, 9 December 1987, Industrial Research Laboratories, Birmingham.*

18.9 *NHBC* Standards, Chapter 4.2, 2017 Building Near Trees.

18.10 *Highways Agency HD 25/95 volume 7 section 2 Part 2 HD 25/94.*

18.11 *Water Regulations Advisory Scheme (2002) The selection of materials for water supply pipes to be laid in contaminated land.*

18.12 *Anon (1997) Dutch in Policy Retreat on Contaminated Land ENDS (Environmental Data Services), 269, 46.*

18.13 *Water Regulations Advisory Scheme (2002) The selection of materials for water supply pipes to be laid in contaminated land.*

18.14 *Piling In Layered Ground: Risks to Groundwater and Archaeology Science Report SC020074/SR Environment Agency October 2006.*

18.15 *Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination: Guidance on Pollution Prevention National Groundwater & Contaminated Land Centre report NC/99/73 F J Westcott, C M B Lean & M L Cunningham May 2001.*

18.16 *'Guidance on Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide are Present', Report Edition No.04 March 2007 NHBC – designed for use with low rise residential properties.*

18.17 *CIRIA C665 'Assessing risks posed by hazardous ground gases for buildings' 2007 - for high rise residential / flats*

18.18 *BS8485:2015 'Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings'.*

18.19 *BRE 414 'Protective measures for housing on gas-contaminated land' Roger Johnson, Parkman Environment 2001.*

18.20 *BS 8500- 1:2006 'Concrete – Complementary British Standard to BS EN 206-1 – Part 1: Method of specifying and guidance for the specifier' November 2006.*

18.21 *'Planning Policy 23:Planning and Pollution Control' Office of the Deputy Prime Minister 2004.*

18.22 *CLR11 'Model Procedures for the Management of Land Contamination' DEFRA 2004.*

18.23 *BRE 465 'Cover Systems for Land Regeneration' 2004.*

18.24 *'The UK Approach for Evaluating the Human Health Risks from Petroleum Hydrocarbons in Soils, Environment Agency Science Report P5-080/TR3', Environment Agency (May 2005).*

18.25 *TOX12- Contaminants in Soil: Collation of Toxicological Data and Intake Values for Humans. Dioxins, Furans and Dioxin-like PCBs' Environment Agency 2003.*

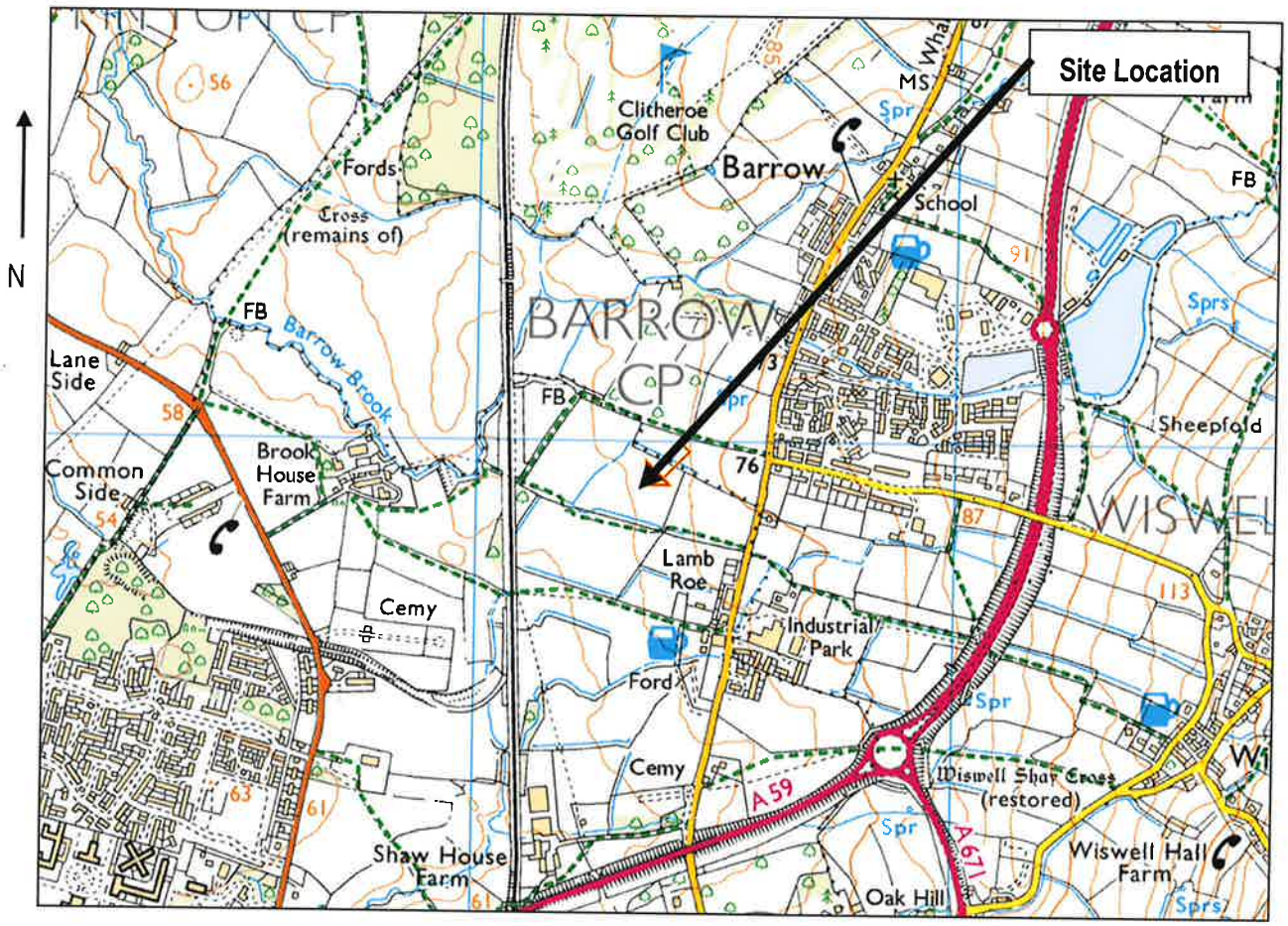
18.26 *Atkins 2017 AtRisksoil.co.uk SSV's derived using CLEA for 1 or 6% SOM. Residential with homegrown produce.*

18.27 *Phase 1 Geo-Environmental Desk Study for the Proposed Development of Land to the West of Whalley Road, Barrow, Lancashire by Capita Symonds – January 2012 (Doc reference: 18394-DS02).*

18.28 *Atkins 2017 AtRisksoil.co.uk SSV's derived using CLEA for 1 or 6% SOM. Residential with homegrown produce.*

APPENDIX A

(i) Site Location Plan



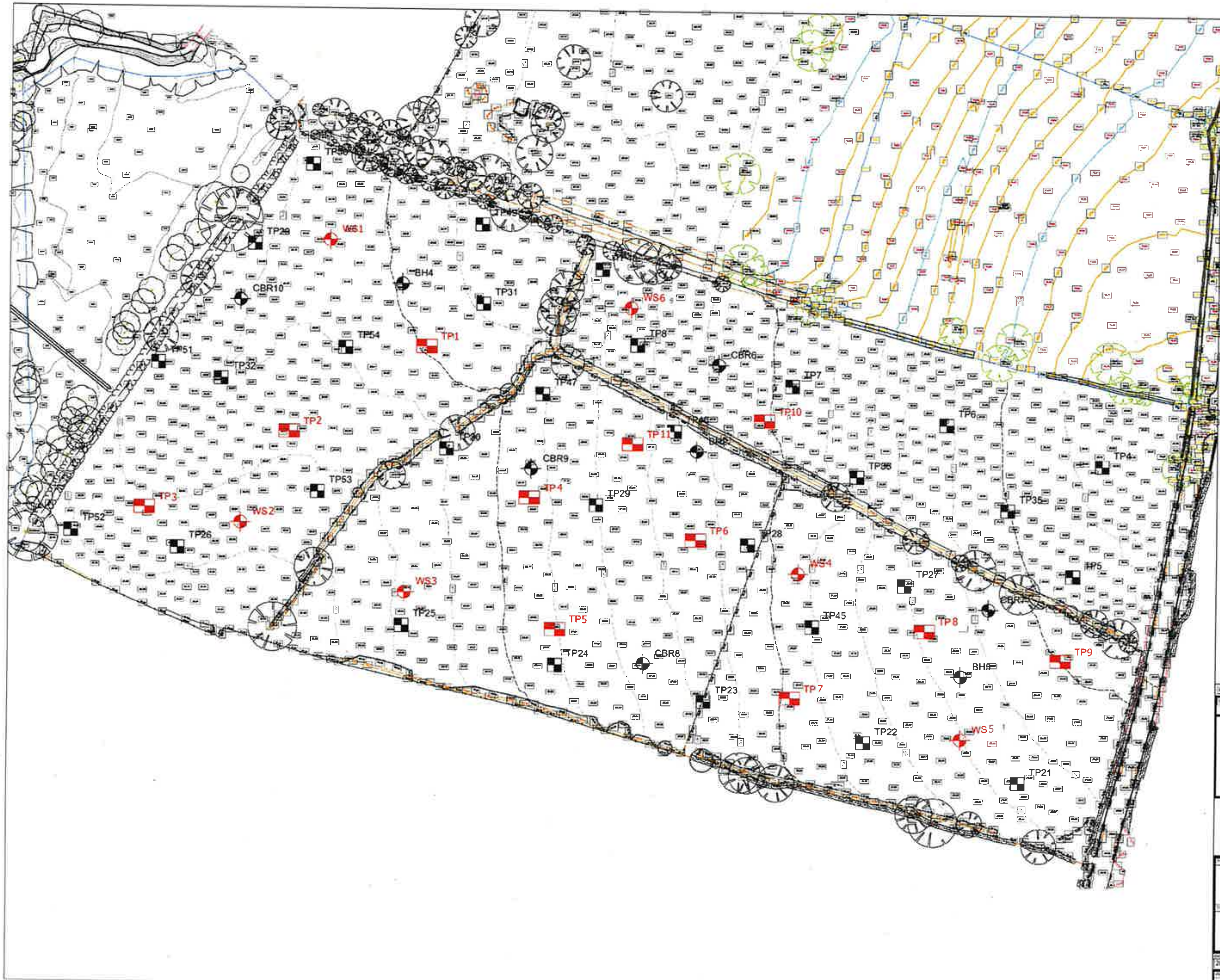
Site Location Plan

West of Whalley Road, Barrow, Clitheroe, Lancashire (nearest postcode: BB7 9BN). The coordinates for the centre of the site on National Grid are: 373355, 437929.

BETTS GEO
CONSULTING ENGINEERS

APPENDIX B

(i) Betts Exploratory Hole Location Plan



DO NOT SCALE

NOTES

THIS DRAWING SHOWS THE INDICATIVE LOCATION OF EXPLORATORY HOLES TO BE UNDERTAKEN BY BETTS GEO LTD IN 2018 AND THE PREVIOUSLY UNDERTAKEN EXPLORATORY HOLES BY JOHN POOLE AND BLOOMER LTD IN MAY 2014.

THE PLAN OVERLAYS THE PROPOSED LAYOUT.

KEY

PROPOSED TRIAL PIT LOCATION

PROPOSED WINDOW SAMPLE LOCATION

PREVIOUSLY UNDERTAKEN SITE INVESTIGATION

PREVIOUSLY UNDERTAKEN TRIAL PIT LOCATION

PREVIOUSLY UNDERTAKEN WINDOW SAMPLE LOCATION

DRAFT

BETTS ASSOCIATES
GEO ENVIRONMENTAL

DAVID WILSON HOMES

WHALLEY ROAD,
BARROW

PROPOSED
EXPLORATORY HOLE
LOCATION PLAN

28/02/18 | NTS @ A3 | PH | BL

18DWH018 | PROP 100 | -

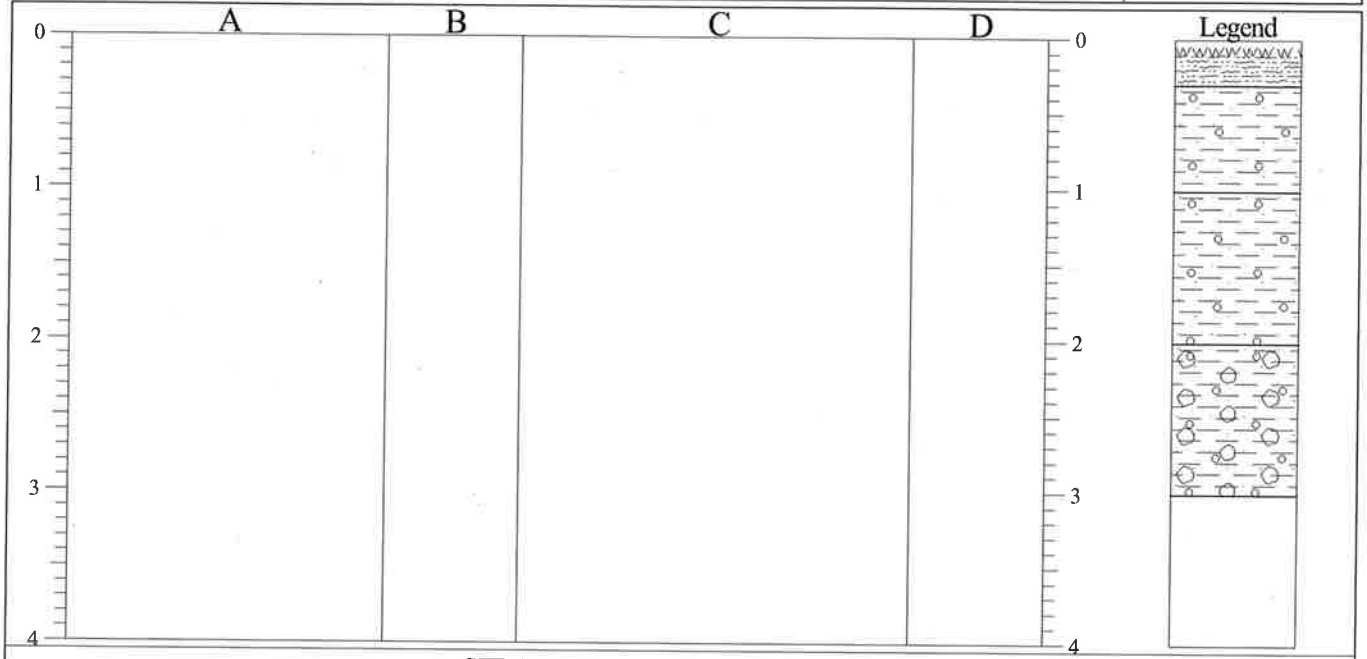
APPENDIX C

(i) Betts Exploratory Hole Logs

BETTS ASSOCIATES Betts Geo Ltd

TRIAL PIT LOG

Project				TRIAL PIT No
Barrow Road Whalley				TP201
Job No	Date	Ground Level (m)	Co-Ordinates ()	
18DWH018	06-04-18			
Contractor				Sheet
BETTS GEO Ltd				1 of 1

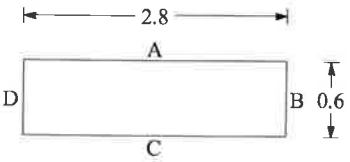


STRATA

SAMPLES & TESTS

Depth	No	DESCRIPTION	Depth	No	Remarks/Tests
0.00-0.30		Grass over TOPSOIL: Brown damp sandy CLAY. Occasional rootlets. (One or two fragments of glass noted within topsoil).	0.10	ES	
0.30-1.00		Firm damp light yellowish / orangish brown slightly gravelly sandy CLAY.			
1.00-2.00		Firm damp greyish brown sandy gravelly CLAY. Frequent subrounded to subangular gravel and cobble of various sizes and lithologies.	1.50	D	
2.00-3.00		Dark greyish brown damp gravelly very sandy cobble CLAY. Gravel and cobble are subrounded to subangular of various sizes and lithologies. Slight seepage at 2.0mbgl.			

Shoring/Support:
Stability: Stable



GENERAL REMARKS

0.0m - 3.0m - Damp.
2.0m - Slight seepage

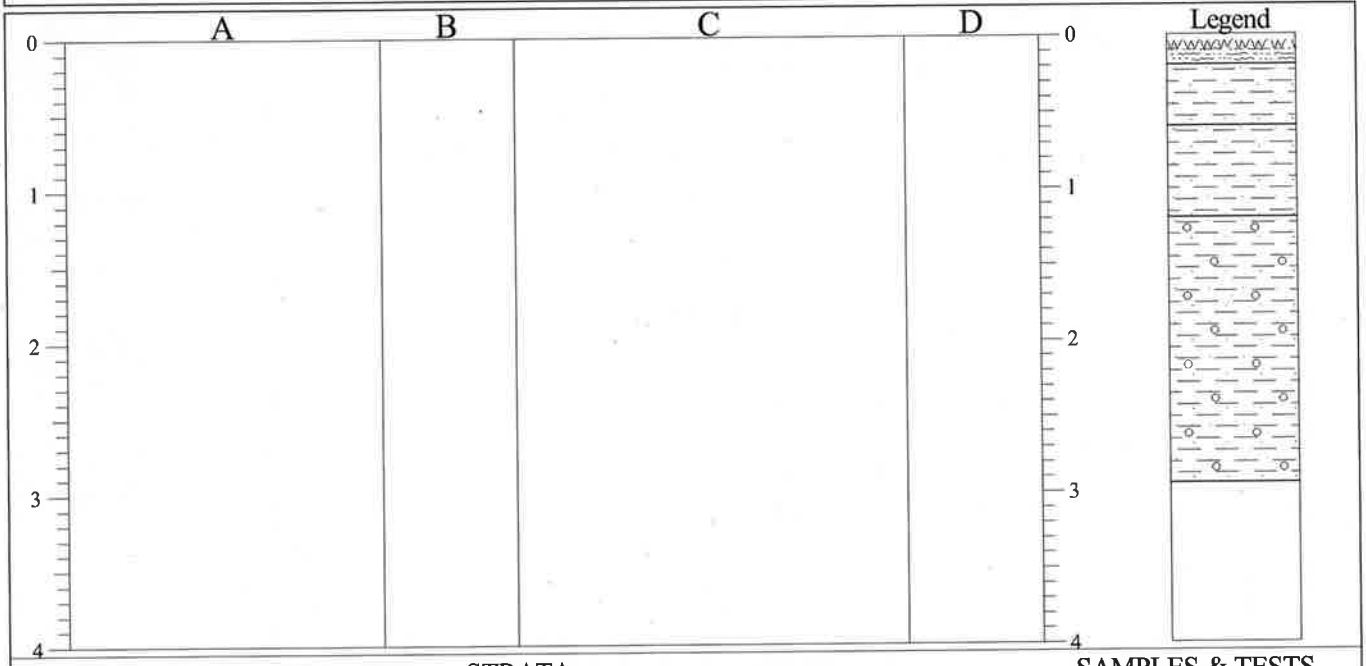
All dimensions in metres Scale 1:50	Client David Wilson Homes	Method/ Plant Used 13t tracked excavator	Logged By PH

AGS3 UK TP 18DWH018 - BARROW ROAD WHALLEY.GPJ GINT STD AGS 3_1.GDT 19/4/18

BETTS ASSOCIATES Betts Geo Ltd

TRIAL PIT LOG

Project				TRIAL PIT No
Barrow Road Whalley				TP202
Job No	Date	Ground Level (m)	Co-Ordinates ()	
18DWH018	06-04-18			
Contractor				Sheet
BETTS GEO Ltd				1 of 1

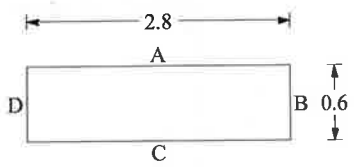


STRATA

SAMPLES & TESTS

Depth	No	DESCRIPTION	Depth	No	Remarks/Tests
0.00-0.20		Grass over TOPSOIL: Brown damp sandy CLAY. Frequent rootlets. Occasional coal fragment.	0.10	ES	
0.20-0.60		Firm orangish brown slightly sandy CLAY. 0.6m - Land drain in back of pit - Fast inflow of water.			
0.60-1.20		Stiff greyish brown slightly sandy CLAY. Rare rounded cobble.	0.80	ES	
1.20-2.95		Stiff dark greyish brown slightly sandy gravelly CLAY. Frequent subrounded to subangular gravel and cobble of various sizes and lithologies. Rare boulder.			

Shoring/Support:
Stability: Stable



GENERAL REMARKS

0.0m - 0.2m - Damp.
0.6m - Land Drain - Back of pit - Fast inflow of water.

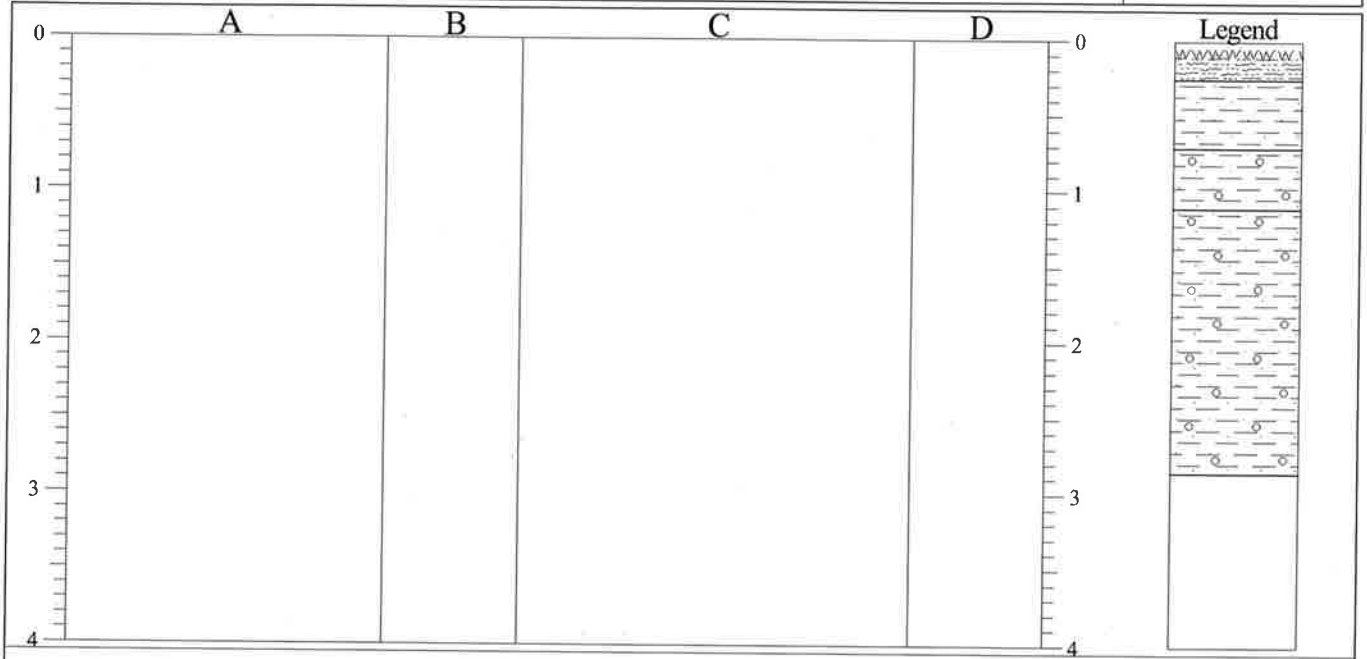
All dimensions in metres Scale 1:50	Client David Wilson Homes	Method/ Plant Used 13t tracked excavator	Logged By PH

AGS3 UK TP 18DWH018 - BARROW ROAD WHALLEY.GPJ GINT STD AGS 3_1.GDT 19/4/18

BETTS ASSOCIATES Betts Geo Ltd

TRIAL PIT LOG

Project				TRIAL PIT No
Barrow Road Whalley				TP203
Job No	Date	Ground Level (m)	Co-Ordinates ()	
18DWH018	06-04-18			
Contractor				Sheet
BETTS GEO Ltd				1 of 1



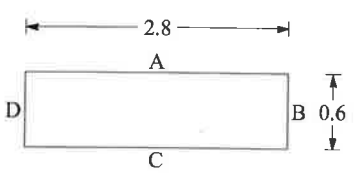
STRATA

Depth	No	DESCRIPTION
0.00-0.25		Grass over TOPSOIL: Brown damp sandy CLAY. Occasional rootlets. (One or two fragments of glass noted within topsoil).
0.25-0.70		Firm yellowish brown sandy CLAY. Occasional subangular to angular gravel and cobble of various lithologies.
0.70-1.10		Firm yellowish brown gravelly very sandy CLAY. Occasional subangular to angular gravel and cobble of various lithologies.
1.10-2.85		Firm with pockets of stiff sandy gravelly CLAY. Frequent subrounded to subangular cobbles of various lithologies. Rare boulder.

SAMPLES & TESTS

Depth	No	Remarks/Tests
0.10	ES	
1.20	D	

Shoring/Support:
Stability: Stable



GENERAL REMARKS

0.2m - Land drain - Dry.

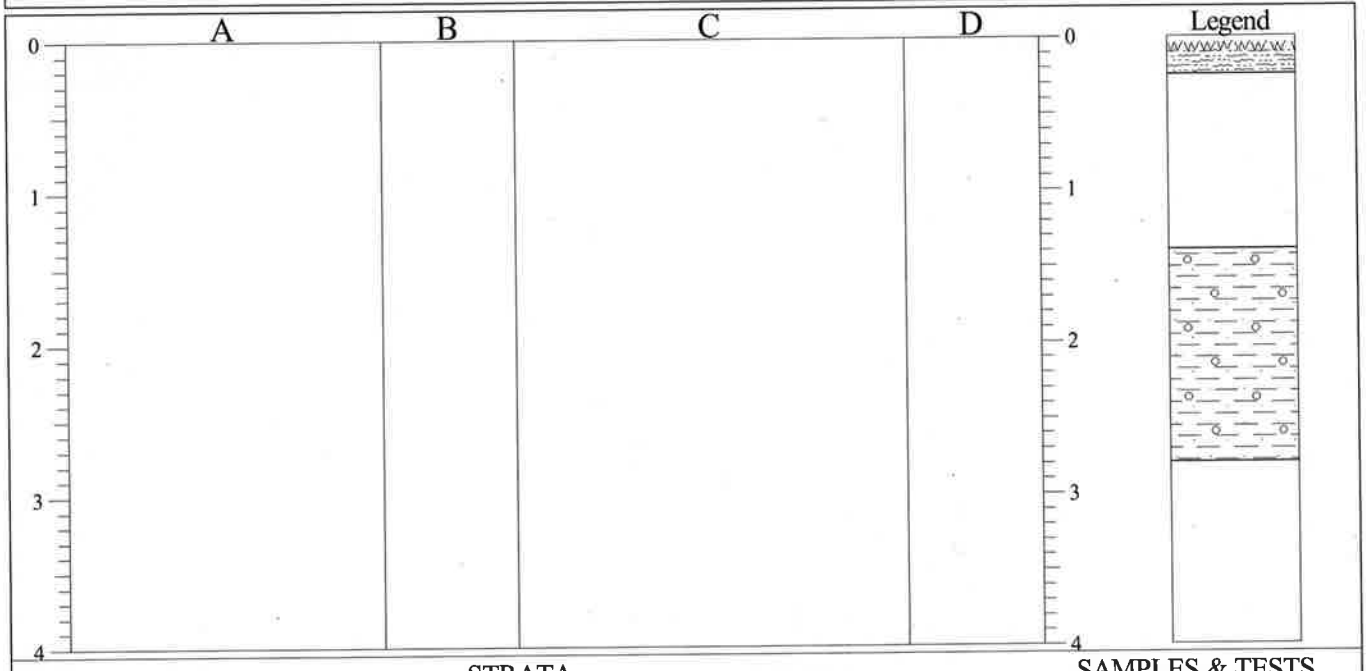
All dimensions in metres Scale 1:50	Client David Wilson Homes	Method/ Plant Used 13t tracked excavator	Logged By PH

AGS3 UK TP 18DWH018 - BARROW ROAD WHALLEY.GPJ GINT STD AGS 3_1.GDT 19/4/18

BETTS ASSOCIATES Betts Geo Ltd

TRIAL PIT LOG

Project				TRIAL PIT No
Barrow Road Whalley				**TP204**
Job No	Date	Ground Level (m)	Co-Ordinates ()	
18DWH018	06-04-18			
Contractor				Sheet
BETTS GEO Ltd				1 of 1



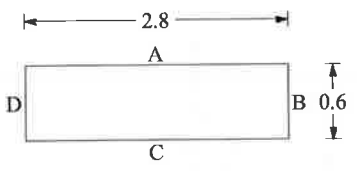
STRATA

Depth	No	DESCRIPTION
0.00-0.25		Grass over TOPSOIL: Brown sandy CLAY. Frequent rootlets. Occasional coal fragment.
0.25-1.40		Firm orangish brown silty sandy CLAY. Boulder at 0.40mbgl. Moderate inflow of water from left side of pit at 0.80mbgl.
1.40-2.80		Stiff dark greyish brown sandy gravelly CLAY. Occasional to frequent subrounded to subangular cobbles of various lithologies. Rare boulder. Slightly friable.

SAMPLES & TESTS

Depth	No	Remarks/Tests
0.10	ES	
0.50	ES	

Shoring/Support:
Stability: Stable



GENERAL REMARKS

0.4m - Boulder.
0.8m - Moderate inflow of water - Left hand side of pit.

All dimensions in metres Scale 1:50	Client David Wilson Homes	Method/ Plant Used 13t tracked excavator	Logged By PH

AGS3 UK TP 18DWH018 - BARROW ROAD WHALLEY.GPJ GINT STD AGS 3_1.GDT 19/4/18