Land West of Park Farm, Thornbury

Combined Phase 1 and Phase 2 Ground Condition Assessment

On behalf of **Barwood Development Securities Limited**

and

North West Thornbury Landowners Consortium

Project Ref: 39209/3501 | Rev: GCA_rev02 | Date: September 2018

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Summary

Site Address	Land at Oldbury Lane, Thornbury
Report Purpose	Support outline planning application for residential development.
Site Setting	Currently a mix of pastoral and arable fields. Pickedmoor Lane Rhine cuts through the site and an underground oil pipe passes through the northwest corner. Park Mill Farm and Park Mill Covert are to the west, a sewage treatment works is to the northwest and a housing development is to the east.
Site History	Site has remained undeveloped since first available mapping dated 1880. Surrounding significant land uses have included Thornbury Castle, quarries and gas works.
Geological Setting	Published geological mapping records Tidal Flat deposits (formerly Estuarine Alluvium) across the southern half of the site with bedrock comprising Mercia Mudstone Group Mudstone and Marginal Facies which are present from ground level and beneath superficial deposits where present.
Groundwater	Tidal Flat Deposits: unproductive strata Mercia Mudstone Group Marginal Facies: Principal Aquifer Mercia Mudstone Group Mudstone: Secondary B Aquifer Site does not lie within an SPZ for groundwater. Depth to groundwater is unknown.
Surface Water	Pickedmoor Lane Rhine bisects the site in the south and drains run along the southern and northern site boundaries. Flow is to the west.
Preliminary Ground Stability Risk Assessment	Moderate hazard potential for shrink-swell of clay soils and compressible ground. Other hazards classified as Low or Very Low. Site falls into a lower probability radon area – less than 1% of homes above action level. No recorded cavities (mining or natural) recorded within 2000m of the site.
Preliminary Contaminated Land Risk Assessment	Risk classifications calculated as Very Low for current site users; Low for groundwater; Low to Moderate/low for surface water; and Moderate for construction workers and future site users.
Ground Investigation Works	5 no. windowless sampler boreholes and 5 no. machine excavated trial pits undertaken by CC Ground Investigation Ltd from 13th to 15th March 2018. In-situ Standard Penetration Tests were undertaken where possible within boreholes at 1m intervals. Soil and groundwater samples were retained for geo-environmental laboratory analysis.
Recorded Ground Conditions	Topsoil was recorded site-wide overlying Tidal Flat Deposits (slightly gravelly very clayey SAND to very sandy CLAY). Tidal Flat Deposits were absent in the northeast corner and in the north of the site. Mercia Mudstone Group (Mudstone and Marginal Facies) deposits were recorded across the entire site. Marginal Facies Deposits comprised sandy clayey GRAVEL of limestone, siltstone and quartz with cobbles of conglomerate. The Mudstone was recorded as firm/ stiff light green slightly gravelly slightly sandy CLAY to very weak reddish brown MUDSTONE. Groundwater was encountered in exploratory holes at depths of 0.45m – 2.20mbgl.

Geo-Environmental Assessment	Ground gas monitoring undertaken recorded carbon dioxide concentrations of 0.2 – 5.4% v/v and methane concentrations of 0.0% v/v, correlating to an Amber 1 or CS-2 classification for ground gas. Ground gas protection measures are advised for future residential buildings. All eight soil samples that underwent laboratory analysis passed the assessment criteria for a residential with pant uptake end use and no exceedances were recorded. Groundwater samples recorded slightly elevated concentrations of selenium, bioavailable lead and total phenol at localized areas on-site.
Tier 2 Risk Assessment	The resultant risk classifications for identified receptors following the semi-quantitative Tier 2 risk assessment are as follows: Human Health – future on-site: Low Human Health – construction workers: Low to Moderate/low Groundwater: Low Surface water: Very Low
Geotechnical Assessment	The site does into fall into a mineral resource area under local authority. Due to the presence of shallow groundwater on-site, shallow soakaway features are not recommended for the Site. Whilst actual loadings for the proposed dwellings are unknown, such properties are considered suitable for the application of traditional shallow foundations. Excavations by standard plant will be feasible on-site through the shallow soils but use of a hydraulic breaker may be required where refusal is met on large cobbles of competent material. Excavation will likely require support and groundwater control measures.
Recommendations	Ground gas protection measures will be required for future dwellings on-site Suspended floor slabs are to be used on-site due to the volume change potential of the Tidal Flat Deposits. Further assessment of controlled waters is advised and should include for sampling and testing of surface water bodies.

1 Introduction

1.1 Brief

1.1.1 Peter Brett Associates LLP (PBA) has been commissioned by Barwood Development Securities Limited and North West Thornbury Landowners Consortium (the Client) to undertake a Phase 1 and Phase 2 Ground Condition Assessment to support an outline planning application for a residential development for an area of land known as Land West of Park Farm, Thornbury (the site).

1.2 Site Location and Description

1.2.1 The site is located off Oldbury Lane, northwest of the town of Thornbury in Gloucestershire.

1.2.2 The site comprises an area of approximately 36 hectares of agricultural fields, centred at approximate National Grid Reference (NGR) ST 631 917.

1.2.3 A Site Location Map is presented as **Figure 1**.

1.1 Objective and Scope of Work

Contamination

1.1.1 As required by the NPPF the assessment has been carried out in accordance with "established procedures" using current UK good practice and guidance given in British Standard BS10175:2011 +A2:2017 (BSi, 2017) and Contaminated Land Report 11 (CLR 11) Model Procedures for the Management of Contaminated Land (EA, 2004).

1.1.2 The scope of work performed by PBA comprises:

a. Collection and review of desk study information relating to the historical, geological, and environmental setting of the site.

b. A walkover to observe the existing condition of the land parcel and the surrounding area.

c. A qualitative preliminary Tier 1 risk assessment utilising a preliminary Conceptual Site Model (CSM) to identify 'source-pathway-receptor' linkages to assess potential geo-environmental hazards, if any, associated with existing potential contamination in the ground. This element has been carried out in accordance with PBA's 'Methodology for Ground Condition Assessment in England', a copy of which is included in **Appendix A**.

d. Drilling of boreholes, groundwater and ground gas monitoring and retention of soil samples for geo-environmental laboratory analysis.

e. Semi-quantitative Tier 2 Risk Assessment using site-specific data to amend the Tier 1 assessment and provide a more informed CSM for the site.

Ground Stability

1.1.3 The report also identifies potential hazards and constraints to the proposed development of the site with regards to the risk of ground instability.

1.1.4 The objective of a ground stability assessment it to identify the likely ground conditions of a defined site and assess the information to identify potential issues that may have associated geotechnical liabilities or other ground engineering constraints that could affect the site

development. This includes potential subsidence arising from artificial cavities, natural cavities, coal and non-coal (underground) mining / extraction activities, and adverse foundation conditions (ranging from soft weak sediments to hard strong rocks).

1.2 Sources of Information

1.2.1 Guidance on the context of this report and general limitations or constraints on its content and usage are given in the final section of this report.

1.2.2 The following primary sources of information were used in the compilation of this report:

- British Geological Survey (BGS) published geological mapping (Chepstow Sheet 250)
- Review of borehole records held by the British Geological Society (BGS) accessed via their website.
- A review of the Public Health England Radon Atlas and Interactive Radon Map.
- A search of the PBA project database to identify any ground condition reports near the site (within 250m).
- Enviro Insight Report and historical mapping obtained from emapsite™.
- Multi-Agency Geographic Information for the Countryside (MAGIC) webhosted database
- Review of the Natural Cavity and Artificial non-coal (underground) mining cavity databases managed and enhanced by PBA.

2 Site Setting

2.1 Current Land Use

On-Site

2.1.1 The current on-site conditions were recorded by a PBA engineer during a walkover on 18th December 2017.

2.1.2 The site is currently used for both pastoral and arable agricultural purposes; ground cover is predominantly grass with gravel access tracks in some areas. Pickedmoor Lane Rhine bisects the site towards the south in an approximately east-west direction.

2.1.3 An underground oil pipeline cuts across the northwest corner of the site, running northeast to southwest.

2.1.4 The site topography is generally flat falling gently from around 12m above Ordnance Datum (m AOD) in the east to about 9m AOD in the west.

2.1.5 Selected photos from the site walkover are presented in **Appendix B**.

Off-Site

2.1.6 The site is bounded by Park Mill Farm buildings to the west, a sewage treatment works to the northwest, a nursery to the north, housing development to the east (under construction at the time of writing) and fields to the south. Sporadic farm buildings and detached properties occupy areas of adjacent land.

2.1.7 Parkmill Covert, an area of ancient woodland, is located on the western site boundary.

2.2 Historical Land Use

2.2.1 Information on the history of the site and surrounding area has been gained from a review of historical mapping, including historical Ordnance Survey maps and Town Plans. Historic maps and plans are presented in **Appendix C**. It should be noted that the boundary shown on the historical mapping relates to the original proposed (larger) development area and not the revised development boundary.

2.2.2 The earliest available County Series map, dated 1880, shows Parkmill Farm and Parkmill Covert to the west, Oldbury Lane to the north and fields to the east and south. The Pickedmoor Rhine is shown on site, indicated to be flowing to the west-northwest. The fields are generally shown to be in the same alignment as the present day. Thornbury Castle is shown about 500m south-southeast of the site and a gas works and quarries are shown about 750m southeast of the site centre.

2.2.3 By the late 1910s, Oak Farm has been built to the north of the site.

2.2.4 By the 1970s the off-site gas works and quarries have been replaced with extensive housing to the east of the site. The layout of the site and surrounding areas shown on mapping from the 1970s largely reflects the present-day layout as observed from mapping and the site reconnaissance.

2.3 Potential Sources of Contamination

2.3.1 Based on the historical and current land use information presented in this section, the following potential sources of contamination have been identified:

a. On- and off-site agricultural activities.

b. Sewage works to the north-west of the site.

3 Geological and Environmental Setting

3.1 Introduction

3.1.1 Information on the geological setting of the site has been informed by reference to British Geological Survey mapping. Information on the environmental status of the site and surrounding area has been informed by reference to the Enviro Insight report (**Appendix D**), the Geo Insight Report (**Appendix E**) and other data sources. It should be noted that the boundary shown on the Enviro Insight and Geo Insight reports is the original proposed (larger) development area and not the most recent development boundary.

3.1.2 Information on the geological and environmental setting is used in the Hazard Assessment section of the Tier 1 (geo-environmental) risk assessment to identify potential sources of contamination, pathways and receptors, and to provide a baseline information to inform the Ground Stability Risk Assessment.

3.2 Published Geology

3.2.1 The 1:50,000-scale BGS geological map of the area (BGS, Chepstow - Sheet 250) indicates that the site is underlain by mudstones of the Mercia Mudstone Group and the Mercia Mudstone Group (Marginal Facies) - Conglomerate. The bedrock is overlain in the southern half of the site by Tidal Flat Deposits (formerly Estuarine Alluvium) comprising clay and silt.

3.2.2 In addition, it is anticipated that a layer of Topsoil will be encountered, reflective of both the greenfield location and agricultural activities.

3.3 Naturally Occurring Potential Geological Hazards

3.3.1 Table 3.1 summarises geological hazards and the potential risk as presented within the Enviro Insight report.

Table 3.1 Summary of Geological Hazards

Hazard	BGS Hazard Rating	PBA Comment
Shrink- Swell	Low	Near surface Tidal Flat Deposits can typically be of a low to medium volume change potential and weathered Mercia Mudstone Group deposits also have medium, locally high shrink-swell potential. PBA consider the hazard to be **Moderate**.
Landslides	Very Low	Agree. The site is relatively flat-lying. No significant risk of landslides.
Ground Dissolution	Low	Agree. Although soluble gypsum can be encountered in the Mercia Mudstone Group, it is unlikely given the geographical location that extensive volumes of gypsum will be encountered such that ground dissolution would present a significant hazard.
Compressible Ground	Moderate	Agree (where Tidal Flat Deposits are present). Clay-rich Tidal Flat Deposits with

Hazard	BGS Hazard Rating	PBA Comment
		variable silt and clay fractions could be susceptible to compression.
Collapsible Deposits	Very Low	Agree.
Running Sand	Moderate	Agree due to sand layers within the Mercia Mudstone (Marginal Facies).

Radon

3.3.2 According to the Geo Insight report and UKradon.org, the site lies within a low probability radon area, where less than 1% of homes are above the Action Level. Guidance from the Building Research Establishment (BRE) indicates that radon protective measures are not required on new properties (BRE, 2007).

Natural Cavity Records

3.3.3 A search of the PBA Natural Cavities database indicated that there are no recorded natural cavities within 2000m of the site centre.

Mining (non-coal) Cavity Records

3.3.4 A search of the PBA Mining (non-coal) database indicated that there are no recorded man-made, non-coal mining records within 2000m of the site centre.

3.4 Hydrogeology

3.4.1 Table 3.2 below summarises the hydrogeological conditions at, and in the immediate vicinity of, the site.

Table 3.2 Summary of Hydrogeological Conditions

Item	Description
Aquifer Classification	Tidal Flat Deposits: Unproductive Strata Mercia Mudstone Group (Marginal Facies) – Conglomerate: Principal Aquifer. A Principal Aquifer is defined as geology of high intergranular and/or fracture permeability, usually providing a high level of water storage and may support water supply/river base flow on a strategic scale. Mercia Mudstone Group: Secondary B Aquifer. A Secondary B aquifer is described as predominantly lower permeability layers which may store/yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. Generally the water-bearing parts of the former non-aquifers.
Groundwater Vulnerability	The Mercia Mudstone Group (Marginal Facies) – Conglomerate is classified as a soil with high leaching potential.

Item	Description
Groundwater Flow Direction	Unknown. Anticipated to be to the south towards Pickedmoor Lane Rhine in the south of the site.
Source Protection Zone	The site does not lie within a Source Protection Zone (SPZ). There are no SPZs recorded within 500m of the site.
Groundwater Abstractions	There is one active groundwater abstraction license, registered to E J Garrett & Partners at Park Mill Farm, around 280m south of the site centre. The license relates to the annual abstraction of around 20,000m³ of groundwater for general farming & domestic purposes. There are no other active abstraction licenses within 1000m of the site centre.

3.5 Hydrology

3.5.1 The following table summarises the surface water conditions in the vicinity of the site.

Table 3.3 Summary of Hydrological Conditions

Item	Description
Nearest Surface Water Feature	One water course is recorded on-site in the south flowing in a westerly direction (Pickedmoor Lane Rhine) and two drains are recorded along the southern and northern site boundaries. Features reportedly contain water year-round in normal conditions according to the Enviro Insight report.
Surface Water Quality	No data available.
Surface Water Abstractions	None recorded within 2000m of the site centre.
Discharge Consents	The nearest active discharge consent relates to sewage discharges from The Keepings entering an unnamed ditch 34m tot eh east of the site.
Pollution Incidents	One pollution incident recorded on-site from June 2001 when agricultural materials and waste causing Minor (Category 3) impact to water. A second pollution incident 16m east of the site took place in February 2002 when oils and fuels were released and caused Minor (category 3) impact to waters.

3.6 Environmental Data

3.6.1 Table 3.4 below summarises the Environmental records obtained from the Enviro Insight report and relevant data searches relating to the site and the surrounding area.

Table 3.4 Summary of Environmental data

Data Type	Number on Site	Number within 250m of the site
Waste Regulation		
Active or Historical Landfill Sites	0	0
Licensed Waste Management Facilities	0	0
Statutory Permits/ Authorisations		
Part A(1) and IPPC Permitted Activities [Note 1]	0	0
Part A(2) and Part B Permitted Activities	0	0
Radioactive Substance Authorisations	0	0
Planning Hazardous Substances [Note 2]	0	0
Potential Past and Current Contaminative Land Uses		
Contaminated Land Register Entries and Notices	0	0
Current Industrial Land use	0	2
Fuel Stations	0	0
Sites Determined as Contaminated Land under Part 2A EPA 1990	0	0
Notes: 1. Includes historical Integrated Pollution Controls, Integrated Pollution Prevention & Control, Local Authority Integrated Pollution Prevention & Control and Pollution Prevention & Control permits. 2. Includes COMAH (Control of Major Accident Hazards) and NHHS (Notification of Installations Handling Hazardous Substances) sites.		

3.6.2 Recorded industrial land uses include a water pumping station (sewage works) 14m to the north and a dairy farm (Park Mill Farm) 157m to the west.

3.7 Tanks

3.7.1 The historical tanks database records the closest tank as 255m to the northwest of the site. This is recorded as a filter tank on the 1970 mapping.

3.7.2 Tanks were not observed during the site walkover.

3.8 Ecological Systems

3.8.1 An area of ancient and semi-natural woodland (Park Mill Covert) is recorded adjacent to the west of the site.

3.9 Listed Buildings & Ancient Monuments

3.9.1 There are no listed buildings or ancient monuments recorded on-site. The closest recorded feature is a Scheduled Monument (Medieval fishponds) recorded approximately 340m to the east of the site.

4 Preliminary Tier 1 Risk Assessment

4.1 Introduction

4.1.1 A preliminary Tier 1 qualitative contamination risk assessment has been undertaken for the Site. The methodology and criteria adopted by PBA for the preliminary geo-environmental risk assessment is presented in **Appendix A**.

4.1.2 When there is a pollutant linkage (and therefore some measure of risk) it is necessary to determine whether the risk matters and therefore whether further action is required. PBA provide an estimation of the level of risk but do not comment on whether or not it is an unacceptable risk as the significance or acceptability of a risk depends on the individual stakeholder. Risk estimation involves predicting the likely consequence (what degree of harm might result) and the probability that the consequence will arise (how likely the outcome is).

4.2 Conceptual Site Model

4.2.1 A Tier 1 Qualitative Risk Assessment includes the development of a conceptual site model (CSM). The CSM describes the types and locations of potential contamination sources, the identification of potential receptors and the identification of potential transport / migration pathways.

4.3 Contamination Source Identification

On-Site

4.3.1 The following potential sources of contamination have been identified within the boundaries of the site and given a classification for their potential to generate contamination in accordance with the PBA Methodology:

a. Agricultural chemicals associated with farming the land. Very Low (1) potential to generate significant contamination. Due to the generally fast breakdown rate of these compounds they are unlikely to remain on-site beyond the site clearance and construction works and are not recognised as a significant source of contamination for the Site's future development.

b. Naturally occurring ground gas associated with the Tidal Flat Deposits. Low (2) to Moderate (3) potential to generate significant contamination.

Off-Site

4.3.2 The following potential sources of contamination have been identified within the surrounding area of the site and given a classification for their potential to generate contamination in accordance with the PBA Methodology:

a. Sewage works off-site to the northwest. Moderate (3) potential to generate contamination.

4.4 Hazard Assessment

4.4.1 In order to determine whether the identified hazards pose a risk it is necessary to identify the presence of potential receptors and pathways by which they can be exposed to the hazard.

Identification of Potential Receptors

4.4.2 It is understood that the site is proposed for a residential end use. Details of the potential receptors considered and whether or not the receptor is plausible is given below:

Table 4-1 Review of Potential Contamination Receptors

Receptor Type	Plausible? Y/N	Sensitivity
Human Health		
Current On-Site	Yes	High (4)
Future On-Site	Yes – residential properties proposed	Very High (5)
Construction & Maintenance Workers	Yes – to be present for duration of the construction phase	High (4)
Off-Site	Yes – off-site land uses	Very High (5)
Controlled Waters		
Surface Water	Yes – surface water features present on-site in the south flowing in a westerly direction.	Low (2)
Groundwater	Yes – Principal Aquifer and Secondary B Aquifer underlie the site.	Moderate (3)
Buildings / Services	Yes – residential properties will occupy the site as part of future development.	Low (2)
Ecological Systems*	Yes – ancient woodland adjacent to the west of the site	Low to Moderate (2/3)
Designated Archaeological Sites	No – none recorded on-site or in the immediate vicinity	-
* Internationally or nationally designated sites (as defined in the statutory guidance (Draft Circular on Contaminated Land, DETR, 2000)) "in the local area" will be identified as potential ecological receptors.		

Identification of Potential Pathways

4.4.3 Table 2 in the PBA methodology describes possible pathways for each receptor type. Each of these possible pathways is then considered when assessing the possible pollutant linkage.

4.5 Risk Estimation

4.5.1 When there is a pollutant linkage (and therefore some measure of risk) it is necessary to determine whether the risk matters and therefore where further action is required. Risk estimation involves predicting the likely consequence (what degree of harm might result) and the probability that the consequences will arise (how likely the outcome is).

4.5.2 Based on the information available, and assuming a worst case scenario, the following potential complete pollutant linkages have been identified:

Table 4-2 Summary of Identified Potential Complete Pollutant Linkages

Source (Hazard potential)	Pathway	Receptor (sensitivity)	Likelihood
Sewage works off-site to the north-west (3)	Leaching of contaminants and migration through groundwater onto site	Groundwater (3)	Unlikely
	Surface water recharge	Surface Water (2)	Low Likelihood
Agricultural chemicals (1)	Direct contact	Current site users (4)	Low likelihood
	Leaching through soils	Groundwater (3)	Likely
	Surface run-off	Surface Water (2)	Unlikely
Ground gas from Tidal Flat Deposits (3)	Accumulation and inhalation indoors	Construction workers (4)	Unlikely
		Future site users (5)	

4.5.3 There were no complete linkages identified that may affect the off-site ecological system, buildings/ property on-site or off-site users.

4.5.4 Agricultural chemicals generally don't take long to break down in the environment and as such are unlikely to impact upon the future construction phase and future site users.

4.6 Conclusions & Risk Evaluation

4.6.1 Following the above assessment, the estimated risks to identified receptors have been designated as follows:

a. Human health – current on-site: Very Low

b. Human health – future on-site: Low

c. Human health – construction workers: Low

d. Groundwater: Very Low to Low

e. Surface water: Very Low to Moderate/low

4.6.2 The Moderate potential risks to construction workers and future site users originates from naturally occurring ground gases that may migrate into buildings and be inhaled indoors. This risk could be mitigated through installation of appropriate ground gas protection measures in future buildings. The requirement for protection measures will be defined through intrusive ground investigation works (see Section 7.3).

5 Ground Investigation

5.1 General

5.1.1 The fieldworks were defined by PBA and carried out from 13th to 15th March 2018 by CC Ground Investigation Ltd. Fieldworks were carried out in general accordance with BS 5930:2015 'Code of practice for ground investigations' (BSI, 2015).

5.1.2 The scope of works comprised five windowless sampler boreholes across the Site and five machine excavated trial pits. Shallow soakaway testing was also scheduled to be undertaken in trial pits. All of the boreholes were installed with groundwater and ground gas monitoring wells. The position of the boreholes is shown on **Figure 2**.

5.2 Boreholes

5.2.1 Boreholes were sunk using a track mounted Terrier rig to a maximum depth of 4.00m bgl. In-situ Standard Penetration Tests (SPTs) were undertaken where possible within the boreholes to provide indicative information on the strength of the soils. On completion of drilling, boreholes were either backfilled with soil arisings or installed with groundwater and ground gas monitoring wells. These comprise plain and slotted 50mm pipework with a pea gravel surround and bentonite seal with gas taps were fitted to allow for post-fieldwork monitoring of ground gas and groundwater.

5.2.2 Borehole logs are presented in the contractor's factual report in **Appendix F**.

5.3 Trial Pits

5.3.1 Trial pits were excavated by a JCB 3CX mechanical excavator with a 0.6m wide bucket to a maximum depth of 1.4m below ground level (bgl). Soils were sequentially stockpiled with topsoil kept separate and arisings logged upon excavation. Photographs were taken of the pits and spoil heap before backfilling with the arisings, laying topsoil back across the surface and surface left slightly mounded to allow for subsequent settlement.

5.3.2 Whilst shallow soakaway testing was scheduled to be undertaken in the trial pits, groundwater levels were such that it was not feasible for testing to go ahead. Groundwater levels were encountered too shallow in the pits to permit the testing to be completed.

5.4 Laboratory Testing

Geo-Environmental Testing

5.4.1 Samples of soil for geo-environmental testing were taken from the boreholes and trial pits by the contractor. Analytical testing was scheduled by PBA and was carried out by i2 Analytical Ltd, an Mcerts and UKAS accredited laboratory.

5.4.2 A programme of geo-environmental laboratory testing was carried out on selected soil samples to determine the concentrations of a range of commonly occurring potential contaminants. This included screening for metals, inorganics, total petroleum hydrocarbons (TPH) and polycyclic aromatic hydrocarbons (PAH).

5.4.3 The results of the geo-environmental testing are included in the contractor's factual report which is presented as **Appendix F**.

6 Ground Conditions

6.1 General

6.1.1 The ground conditions encountered on-site were generally as expected based on the BGS geological mapping. Ground conditions were recorded comprising topsoil overlying Tidal Flat Deposits (Estuarine Alluvium across most of the Site) locally with Mercia Mudstone Group underlying this, and present directly beneath topsoil where superficial deposits were absent.

6.2 Topsoil

6.2.1 Topsoil was recorded in all locations to a depth of 0.2 – 0.9m bgl and generally comprised grass over soft very sandy CLAY to slightly gravelly very clayey SAND.

6.3 Tidal Flat Deposits

6.3.1 The Tidal Flat Deposits were recorded across the majority of the site underlying topsoil to a maximum depth of 1.55m bgl and an average depth of 0.8m bgl. The Tidal Flat Deposits were absent in the north-east in WS101and in the north in TP103. The strata of the Tidal Flat Deposits were recorded as comprising orangish brown and reddish brown slightly gravelly very clayey SAND to soft/ firm very sandy CLAY.

6.3.2 An in-situ Standard Penetration Test (SPT) undertaken in the Tidal Flat Deposits recorded an N value of 14 at a depth of 1.2m bgl.

6.4 Mercia Mudstone Group

6.4.1 The Mercia Mudstone Group deposits on-site can be sub-divided into Mudstone and Marginal Facies deposits.

6.4.2 Marginal Facies deposits were recorded across most of the site and in some locations was recorded as interbedded with Mercia Mudstone group Mudstone. These deposits were recorded as comprising sandy clayey GRAVEL of micritic limestone, siltstone and quartz and cobbles of dolomitic conglomerate.

6.4.3 Mercia Mudstone Group Mudstone was recorded as varying from firm/ stiff light green slightly gravelly slightly sandy CLAY to very weak reddish brown MUDSTONE. SPTs undertaken in these deposits recorded N values ranging from N= 10 at 1.2m bgl to N= >50 from 1.8m bgl.

6.5 Groundwater

6.5.1 Groundwater was encountered in exploratory holes during the works at strike depths of 0.45m to 2.20m rising to between 0.87mand 1.90m after a short period (10-20 minutes) of monitoring.

6.5.2 Following completion of the site works, three return visits to site were undertaken to monitor groundwater levels in the installed wells. Results of the monitoring works are summarised in the table below.

Table 6-1 Summary of Groundwater Monitoring Results

Location	Groundwater Depth (m bgl) 20/03/18	Groundwater Depth (m bgl) 27/03/18	Groundwater Depth (m bgl) 05/04/18
WS101	0.96	1.02	0.68
WS102	0.77	0.82	0.58
WS103A	1.54	1.69	1.19
WS104	1.04	1.14	0.97
WS105A	0.36	0.51	0.21

6.6 Ground Gas

6.6.1 Ground gas monitoring was undertaken following completion of Site works on three occasions in conjunction with the groundwater monitoring visits. The table below summarises the results of the monitoring data.

Table 6-2 Summary of Ground Gas Monitoring Results

Location	Atmospheric Pressure (mbar)	Flow (l/h)	Carbon Dioxide (%v/v)	Methane (%v/v)
WS101	1005-1030	-0.1 – 0.0	1.1 – 3.1	0.0
WS102	1005 – 1031	-0.3 – 0.1	1.6 – 5.4	0.0
WS103A	1005 – 1029	0.0 – 0.1	0.8 – 3.0	0.0
WS104	1005 – 1030	0.0 – 0.1	0.2 – 1.9	0.0
WS105A	1005 – 1031	0.1 – 10.1	0.4 – 2.2	0.0

6.6.2 The recorded monitoring data for WS105A is not considered to be reliable due to the shallow groundwater levels also recorded. With groundwater levels of <0.5m bgl recorded there would be minimal capacity for ground gas to accumulate, and would have also created a high differential pressure, in turn, generating higher than normal flow rates. For this reason, the recorded flow rate of 10.1l/h is considered to be anomalous and will not be used as part of the ground gas risk assessment.

6.6.3 Complete monitoring results are presented in **Appendix F**.

7 Geo-Environmental Assessment

7.1 Introduction

7.1.1 The following section provides a review of soil laboratory analysis undertaken following completion of the site works.

7.1.2 A programme of geo-environmental laboratory testing was carried out on selected soil samples to determine the concentrations of a range of commonly occurring potential contaminants. This included screening for metals, inorganics, total petroleum hydrocarbons (TPH) and polycyclic aromatic hydrocarbons (PAH).

7.2 Review of Laboratory Analysis

Assessment Criteria

7.2.1 The rationale used by PBA in reviewing analytical data is outlined in **Appendix G**. The criteria routinely used by PBA for Tier 2 soil screening for the protection of human health are the 'Suitable for use levels' (S4ULs) published in 2015 which adopt a minimal or tolerable risk approach. For the proposed residential form of development, the 'Residential end-use with home grown produce' (RWHP) category has been used.

7.2.2 A summary of the soils assessment is presented as **Appendix H**.

Soil Analysis

Table 7-1 Summary of Geo-Environmental Laboratory Soil Analysis

Determinand	Residential with Plant Uptake Criteria (mg/kg)	Maximum Recorded Concentration (mg/kg)	Pass/ Fail
Arsenic	37	12	PASS
Cadmium	11	0.5	PASS
Chromium	910	45	PASS
Copper	2400	91	PASS
Lead	200	110	PASS
Mercury	40	<0.3	PASS
Nickel	130	32	PASS
Selenium	250	<1	PASS
Zinc	3700	390	PASS
Total Phenol	200	<1	PASS

Determinand	Residential with Plant Uptake Criteria (mg/kg)	Maximum Recorded Concentration (mg/kg)	Pass/ Fail
Total Aliphatic Hydrocarbons	65 (minimum criteria for single band)	<10	PASS
Total Aromatic Hydrocarbons	83 (minimum criteria for single band)	<10	PASS
Hazard Index	1	0.0407	PASS
Benzo(a)pyrene	2.7	<0.05	PASS
Asbestos Identification	Detect	None detected	PASS

7.2.3 Of the eight samples submitted for analysis, six came from topsoil and two from the Tidal Flat Deposits. All samples passed the assessment criteria for a residential with plant uptake end use and no exceedances were recorded.

Groundwater

7.2.4 As the site is underlain by a Principal Aquifer and surface water features are present on-site, the results of the laboratory analysis have been compared against both the freshwater criteria and human consumption criteria.

7.2.5 A summary of the waters assessment is presented in **Appendix I**.

Table 7-2 Summary of Geo-Environmental Laboratory Water Analysis

Determinand	Freshwater Criteria	Human Consumption Criteria	Maximum Recorded Concentration	Pass / Fail
Arsenic	20 µg/l	10 µg/l	0.68 µg/l	PASS
Cadmium	0.08 µg/l	5 µg/l	0.04 µg/l	PASS
Chromium	4.7 µg/l	50 µg/l	0.6 µg/l	PASS
Copper	1 µg/l (bioavailable concentration)	2000 µg/l	3.8 µg/l (total) 0.99 µg/l (bioavailable*)	PASS
Lead	1.2 µg/l (bioavailable concentration)	10 µg/l	2.1 µg/l (total) 2.1 µg/l (bioavailable*)	PASS (Human consumption) **FAIL** (Freshwater)
Mercury	0.07 µg/l	1 µg/l	<0.05 µg/l	PASS

Determinand	Freshwater Criteria	Human Consumption Criteria	Maximum Recorded Concentration	Pass / Fail
Nickel	4 µg/l (bioavailable concentration)	20 µg/l	1.9 µg/l	PASS
Selenium	-	10 µg/l	12 µg/l (WS105)	**FAIL**
Zinc	10.9 µg/l (bioavailable concentration)	5000 µg/l	13 µg/l (total) 7.68 µg/l (bioavailable*)	PASS
Ammoniacal Nitrogen	-	500mg/l	24mg/l	PASS
Total Phenol	7.7 µg/l	500 µg/l	18 µg/l	PASS (Human consumption) **FAIL** (Freshwater)
Chloride	-	25,0000 µg/l	29 µg/l	PASS
Sulphate	-	250 mg/l	47 mg/l	PASS
Benzene	10 µg/l	1 µg/l	<1 µg/l	PASS
Benzo(a)pyrene	0.0017 µg/l	0.01 µg/l	<0.01 µg/l	PASS (Human consumption)
Total PAH	-	0.1 µg/l	<0.16 µg/l	See section below
*assumes dissolved organic carbon concentration of 1mg/l				

7.2.6 The maximum concentration of lead recorded reportedly exceeds the freshwater assessment criteria according to the above table. However, the other four recorded concentrations are <1µg/l, and the average concentration is 0.66 µg/l as a result of this.

7.2.7 Selenium marginally exceeds the assessment criteria for human health at one location (WS105). All other locations recorded concentrations of 0.6 to 5.6µg/l. There is no criteria for freshwater receptors for selenium.

7.2.8 The total phenol concentrations recorded exceed the freshwater assessment criteria at two locations (WS102 and WS103A) on-site with both locations recording concentrations of 18µg/l.

7.2.9 The freshwater assessment criteria for benzo(a)pyrene is an order of magnitude lower than the laboratory limit of detection. However, benzo(a)pyrene is not recognised as a contaminant of concern on-site as soil concentrations were all recorded as <0.05mg/kg and there is no recorded source for the benzo(a)pyrene either off-site or on-site. The same applies for the recorded Total PAH concentrations assessed against human consumption criteria.

7.3 Ground Gas

7.3.1 The results of the ground gas monitoring have been used to calculate Gas Screening Values (GSVs) for the site as follows:

Table 7-3 Calculated Gas Screening Values

Location	Gas Screening Value
WS101	0.0031
WS102	0.0162
WS103A	0.003
WS104	0.0019
WS105A	0.0022

7.3.2 The GSV for WS105A was calculated using the next greatest flow rate recorded following removal of the anomalous visit where a flow of 10.1l/h was recorded.

7.3.3 The monitoring results have been reviewed against the guidance set out in CIRIA C665 (Assessing Risks Posed by Hazardous Ground Gases to Buildings) and the NHBC guidance on evaluation of development proposals on sites where methane and carbon dioxide are present. The GSV results correlate to generally a Green or CS-1 classification. As one of the three monitoring visits is considered to have provided anomalous data, it would be considered prudent to undertake further monitoring and analysis of the ground gas regime on-site, as whilst the classification is anticipated to be Green, elevated concentrations of carbon dioxide (>5%) were recorded in WS102, and as such this area could be considered as an Amber 1 or CS-2 classification.

7.3.4 Ground Gas is discussed further in Section 10.

8 Semi-Quantitative Tier 2 Risk Assessment

8.1 Introduction

8.1.1 This Tier 2 risk assessment has been undertaken for the Site and builds on the findings of the Preliminary Tier 1 assessment. The methodology and criteria adopted by PBA for the geo-environmental risk assessment remains the same as that for the Tier 1 and is presented in **Appendix A**.

8.2 Contamination Source Identification

On-Site

8.2.1 The Tier 1 assessment identified two potential on-site source of contamination; agrochemicals associated with agricultural working of the fields and ground gas generated from the superficial Tidal Flat Deposits. The results of the Tier 1 assessment concluded that the risk from agrochemical was considered to be negligible but the results of the post-fieldwork ground gas monitoring have proven the potential presence of natural ground gas on-site and this contamination source remains relevant for the site. Assessment of agrochemicals in the soils was not undertaken as part of this investigation due to the generally fast breakdown rate of these compounds. On this basis, they will be removed as part of this assessment on the assumption that they will be present on-site in some form but do not have a high potential to generate contamination.

8.2.2 Groundwater laboratory analysis has recorded some slightly elevated concentrations of selenium and total phenol in some of the boreholes on-site. As the concentrations are only slightly exceeding the assessment criteria and are not site-wide, groundwater contamination is considered to have a Low potential to generate contamination on-site.

Off-Site

8.2.3 Off-site potential sources identified as part of the Tier 1 assessment only comprised the sewage works located off-site to the northwest. This were classified as having Moderate potential to generate contamination. The results of the soil contamination analysis undertaken suggest that there has not been any impact to the site from the off-site source.

8.3 Hazard Assessment

Identification of Receptors

Table 8-1 Review of Tier 2 Contamination Receptors

Receptor Type	Plausible? Y/N	Sensitivity
<u>Human Health</u>		
Current On-Site	Yes	High / 4
Future On-Site	Yes – residential properties proposed	Very High / 5
Construction & Maintenance Workers	Yes – to be present for duration of the construction phase	High / 4
<u>Controlled Waters</u>		
Surface Water		Low (2)

Receptor Type	Plausible? Y/N	Sensitivity
Groundwater	Yes – surface water features present on-site in the south flowing in a westerly direction. Yes – Principal Aquifer and Secondary B Aquifer underlie the site.	Moderate (3)

Identification of Pathways

8.3.1 Table 2 in the PBA methodology describes possible pathways for each receptor type. Each of these possible pathways is then considered when assessing the possible pollutant linkage.

8.4 Risk Estimation

8.4.1 Based on the information available, and assuming a worst-case scenario, the following potential complete pollutant linkages have been identified:

Table 8-2 Summary of Tier 2 Risk Assessment

Source (Hazard potential)	Pathway	Receptor (sensitivity)	Likelihood
Ground gas from Tidal Flat Deposits (3)	Accumulation and inhalation indoors	Construction workers (4)	Unlikely
		Future site users (5)	
Contaminants recorded in groundwater slightly exceeding criteria (2)	Groundwater recharge	Surface water (2)	Low Likelihood
	Direct contact and ingestion	Construction workers (4)	Likely
	Migration off-site	Groundwater (3)	Low Likelihood

8.5 Risk Evaluation

8.5.1 Following the above assessment, the estimated risks have been designated as follows:

a. Human Health – future on-site: Low

b. Human Health – construction workers: Low to Moderate/low

c. Groundwater: Low

d. Surface water: Very Low

8.5.2 Whilst a risk from ground gas has been identified, minimal monitoring has been undertaken to date and it would be recommended to undertaken further monitoring. However, the potential risk from ground gas may be mitigated through the installation of ground gas protection measures at construction phase. This will break the pollution linkage and eliminate the potential risk to human health.

9 Geotechnical Assessment

9.1 Introduction

9.1.1 A key consideration for the proposed development is the geological setting of the Site and the geotechnical implications on future foundation design. This section provides outline geotechnical recommendations based on information collected as part of the ground investigation works and buildings on the data provided in the front section of this report.

9.2 Mineral Resource

9.2.1 According to the BGS Gloucestershire Mineral Resource Information in Support of National, Regional and Local Planning Scale 1:100,000 mapping the site does not fall within a mineral resource area. In addition, the South Gloucestershire Minerals and Waste Local Plan Proposals Map indicates the site does into fall into a mineral resource area under local authority.

9.3 Infiltration Potential

9.3.1 The intrusive ground investigation works encountered groundwater from as shallow as 0.45m bgl. Due to the presence of shallow groundwater and the requirement to have a minimum off-set of 1m between the base of a soakaway and maximum groundwater level (BRE 635) surface water drainage using soakaways is unlikely to be feasible for the Site.

9.4 Foundations

9.4.1 Geology of the site generally comprises Tidal Flat Deposits overlying Mercia Mudstone Group Mudstone and Marginal Facies (conglomerate).

9.4.2 Generally the Tidal Flat Deposits were less than about 1m thick with only one location recorded at a thickness of 1.55m (WS104). Given that the Tidal Flat Deposits are of limited thickness and variable in nature possibly including material that would be compressible foundations for the proposed development would be best taken down to the level of the underlying Mercia Mudstone or Marginal Facies.

9.4.3 The Mercia Mudstone strata was generally encountered as slightly sandy clay and typically the clays of the Mercia Mudstone Group tend to be of medium to high plasticity and as such would be of medium to high shrinkage potential.

9.4.4 Whilst actual loadings for the proposed dwellings are unknown, the proposed development is for residential housing and foundation pressures for low rise housing would not be expected to be very high. In consideration of this shallow spread strip of trench fill foundations would be expected to be appropriate for the development based on either the Mercia Mudstone or Marginal Facies. Though there is some variability in the nature of the solid geology beneath the Tidal Flat Deposits these natural strata are unlikely to be highly compressible and under typical low rise residential foundation loading, settlements would be expected to be within normally acceptable tolerances for residential development.

9.4.5 Further ground investigation and geotechnical laboratory testing will be necessary to assess formation bearing resistance and shrinkage potential to enable recommendations to be made regarding foundation depths and widths.

9.5 Excavations

9.5.1 Excavations using conventional plant should be feasible on-site through the near surface soils however, use of a hydraulic breaker may be required where more competent conglomerate or mudstone material are encountered as observed in the ground investigation. The presence of groundwater from a shallow depth on-site and layers of sand also recorded during the investigation and subsequent monitoring is such that that excavation for foundations and service trenches will likely encounter groundwater and may require support and groundwater control measures. In addition the soft/potentially loose consistency of the near surface soils may impact on plant movements across the Site, particularly during periods of inclement weather.

9.6 Floor Slabs

9.6.1 Suspended floor slabs will most likely be required particularly where underlain by Tidal Flat Deposits or the near surface strata has a volume change potential.

9.7 Concrete in Aggressive Ground

9.7.1 The sulphate analysis undertaken on water samples as part of the geo-environmental laboratory analysis recorded concentrations of up to 47mg/l and soil concentrations of up to 95.7mg/l in the Tidal Flat Deposits. In accordance with BRE Special Digest 1 guidance, these results place the Site (classification for natural ground) in a Design Sulphate class DS-1 and an Aggressive Chemical Environment for Concrete class AC-1.

10 Conclusions & Recommendations

10.1 General

10.1.1 Current on-site conditions comprise pastoral and arable agricultural fields with ground cover predominately grass and gravel access tracks. Pickedmoor Lane Rhine bisects the site towards the south in an approximately east-west direction. A sewage treatment works is located off-site to the northwest, Park Mill Farm and Park Mill Covert (woodland) are to the west and a residential development currently under construction is to the east.

10.1.2 Historically the site has been undeveloped fields since first available mapping dated 1880, with surrounding land uses including Thornbury Castle 500m and gas works and quarries 750m southeast.

10.1.3 Published geology records Tidal Flat Deposits (clay and silt) overlying Mercia Mudstone Group Mudstone and Marginal Facies (conglomerate). The Marginal Facies are recorded as a Principal Aquifer whilst the Mudstone is a Secondary B Aquifer. Tidal Flat Deposits are unproductive strata.

10.1.4 Ground investigation works comprised five windowless sampler boreholes and five machine excavated trial pits. Boreholes were installed for post-fieldwork monitoring purposes. Tidal Flat Deposits were confirmed across most of the site comprising very clayey SAND to very sandy CLAY. Marginal Facies deposits were recorded as predominately GRAVEL of micritic limestone and dolomitic conglomerate. Mercia Mudstone ranged from firm to stiff green CLAY to reddish brown MUDSTONE.

10.1.5 Groundwater was struck at depths of 0.45- 2.2m bgl and monitored at levels of 0.21 – 1.69m bgl during post-fieldwork monitoring.

10.2 Geo-Environmental

10.2.1 Soil samples (total of 8 samples) submitted for geo-environmental laboratory analysis all passed the contamination assessment criteria for a residential with plant uptake end use scenario.

10.2.2 Groundwater samples were taken from all borehole installations and submitted for geo-environmental laboratory analysis. The results recorded slightly elevated concentration of selenium and total phenol, as well as potentially elevated concentrations of bioavailable metals. As such groundwater is considered to pose a potential risk to freshwater organisms and further assessment is required to define the extents of this risk.

10.2.3 Results of the ground gas monitoring concluded that the site generally falls into a Green / CS-1 classification but would locally be classified as Amber 1 / CS-2 around WS102 and. Further monitoring is recommended to make this assessment more robust and provide more surety for the protection measures required. The CIRIA C665 document specifies a minimum of 6 monitoring visits over 3 months for a residential with gardens end use.

10.2.4 The semi-quantitative tier 2 risk assessment identified the potential risks to site receptors as ranging from Very Low for surface water and current on-site users to Moderate for construction workers and future on-site users. The risk to groundwater was defined as Moderate/Low, however, it should be noted that elevated concentrations of potential contaminants have also been recorded in groundwater.

10.2.5 Further gas and groundwater monitoring is likely to be required to inform detailed design.

10.3 Geotechnical

10.3.1 The preliminary geological hazards assessment identified a Moderate potential for shrink-swelling clays and running sands hazards associated with the Tidal Flat Deposits and Marginal Facies deposits respectively.

10.3.2 Due to the presence of shallow groundwater on-site, it is considered unlikely that shallow infiltration drainage will be a viable solution for the proposed development.

10.3.3 During excavation of trial pits, refusal was met at a shallow depth on competent strata. As such, it is anticipated that hydraulic breakers or similar may be required during the construction phase to facilitate excavation works.

10.3.4 Shallow traditional foundations are anticipated to be suitable for the proposed development based on the material encountered during the ground investigation. Design of foundations should take into consideration the presence of superficial deposits and the lateral variation in ground conditions across the site.

10.4 Recommendations

10.4.1 Due to the presence of compressible Tidal Flat Deposits beneath most of the site, suspended floor slabs are recommended.

10.4.2 Ground gas protection measures will be required for future dwellings on-site. Following the outline assessment presented in this report such measures may include: reinforced concrete cast in-situ floor slab (suspended, non-suspended or raft) with at least 1200 g DPM2 and underfloor venting; or beam and block or pre-cast concrete and 2000 g DPM/ reinforced gas membrane and underfloor venting. All joints and penetrations are to be sealed. However, in accordance with CIRIA guidance it is recommended that further ground gas monitoring is undertaken to provide a more robust assessment, targeting low pressure weather systems to reflect a worst-case ground gas regime.

10.4.3 Due to the results of the groundwater laboratory analysis, it would be considered prudent to return to site and take water samples from the surface water bodies on-site and additional groundwater samples to provide a more robust dataset for analysis and assess whether the slightly elevated concentrations recorded are localised, anomalous or part of a more widespread issue. This would be required to inform the detailed design.

10.4.4 Geotechnical investigation works will also be required in the future to assess the bearing resistance of the strata and the shrink-swell potential of the shallow material. Such investigation would allow for assessment of CBR values to inform pavement design.

11 Essential Guidance for Report Readers

This report has been prepared within an agreed timeframe and to an agreed budget that will necessarily apply some constraints on its content and usage. The remarks below are presented to assist the reader in understanding the context of this report and any general limitations or constraints. If there are any specific limitations and constraints they are described in the report text.

The opinions and recommendations expressed in this report are based on statute, guidance, and good practice current at the time of its publication. Peter Brett Associates LLP (PBA) does not accept any liability whatsoever for the consequences of any future legislative changes or the release of subsequent guidance documentation, etc. Such changes may render some of the opinions and advice in this report inappropriate or incorrect and the report should be returned to us and reassessed if required for re-use after one year from date of publication. Following delivery of the report PBA has no obligation to advise the Client or any other party of such changes or their repercussions.

Some of the conclusions in this report may be based on third party data. No guarantee can be given for the accuracy or completeness of any of the third party data used. Historical maps and aerial photographs provide a “snap shot” in time about conditions or activities at the site and cannot be relied upon as indicators of any events or activities that may have taken place at other times.

The conclusions and recommendations made in this report and the opinions expressed are based on the information reviewed and/or the ground conditions encountered in exploratory holes and the results of any field or laboratory testing undertaken. There may be ground conditions at the site that have not been disclosed by the information reviewed or by the investigative work undertaken. Such undisclosed conditions cannot be taken into account in any analysis and reporting.

It should be noted that groundwater levels, groundwater chemistry, surface water levels, surface water chemistry, soil gas concentrations and soil gas flow rates can vary due to seasonal, climatic, tidal and man-made effects.

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Any interpretation carried out in this report is based on scientific and engineering appraisal carried out by suitably experienced and qualified technical consultants based on the scope of our engagement. We have not taken into account the perceptions of, for example, banks, insurers, other funders, lay people, etc, unless the report has been prepared specifically for that purpose. Advice from other specialists may be required such as the legal, planning and architecture professions, whether specifically recommended in our report or not.

Public or legal consultations or enquiries, or consultation with any Regulatory Bodies (such as the Environment Agency, Natural England or Local Authority) have taken place only as part of this work where specifically stated.

12 References

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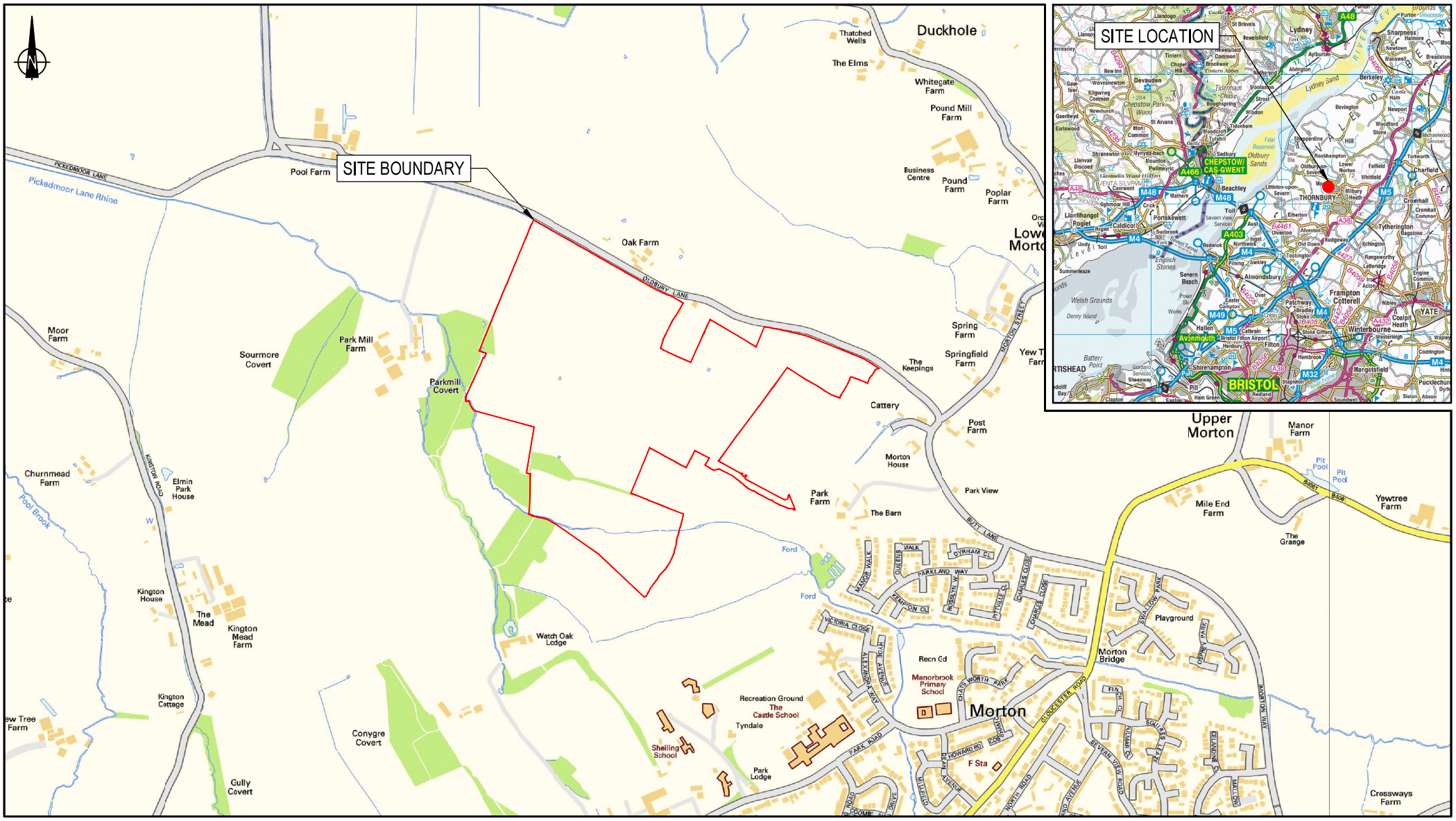
Figures



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Client

BARWOOD DEVELOPMENT SECURITIES

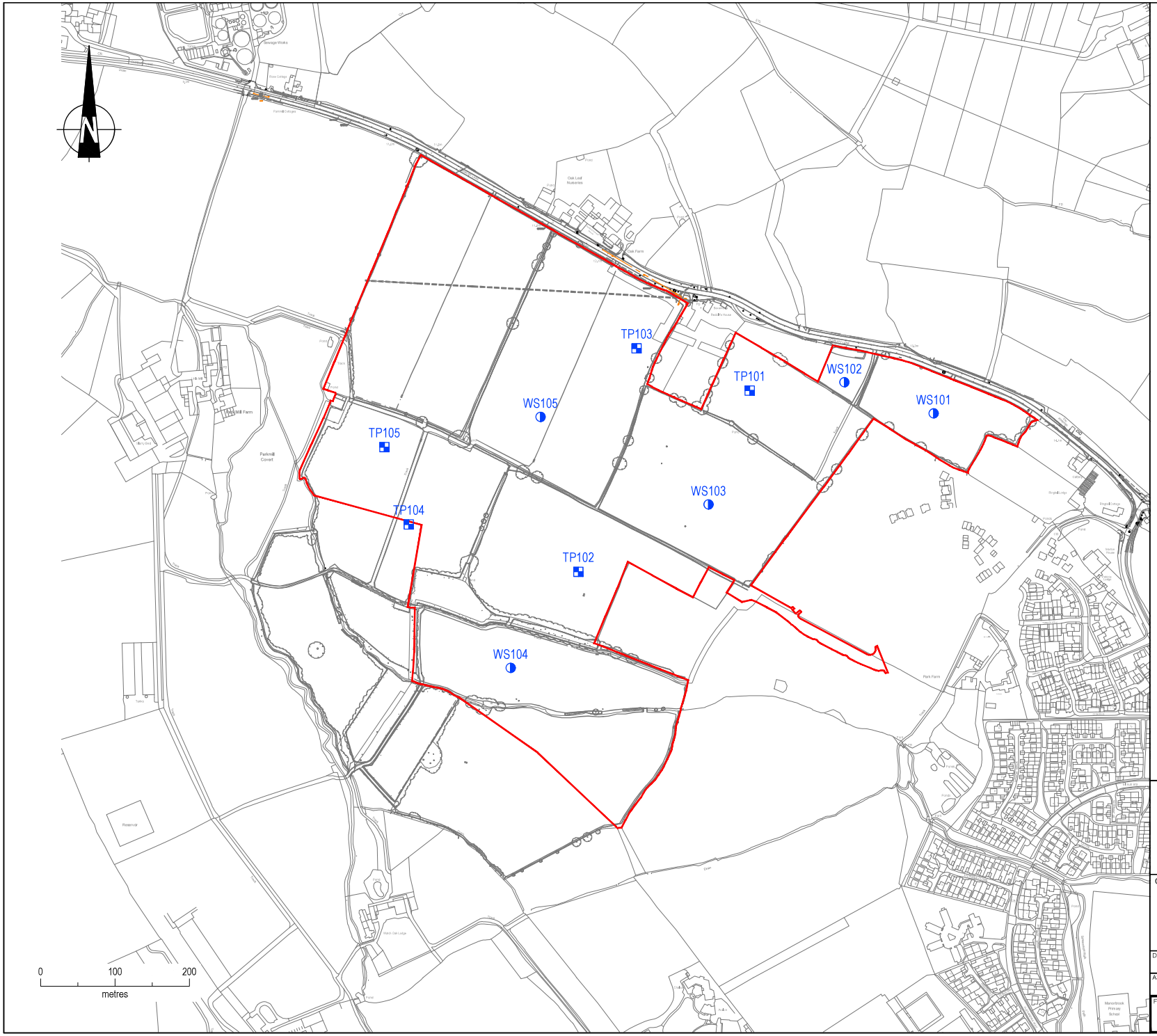
LAND TO THE WEST OF PARK FARM, THORNBURY

SITE LOCATION PLAN

Date	26.01.2018
A4 Scale	NTS
Drawn by	EW
Checked by	JHi

Figure Number

FIGURE 1



Key

- Proposed Trial Pit Locations
- Proposed Window Sample Location

LAND TO THE WEST OF PARK FARM
THORNBURY

SITE LAYOUT PLAN

Client
Barwood Development Securities Ltd

Date of 1st Issue	Drawn by
16.03.2018	davco
A3 Scale	Checked by
1:	OE

Figure Number
FIGURE 2

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