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Warminster South - Land at Bugley Barton Farm Proposed Residential Development Geo-Environmental & Geotechnical Assessment

Report Reference: ESP.6271t.02.3602

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Warminster South - Land at Bugley Barton Farm Proposed Residential Development Geo-Environmental & Geotechnical Assessment

Prepared for:
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Report Reference: **ESP.6271t.02.3602**

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General Notes

General Construction Advice

Executive Summary

Persimmon Homes Wessex are proposing to redevelop the subject site for residential purposes. ESP have undertaken a geo-environmental and geotechnical assessment and the key potential land quality issues identified by the assessment are summarised below:

	Potential Hazard	Anticipated Risk	Discussion
Site Setting	Current Site Status. (Section 2.1)	-	The farmyard area site is currently occupied by large portal framed barns and structures associated with the wider farm site. Areas of hardstanding and gravel surfacing are present.
	Identified Ground Conditions. (Section 5.1)	-	The exploratory holes have identified the farmyard area to be generally underlain by variable thicknesses of Made Ground, overlying natural Boyne Hollow Chert Member bedrock. Shaftesbury Sandstone Member bedrock was also identified in some areas.
	Groundwater Conditions. (Section 5.2)	-	The site is underlain by a Principal Aquifer and within a Zone 3 Source Protection Zone (SPZ).
	Historical Land Use. (Section 2.2)	-	The site has been identified as a farm since the earliest mapping published in 1886.
Geo-environmental	Potential Contamination Sources (Section 3.1.2)	High	Several potential contamination sources identified, including probable asbestos cement cladding and roofing on farm buildings, Made Ground across the site, diesel tank and slurry pit/outfall pipe.
	Chronic Risks to Human Health (Section 7.1)	Moderate/ Low	Elevated levels of PAH contamination identified in Made Ground. Localised in southeast.
	Risks to Controlled Waters (Section 7.2)	Moderate/ Low	Elevated levels of metals and PAHs identified. Due to groundwater conditions (Principal Aquifer and SPZ 3), further assessment likely required.
	Hazardous Ground Gas (Section 7.3)	Moderate	Based on the above calculated GSV, we consider that the site would be classified as Characteristic Situation CS-2 for a residential development (CIRIA C665:2007). Gas protective measures will be required.
	Other Hazards (Section 7.1.1)	High	Farm buildings and possible asbestos containing materials in stockpile require inspection by asbestos specialist
Geotechnical	Weak/Compressible Ground, requiring non-traditional foundations (Section 8.3 and Section 8.4)	Moderate/ Low	Traditional trench foundations likely achievable at approximately 1.3m depth (with localised deepening, See Section 8.3). Ground bearing floor slabs achievable in areas of limited Made Ground, however they should be suspended where deeper Made Ground is identified (e.g., WS207 & WS208).
	Shrinkage or Swelling (Section 8.2.2)	Moderate	Laboratory testing has indicated that the fine-grained soils at shallow depth are of medium volume change potential.
	Sulphate Attack on Buried Concrete (Section 7.4.2)	Moderate/ Low	We consider that the farmyard area site would be classified as Design Sulphate Class DS-1 and Aggressive Chemical Environment for Concrete Class AC-1, allowing for mobile groundwater. The previous assessment identified that the wider site would be classified as Design Sulphate Class DS-1, and Aggressive Chemical Environment for Concrete Class AC-2z, allowing for mobile groundwater.
	Soakaway Feasibility (Section 8.8)	-	No soakaway infiltration testing has been undertaken at the farmyard area site. Soakaway testing was undertaken across the wider site as part of the previous assessment (ESP, 2016) and this should be referred to for soakaway drainage recommendations.
Others	UXO (Section 2.10.5)	-	A Preliminary Desk Study assessment of risk concludes that 'a detailed desk study, whilst always prudent, is not considered essential in this instance'.
	Flooding (Section 2.6)	Low	See Section 2.6.
	Invasive Plants (Section 8.1.2)	-	No evidence of invasive species identified.
	Further Investigation Required?	Yes	See Section 9.

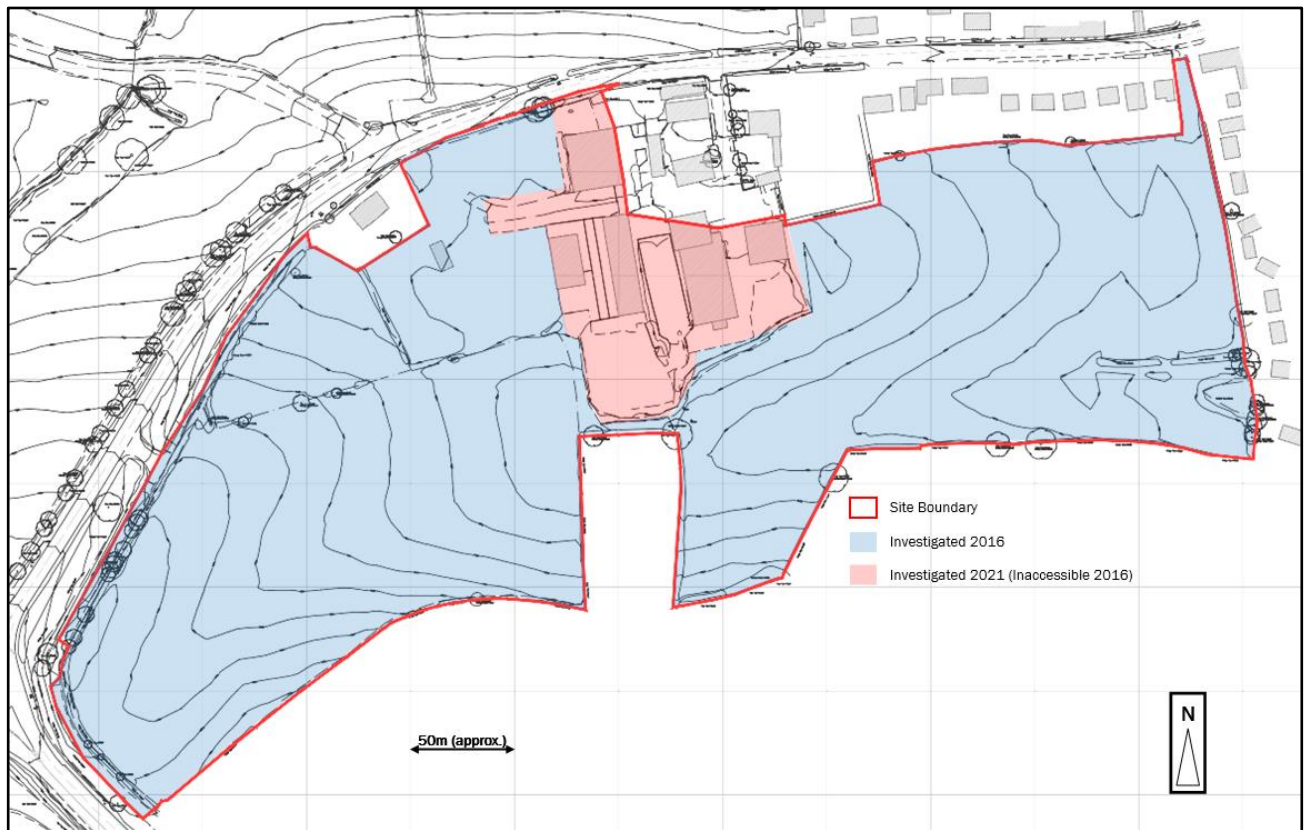
Note: The above is intended to provide a summary of the conclusions of the assessment. It does not provide a definitive assessment and must not be referenced as a separate document. Refer to the main body of the report for details.

1 Introduction

1.1 Background

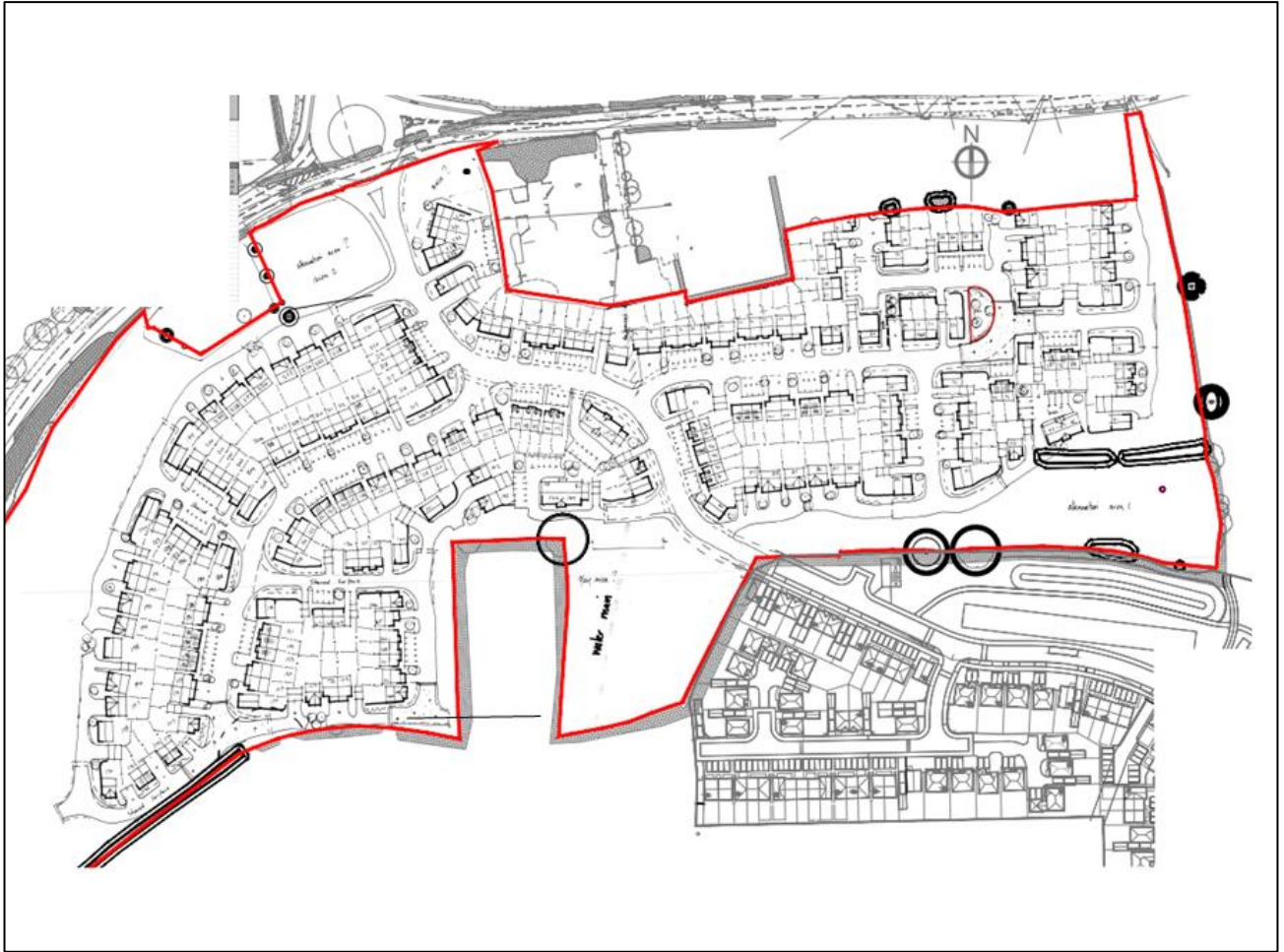
Persimmon Homes Wessex (hereafter known as the Client) are proposing to redevelop the subject site for residential purposes. The Earth Science Partnership Ltd (ESP), Consulting Engineers, Geologists and Environmental Scientists, were instructed by the Client to undertake an integrated geotechnical and geo-environmental investigation and assessment to identify and evaluate potential ground hazards which could impact on the proposed development. The site location is shown on Insert 3 in Section 2.1.

ESP have previously undertaken an integrated geotechnical and geo-environmental investigation and assessment across the wider site in 2016, with the final report issued in January 2017 (Ref: ESP.6271t.2676). During this investigation, the farmyard area in the north could not be accessed, therefore the remainder of the site was investigated, with the farmyard area to be investigated later (see Insert 1 below). The investigation works in the farmyard area have now been undertaken and the findings are presented in this report.



Insert 1 – Investigation Areas – 2016 and 2021

We have not been provided with a recent proposed development layout, however based on the previous information provided by the Client and the proposed development layout sketch for the whole site (see Insert 2), we understand that the proposed development will comprise approximately 233no.dwellings across the previously investigated site (ESP, 2016) and the recently investigated farm yard area, ranging from one bedroom flats to four bedroom houses, with private gardens, garages, car parking and access roads, and areas of landscaping. During the 2016 investigation, the proposed development layout was provided following completion of the site works, and so could not be considered in designing the investigation.



Insert 2 – Proposed Development Layout Sketch (after Persimmon Homes, 2016)

We have not been advised that the development requires any significant earthworks. However, given the current changes in elevation across the site, particularly around the slurry pit (see Figure 1) and margins of the farm buildings, we consider that some earthworks will be required to create suitable development platforms.

Based on the above, we understand that the proposed structures would be classified as Geotechnical Category 2 (BS5930:2015).

1.2 Objective and Scope of Works

The objective of the investigation was to obtain information on the geotechnical character and properties of the ground beneath the site, potential risks posed by contamination and ground gas, and to allow an assessment of these ground conditions with reference to the potential impact on the proposed development.

We are not aware of any ground hazard related planning conditions relating to the development.

The scope of works for the investigation was designed by ESP within an agreed budget, and comprised a desk study review of the previous investigation (ESP, 2016), available historical Ordnance Survey maps, environmental data, geological maps, memoirs and data, and further desk study information, a field reconnaissance visit, the supervision and direction windowless sample boreholes, hand excavated trial pits, geotechnical and geo-environmental laboratory testing, assessment of foundation options, risks to human health and controlled waters, and reporting.

The contract was awarded based on a competitive tender quotation. The terms of reference for the assessment are as laid down in the Earth Science Partnership proposal of 29th June 2021 (ref: ESP.6271t.02.It1.Proposal - Warminster South). The investigation and assessment were undertaken in between July and September 2021.

1.3 Report Format

The previous Desk Study (ESP, 2016) was undertaken for the site as a whole (including the central farmyard area being assessed within this report) as shown in Insert 1 within the red line boundary. Therefore, this report includes a brief summary of the Desk Study (Section 2), updated with pertinent information relating the farmyard area only. The full details of the Desk Study should be referred to from our previous report.

The remainder of the report (Sections 4 to 9) refers to the investigation of the farmyard area only (see Insert 1). For details of the assessment of the wider site, our previous investigation report should be referred to (ESP, 2016). Pertinent information from the 2016 investigation has been used in the relevant sections.

This report includes the desk study and field reconnaissance reports (Section 2), and details of the investigation undertaken of BS5930:2015 (Section 4), along with the Preliminary Risk Assessment stage (Section 3) and Generic Quantitative Risk Assessment (Section 5) of CLR11. A preliminary evaluation of the resulting risks and any remedial measures potentially required to mitigate identified unacceptable risks from contamination and hazardous ground gas is included in Sections 6 and 7. However, it should be appreciated that this is a preliminary evaluation only and will not generally meet the requirements of the Options Appraisal report of CLR11.

A preliminary risk register, identifying potential geotechnical hazards from the desk study review, is presented as Section 2.9, with a full assessment of the geotechnical conditions including foundation and floor slab options, the feasibility of soakaways, etc. in Section 8 – this complies the relevant elements of the BS5930:2015. The geotechnical risk register is updated using the findings of the intrusive investigation and assessment in Section 8.2. The report concludes with a summary of any further surveys/ investigations/ assessments recommended (Section 9).

The assessment of the potential for hazardous substances (contamination) or conditions to exist on, at or near the site at levels or in a situation likely to warrant mitigation or consideration appropriate to the proposed end use has been undertaken using the guidance published by CIRIA (2001). This is discussed in more detail in Section 3.2.1 and in Appendix A.

This report is issued as a digital version only.

1.4 Limitations of Report

This report represents the findings of the brief relating to the proposed end use and geotechnical category of structure(s) as detailed in Section 1.1 above. The brief did not require an assessment of the implications for any other end use or structures, nor is the report a comprehensive site characterisation and should not be construed as such. Should an alternative end use or structure be considered, the findings of the assessment should be re-examined relating to the new proposals.

Where preventative, ameliorative or remediation works are required, professional judgement will be used to make recommendations that satisfy the site-specific requirements in accordance with good practice guidance.

Consultation with regulatory authorities will be required with respect to proposed works as there may be overriding regional or policy requirements which demand additional work to be undertaken. It should be noted that both regulations and their interpretation by statutory authorities are continually changing.

This report represents the findings and opinions of experienced geo-environmental and geotechnical specialists. Earth Science Partnership does not provide legal advice and the advice of lawyers may also be required.

2 Summary of Previous Desk Study

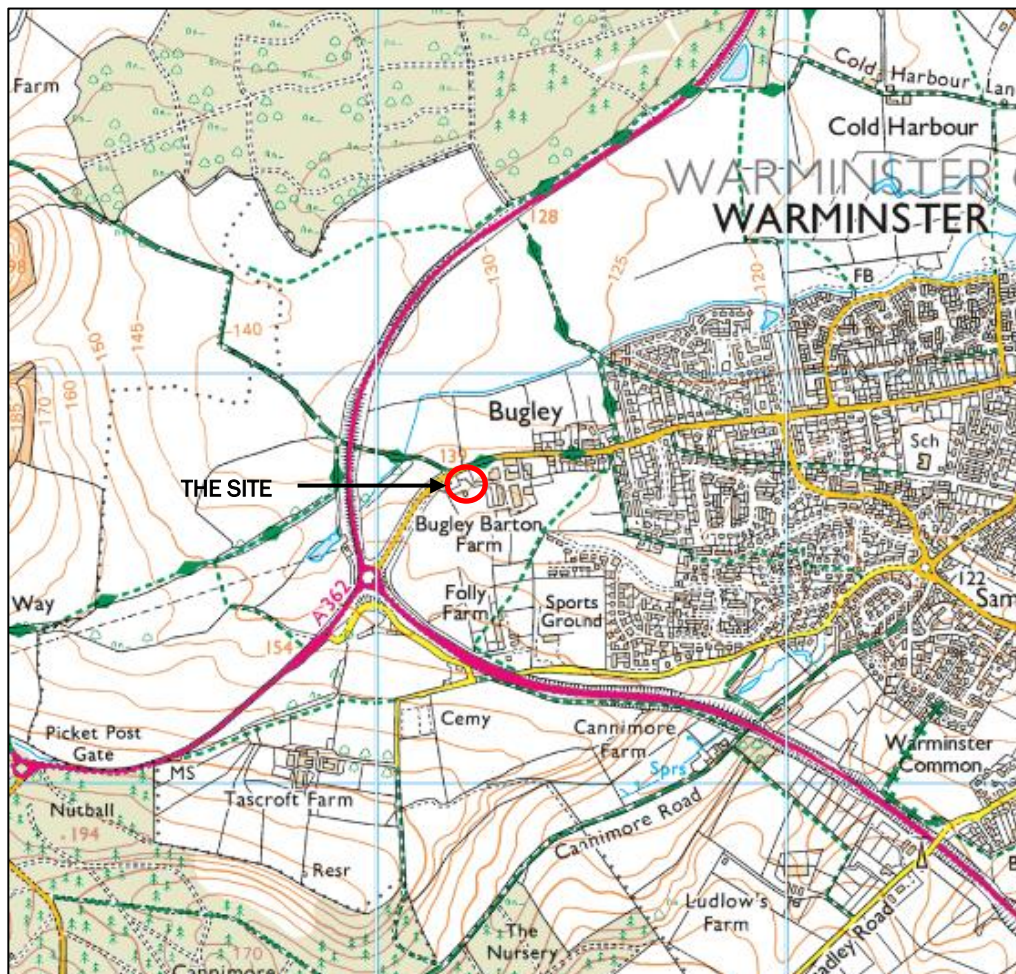
The following Desk Study refers to information pertinent to the recent investigation within the central farmyard area. Where relevant, information from the wider site has been included, however our previous assessment (ESP, 2016) should be referred to for the findings of the Desk Study on the wider site as a whole.

The information presented in this section was obtained from desk-based research of sources detailed in the text, including historical maps, an environmental data report, a geological data report and information from the previous investigation across the wider site (ESP, 2016). Further desk study reports/data/records are included as subsequent appendices as referenced in the text.

The farmyard site description is largely based on a field reconnaissance and site inspection visit of the yard area made on 27th July 2021 (including any relevant information on the wider site from the 2016 reconnaissance).

2.1 Site Location and Description

The farmyard area assessed as part this report, is located off Victoria Road on the south-western margins of Warminster in Wiltshire. The National Grid Reference of the centre of the site is (ST) 385319 144624 and the postcode is BA12 7RB. A Location Plan is presented as Insert 3 below.



Insert 3 - Location Plan from Ordnance Survey 1:25,000 scale map.
Reproduced with permission (OS License No.: AL100015788).

2.1.1 General Overview

The farmhouse and further farm buildings lie outside the farmyard site boundary to the north/northeast. Areas of concrete hardstanding and loose gravel surfacing surround the farm complex with apparent remnant concrete floor slabs in the north-western part of the farm buildings. A mound of probable sub-base materials was noted during the previous assessment (ESP, 2016); however, this was not present during the recent walkover.

Immediately to the south of the hardstanding and farm buildings in the central part of the farmyard site, lies a former slurry pit. This is now heavily overgrown, and has a predominantly solid surface, albeit very soft, however, the southern part of the pit remains a liquid and could not be accessed safely. An apparent outlet pipe runs from this pit into the field to the east.

The farm buildings are generally of brick or concrete block construction with asbestos cement roofs, and some asbestos cement panel side cladding. One of the buildings includes a large generator/engine which was apparently used to power a probable air extraction system for the barns (probably used during the dairy farming). A small above-ground, steel diesel tank lies adjacent to the engine, within the building. Large plastic, circular tanks are located adjacent to the farmhouse around 10m north of the site boundary and are apparently for the storage of heating oil.

Vehicular access to the farmyard site is currently gained via the driveway to the main farmhouse off Victoria Road in the north of the site.

2.1.2 Site Boundaries

The farmyard site is bounded by:

- To the north: Victoria Road, extending west to east across the north of the site, followed by open farmland. A private dwelling is located to the south-east of Victoria Road on the northern boundary of the western field, immediately to the east of the farm buildings complex. Further residential dwellings lie to the north of the eastern field.
- To the east: by the wider site followed by residential properties off Haygrove Close.
- To the south: by the wider site followed by a housing development and sports pitches.
- To the west: by the wider site and then by Victoria Road and the junction with the A36 road, followed by open farmland.

2.1.3 Topography

The general topography of the area is gently undulating. The area of the farmyard is generally flat and level and elevated above the fields to the south-east and south-west within the wider site.

ESP have produced a Site Features Plan (Figure 1), which includes available topographical information for the farmyard site and the wider site.

The area around the farm buildings complex is shown at an elevation of around 139m AOD. This is some 1.5 to 2m above the adjacent field levels of the wider site, which then fall to around 132m AOD in the south-east and rise to around 146m AOD in the south-western margins.

2.1.4 Existing Services

The Client has provided ESP with a series of plans showing the locations of recorded underground services near the farmyard site. Site observations and these utility plans indicate that the site is crossed by the following services:

- A water main trending north to south through the centre of the site.
- A low voltage electricity cable running west to east, marginally entering the site in the north portion; and
- BT cables trending northeast to southwest along the margins of the northwest and west boundaries.

2.2 Site History

2.2.1 Published Historical Maps

The farmyard site history has been assessed from a review of available historical Ordnance Survey County Series and National Grid maps (Appendix B). The salient features since the First Edition of the County Series maps are summarised in the table below.

Table 1: Review of Historical Maps

Date	On-Site	In Vicinity of Site
1886	The site is indicted to be part of Bugley Farm. A small structure is identified centrally in the north, likely associated with Bugley Farm. In addition, a further small building is shown in the northwest, likely associated with an adjacent residential property.	Bugley Farm farmhouse is located directly adjacent to the site boundary in the north and several small associated buildings are shown adjacent. A road running north-east to south-west adjacent to the north boundary. Several wells are identified close to the site including at some 70m SW, 170m S, 20m E, 40m E and adjacent to the boundary in the northeast. The surrounding area was largely farmland and occasional residential properties, with the town of Warminster located approximately 750m east.
1899	No further significant changes identified.	A spring is identified some 180m west of the site. No further significant changes identified.
1923	No significant changes identified.	The wells identified previously around the site are no longer indicated. No further significant changes identified
1926 - 1941	No significant changes identified.	No significant changes identified.
1956	A building likely associated with Bugley Farm is shown to encroach onto the site in the north. No further significant changes have been identified.	The town of Warminster is shown to have expanded to the east. A small number of residential properties are now indicated adjacent to the north-west boundary. No further significant changes have been identified.
1973	Several structures are now identified in the north and north-west and the layout resembles that present today. A roughly rectangular area of land is identified to be highlighted in the centre of the site, which is considered to be the slurry pit.	The town of Warminster has expanded further.
1984 - 1992	No significant changes identified.	No significant changes identified.
2002 - 2014	The site is now developed to its present-day layout.	The surrounding area is now developed to its present status.
Notes: 1. Historical maps presented in Appendix B. 2. Features may have been present on site between the dates of the individual mapping, and it should be appreciated that these cannot be identified from the map review.		

2.2.2 Other Sources

As discussed in Section 2.1, the farm was formerly a dairy farm and several associated structures (barns, large capacity sheds etc.) remain. No further relevant information on the site history has been identified as part of this assessment.

2.3 Previous Investigations and Assessments

ESP have previously undertaken an investigation of the wider site (excluding the farmyard area as presented in Insert 1) in 2016. The salient findings of the previous investigation of the wider site, as they relate to the farmyard area and proposed development, are discussed in subsequent sections.

The findings are summarised in the relevant sections and the records (including a plan of their positions) are presented in Appendix E.

2.4 Contact with Regulatory Bodies & Local Information Sources

At the time of issue of this report, we have not yet received a response from the consultees. Once received, any response will be forwarded under separate cover. It should be appreciated that their responses may contain salient information on the site which could not be considered during the preparation of this report.

2.5 Hydrology

2.5.1 Surface Water Features

The nearest major surface water feature is an unnamed Tertiary River some 110m to the north-west. Several wells and a spring are shown in the area on historical maps.

A small stream is present extending to within 30m of the eastern wider site boundary, just to the east of Haygrove Close. This appears to be a tributary to the river Wylfe.

During the previous assessment (ESP, 2016), a marshy area in the eastern margins of the wider site was identified to potentially represent a continuation of this stream.

2.5.2 Surface Water Abstractions

The environmental data report (Appendix C) indicates that there are no surface water abstractions within 2km.

2.6 Flooding

2.6.1 Rivers and Seas

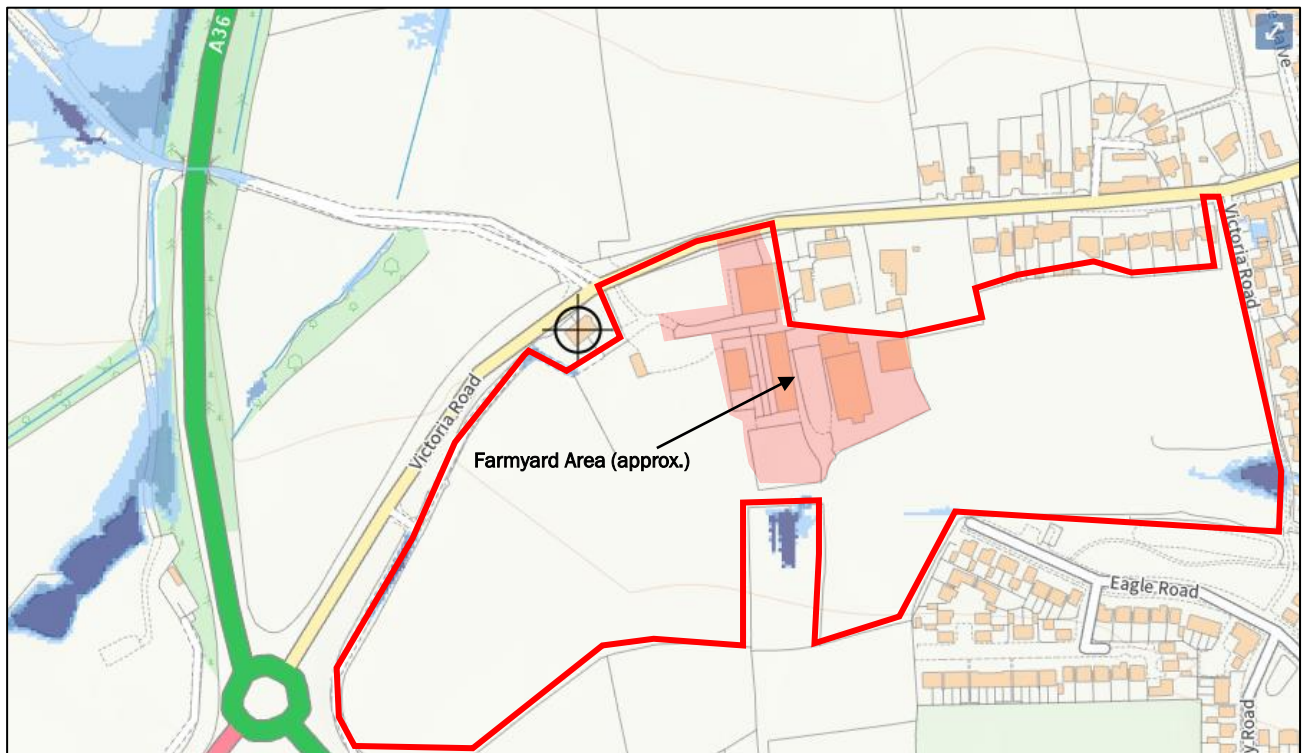
From a review of topographical plans and flooding maps presented in the environmental data report (Appendix C) and the Environment Agency website, the farmyard site is not indicated to be at risk of flooding by rivers, reservoirs, or surface water, and it does not lie within a Flood Alert or Warning Area.

2.6.2 Surface Water

Surface water flooding happens when rainwater does not drain away through the normal drainage systems or soak into the ground but lies on or flows over the ground instead. This type of flooding can be difficult to predict, much more so than river or sea flooding as it is hard to forecast exactly where or how much rain will fall in any storm. The information available depends on available records including ground levels and drainage.

From a review of information available on the Environment Agency (EA) website (2021), small parts of the wider site are indicated to be in an area of Low to High risk from surface water flooding, as shown in Insert 4 below.

The farmyard area is not shown to be at risk from surface water flooding.



Insert 4- Potential Surface Water Flooding Areas (site boundary approximate)

A Low risk means that in each year, the area has a chance of flooding of between 0.1% (1 in 1000) and (1%) and 1 in 100.

A medium risk means that each year, the area has a chance of flooding of between 1% (1 in 100) and 3.3% (1 in 30).

A high risk means that each year, this area has a chance of flooding of greater than 3.3% (1 in 30).

2.6.3 Groundwater

Groundwater flooding is defined as the emergence of groundwater at the ground surface away from river valleys or the rising of groundwater into man-made ground under conditions where the 'normal' range of groundwater levels and groundwater flows is exceeded and predicted risk from groundwater flooding aims to identify locations where this form of groundwater flooding could happen.

It does not incorporate anomalous discharge from springs leading to groundwater flooding down the topographic slope or flooding associated with urban groundwater rebound, mine water discharge, urban drainage, or any other flooding associated with changes in the engineered environment.

The environmental report in Appendix C indicates that the site as a whole is at a potential risk at surface from clearwater flooding and the British Geological Survey (BGS) confidence in this rating is Low.

Where potential for groundwater flooding to occur at surface is indicated, this means that given the geological conditions in the area groundwater flooding hazard should be considered in all land-use planning decisions. It is recommended that other relevant information e.g., records of previous incidence of groundwater flooding, rainfall, property type, and land drainage information be investigated to establish relative, but not absolute, risk of groundwater flooding.

2.7 Geology

2.7.1 Published Geology

2.7.1.1 Overview

The published 1:50,000 scale geological map for the area (Sheet 281) indicates the farmyard site to be substantially underlain by Boyne Hollow Chert Member bedrock. The Boyne Hollow Chert is part of the Upper Greensand Formation of Cretaceous age. Chalk bedrock is shown to crop out to the north of Victoria Road but is not present beneath the site.

The Shaftesbury Sandstone Member indicated to crop out in the south-eastern margins of the wider site, however, could be present beneath the investigation as it underlies the Boyne Hollow Chert in succession.

No superficial deposits are shown within the farmyard site boundaries, but deposits of Head are shown to the south, and River Alluvium is shown around the stream to the east of the wider site.

The up-to-date mapping available on the website of the BGS (2021) and the geological data report obtained as part of this assessment (Appendix D) both indicate a similar succession to that described above.

The Boyne Hollow Chert Member bedrock typically comprises glauconitic sand and sandstone, with regularly developed nodular and tabular beds of chert/flint. The Shaftesbury Sandstone Member bedrock typically comprises an alternating succession of fine- to medium-grained, glauconitic sand and sandstone, with a band of 'ragstone' at the top of the strata, immediately underlying the Boyne Hollow Chert Member.

2.7.1.2 Previous Findings (ESP, 2016)

The previous investigation identified the wider site to be generally underlain by a thin veneer of Topsoil overlying weathered Boyne Hollow Chert Member and Shaftesbury Sandstone Member bedrock (both Upper Greensand formation).

Probable Made Ground was identified around the slurry pit and beneath the north-west of the wider site.

2.7.2 Available British Geological Survey (BGS) Borehole Records

No available pertinent BGS information is available for the site.

2.7.3 Available Previous Investigation Records

The investigation point records from the ESP investigation (ESP, 2016) are presented in Appendix E, with the investigation findings presented where relevant in subsequent sections.

2.8 Hydrogeology

2.8.1 Aquifer Classification

Reference to the aquifer maps published in the environmental data report (Appendix C) and the Environment Agency website (EA, 2016) indicates that the Boyne Hollow Chert Member and the Shaftesbury Sandstone Member bedrock beneath the site are both classed as Principal Aquifers.

Principal Aquifers generally correspond with the previously classified major aquifers and are described by the Environment Agency as 'rock or drift deposits that have high intergranular and/or fracture permeability'. They may support water supply and/or river base flow on a strategic scale. Principal Aquifers are particularly sensitive to pollution.

2.8.2 Anticipated Groundwater Bodies

2.8.2.1 Overview

Reference to the Hydrogeological Map of the Chalk and Associated Minor Aquifers of Wessex (IGS, 1979) indicates the piezometric surface of the main groundwater body within the chalk and Upper Greensand strata beneath the site to be at around 140m AOD beneath the central part of the wider site, falling to around 130m AOD just east of the site. Therefore, groundwater levels would be expected to be at around 142m AOD beneath the western margins and at around 132m AOD beneath the eastern margins.

2.8.2.2 Previous Findings (ESP, 2016)

Based on previous findings within the wider site area (see Insert 1 and Appendix E), the main groundwater body beneath the wider site appears to be located within the coarse-grained Shaftesbury Sandstone Formation, generally at between 1.0 and 3.0m depth. However, in the south-east of the wider site, groundwater was identified within the River Alluvium at a shallow depth of 0.5m (Well within WS3).

2.8.3 Abstractions and Groundwater Vulnerability

The environmental data report (Appendix C) and the Environment Agency website (EA, 2016) indicate that there are groundwater abstractions within 2km of the site. The site lies within a Zone 3 Source Protection Zone (SPZ). Zone 3 is defined as the total catchment around an abstraction well, within which all groundwater recharge is presumed to be discharged at the source, i.e., the area in which any pollution of the groundwater could lead to pollution at the abstraction. The associated abstraction well is indicated to be a public water supply well some 1km to the east of the site (within the town centre of Warminster) operated by Warminster Maltings Ltd, and abstracting 30m³ per day.

The groundwater vulnerability is shown in the environmental data report to be 'major aquifer high'.

2.8.4 Groundwater Movement

Groundwater movement within the Boyne Hollow Chert Member and the Shaftesbury Sandstone Member bedrock will be controlled by intergranular flow where they are weathered near the surface to a soil.

2.9 Environmental Setting

2.9.1 Salient Environmental Features

The environmental data report identified the following salient environmental features on and in the vicinity of the site.

Potentially Contaminative Land Use/Current Land Use

The recent site walkover of the farmyard areas has identified past and existing contaminative uses on the site, including probable asbestos containing materials (roofing and wall panelling) on the existing farm buildings the engine and diesel tank in one of the buildings, the slurry pit, and heating oil tanks just to the north.

Potentially Infilled Land

No potentially infilled land has been identified in the environmental data report at the farmyard area site. However, a slurry pit is present in the central area. The slurry pit is also recorded as a waste storage/processing feature.

Pollution Incidents

A pollution incident is recorded at the site in May 2003 when 'agricultural materials and wastes (silage liquors)' reportedly spilt into water, with a reported 'minor impact' to water and air and 'no impact' to land. This is likely to be associated with the operation of the slurry pit.

2.9.2 On-Site Bulk Liquid Storage

A steel, diesel tank is located within one of the buildings adjacent to the engine in the central area – this visually appeared to have been unused for several years and it is not known if it still contains fuel. Further plastic heating fuel tanks are located adjacent to the farmhouse to the north of the site (just outside the site boundary), as shown on Figure 1.

The slurry pit in the central area appears abandoned, but still contains liquid in the southern margins.

2.9.3 On-Site Bulk Materials and Waste Storage

No significant storage of general materials was observed; however, a stockpile was noted in the centre of the yard area during the 2021 investigation (see Figure 1), noted to contain possible asbestos cement. As discussed in Section 2.9.2, the slurry pit has been recorded as a waste feature in the environmental data report.

2.10 Preliminary Geotechnical Risk Register

The potential for various geotechnical and geomorphological hazards at the site is provided in the environmental data and geological data report (Appendices C and D). The potential hazards, as defined by the British Geological Survey (BGS) and reported in the above report(s), along with any salient further information has been considered in the preparation of this report.

Where a potential geotechnical hazard has been identified, it is discussed further in subsequent sections.

2.10.1 Past Mining (Non-Coal)

Possible chalk mining has been identified in the geological data report (Appendix D) between 170m and 310m north and north-west of the site. However, the site is not underlain by chalk bedrock, so a chalk mining hazard is not present.

2.10.2 Shrinkable and Swelling Soils

The previous investigation (ESP, 2016) identified fine grained soils (possible Head Deposits) in the west of the site (TP16 and TP17 only), to a depth of around 1.0m. Possible River Alluvium was also noted in the eastern margin, in WS1, WS2 and WS3 to a maximum depth of 2.2m.

Based on the previous findings, fine-grained soils could be present beneath the site surface and therefore the potential hazard at this stage should be considered low to moderate.

2.10.3 Running Sand

The previous investigation of the wider site (ESP, 2016) did not identify running sand; however, during the excavation of the trial pits, thick horizons of sand were present, and groundwater was identified at depths as shallow as 0.5m.

Therefore, the potential for running sand cannot be discounted, which could lead to collapse of excavation sides.

Based on the previous findings, there is potential for running sands to occur beneath the farmyard area site surface and therefore the potential hazard at this stage should be considered low to moderate.

2.10.4 Pyritic Ground

The weathered Upper Greensand Formation soils are not anticipated to contain any significant levels of sulphate or sulphide, which could lead to aggressive attack on buried concrete. Any Made Ground present could contain elevated levels of sulphates, depending on its origins.

The previous assessment identified that the wider site would be classified as Design Sulphate Class DS-1, and Aggressive Chemical Environment for Concrete Class AC-2z, allowing for mobile groundwater.

2.10.5 Unexploded Ordnance

The environmental data report does not consider the potential risk from unexploded ordnance at the site.

A Preliminary (Pre-Desk Study) UXO Desk Study assessment of risk has been completed by a specialist Ordnance consultant in accordance with CIRIA guidelines (Stone et al, 2009) and is presented in Appendix F (Zetica, 2021).

The assessment concludes that '*a detailed desk study, whilst always prudent, is not considered essential in this instance*'.

This is in line with the previous findings (ESP, 2016).

2.11 Radon Hazard

Radon is a colourless, odourless, radioactive gas, which can pose a risk to human health. It originates in the bedrock beneath the site, where uranium and radium rich minerals are naturally present, and can move through fractures in the bedrock, and overlying superficial deposits, to collect in spaces within/beneath structures.

The environmental and geotechnical data reports (Appendix C and D respectively) indicate that the site lies in a radon affected area as defined by the Health Protection Agency, with between 1% and 3% of properties above the action level.

Given the currently available information, the risk from radon is considered Low. This is in line with the previous findings (ESP, 2016).

3 Preliminary Geo-Environmental Risk Assessment

3.1 Phase One Conceptual Site Model

3.1.1 Background

The Phase One Conceptual Site Model lists the potential sources of geo-environmental risk (both contamination and hazardous gas), the receptors at risk (both human and non-human), and any feasible pathways between the two. These are discussed in the following sections.

3.1.2 Potential Soil Contamination Sources

The site history has indicated that it has been developed as a farm which has areas of potentially contaminative use, all located around the farm buildings and slurry pit in the centre of the site. No contamination sources have been identified in the wider site.

From the available information, we consider that the following features on site could prove point sources of contamination that could impact on the development, environment, or site users:

- Made Ground.
- Spills of fuel/oils around the steel diesel storage tank and engine.
- Probable asbestos cement within farm building construction.
- Slurry pit and outfall pipe.

3.1.3 Potential Contaminants Present

Previous analysis (ESP, 2016) identified that biological contamination is present within the slurry pit materials and in soils around the slurry pit.

The previous assessment of the wider site (ESP, 2016) identified the levels of contaminants to be below the assessment criteria adopted. No asbestos was identified within the shallow soils of the wider site; however, it was noted that the farm buildings had asbestos sheet cladding/roofing.

The levels of leachable contaminants were also generally low, below assessment criteria designed to be protective of the groundwater. However, the levels of polyaromatic hydrocarbon compounds were found to be elevated above the assessment criteria limited Made Ground identified and some natural soils.

The potential contaminants associated with the above potential sources have been identified from various guidelines published by DEFRA, the Environment Agency, and others.

Based on this guidance and our experience, we consider that the following contaminants could be present on the site:

- heavy metals and semi-metals (arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium, zinc).
- cyanide, sulphate, sulphide.
- polyaromatic hydrocarbon (PAH) compounds.
- petroleum hydrocarbons, including methyl-tert-butyl-ether (MTBE).
- Phenols.
- Pathogens.
- asbestos.

No evidence has been identified from the desk study to suggest that radioactive substances may be present. The potential presence of radon is discussed in Section 2.11.

3.1.4 Potential Sources of Hazardous Ground Gas

The previous assessment identified and classified the wider site as CS2, for which ground gas protection measures are required.

This section considers the potential sources of hazardous gases such as methane, carbon dioxide and hydrocarbon vapours. The potential for radon was discussed in Section 0.

Based on the available desk study information, the following potential sources of hazardous ground gas have been identified on, or in close vicinity of, the farmyard area site:

- Slurry Pit – on site source
- General Made Ground – on site source (yard area).
- Alluvial soils and peat – off site source.

If fuels and oils have been spilled and Made Ground is present, these can also lead to the generation of hazardous gas.

Based on the guidelines presented by O'Riordan and Milloy (1995) and revised by Wilson et al (2009), the above potential gas sources would generally be classified as of very low/low gas generation potential, however, the slurry pit would likely be classified as of moderate to very high gas generation potential.

3.1.5 Potential Receptors

We consider that the most vulnerable receptors with regards to any contamination or hazardous ground gas present are likely to be as follows.

- Future residents, the critical receptors being young children playing in private garden areas.
- Construction and maintenance workers.
- Buried concrete (foundations, drainage etc.).
- The groundwater within the Upper Greensand strata beneath the site (classified as a Principal Aquifer and within a Zone 3 SPZ around a potable groundwater abstraction).

3.1.6 Potential Migration Pathways

Based on the Conceptual Site Model discussed in the previous sections, the following are considered the most likely migration pathways regarding any contamination or hazardous ground gas present beneath the site.

Site Users:

- Ingestion of soils and inhalation of dust in garden areas.
- Ingestion of soils and inhalation of dust in landscaping areas.
- Ingestion of edible plants and dust associated with such plants.
- Dermal contact with contaminated soils.
- Exposure to asbestos containing materials within the shallow soils.
- Potential explosive risk from flammable ground gas/vapours from on-site sources.
- Potential risk from toxic ground gas/vapours from on-site sources.

Construction and Maintenance Workers:

- Exposure to asbestos containing materials within the existing buildings.
- Exposure to asbestos containing materials within the shallow soils.
- Ingestion of soils and inhalation of dust across site.
- Dermal contact with contaminated soils.
- Potential explosive risk from flammable or toxic ground gas/vapours from on-site sources.

Groundwater:

- Leaching of mobile contaminants into the water-bearing strata within the bedrock.

Buildings:

- Sulphate attack on buried concrete (foundations, drainage etc.).
- Potential explosive risk from flammable ground gas/vapours from on-site sources.

3.2 Preliminary Risk Evaluation & Plausible Pollutant Linkages

The land use history of the site and surrounding area, as established from the desk study and walkover, has identified several potential contamination linkages due to ground conditions or former operations either on, adjacent to, or in the vicinity of the site. Note that these potential linkages will need to be later assessed and re-established using actual site data obtained from an exploratory investigation.

3.2.1 Introduction to Risk Evaluation Methodology

The general methodology set out in CIRIA C552 *Contaminated Land Risk Assessment – A Guide to Good Practice* (Rudland et al, 2001), has been used to assess whether risks are acceptable, and to determine the need for collating further information or remedial action.

Whilst at a later stage, this methodology may be informed by quantitative data (such as laboratory test results) the assessment is a qualitative method of interpreting findings to date and evaluating risk.

The methodology requires the classification of:

- The magnitude of the potential consequence (severity) of risk occurring (Table A1 in Appendix A):
- The magnitude of the probability (likelihood) of risk occurring (Table A2 in Appendix A).

The classifications defined above are then compared to indicate the risk presented by each pollutant linkage, allowing evaluation of a risk category (Tables A3 and A4 in Appendix A). These tables have been revised slightly by ESP from those presented in CIRIA C552, to allow for the circumstances where no plausible linkage has been identified and, therefore, no risk would exist.

The methodology described above has been used to establish Plausible Pollutant Linkages (PPL) based on the Conceptual Site Model generated for the site and proposed development, and to evaluate the risks posed by those linkages, using information known about the site, at this desk study stage. This is presented as Table 2 in Section 3.2.2 below.

3.2.2 Tabulated Preliminary Risk Evaluation & Plausible Pollutant Linkages

Table 2: Preliminary Risk Evaluation & Plausible Pollutant Linkages (PPL)

Source	Pathway	Receptor	Classification of Consequence	Classification of Probability	Risk Category	Further Investigation or Remedial Action to be Taken
Potential general contaminants in shallow soils	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users (residents)	Medium – potential for chronic levels.	Low likelihood ²	Moderate/Low Risk	Sampling of near-surface soils to confirm levels of total contamination present.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	Low likelihood ²	Very Low Risk	
	Leaching of soil contaminants	Impact on Groundwater /Potable Water	Medium – Principal Aquifer and Zone 3 SPZ.	Low likelihood ²	Moderate/Low Risk	Sampling of near-surface soils to confirm levels of leachable contamination present.
Pathogens in slurry pit	Direct contact/ingestion of contaminated soil	Site Users (residents)	Medium – potential for chronic levels.	Likely ³	Moderate Risk	Sampling of shallow soils around slurry pit.
	Direct contact/ingestion of contaminated soil	Construction/ Maintenance Workers	Medium – additional PPE may be required	Likely ³	Moderate Risk	
Asbestos in existing buildings	Ingestion of fibres	Demolition Workers/ Ground Workers	Medium – potential for chronic levels	High Likelihood ⁴	High Risk	Asbestos survey of buildings.
Asbestos in shallow soils	Ingestion of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	High Likelihood ⁴	High Risk	Sampling of shallow soils for asbestos.
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	Low likelihood ⁵	Low Risk	Sampling of soils to confirm levels of sulphate and pH.
Hazardous ground gas/vapours	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	Likely ^{3,6}	High Risk	Install and monitor gas wells.
	Damage through explosion.	Building/Property	Severe – acute risk.		High Risk	
	Asphyxiation/poisoning. Injury due to explosion.	Construction and Maintenance Workers.	Severe – acute risk.		High Risk	
Radon gas	Migration into Buildings	Site Users (residents)	Medium – potential for chronic levels	Unlikely ⁷	Low Risk	None required.

Notes:

1. Methodology and details of risk consequence, probability and category based on CIRIA C552 (2001) and presented in Section 3.2.1.
2. Although Made Ground is anticipated, the presence of contamination has yet to be confirmed on site.
3. Previous investigations identified potential risk from biological contamination. Further sampling required to confirm and assess disposal options.
4. Probable asbestos roofing and cladding noted on existing farm buildings and possible asbestos cement stockpile identified in the centre of the yard area (see Figure 1).
5. The weathered Upper Greensand is not anticipated to contain elevated levels of sulphate.
6. The previous assessment identified classified the wider site as CS2, for which ground gas protection measures are required. The on-site Made Ground and diesel tank/generator and slurry pit form potential sources of ground gas. The previous investigation also identified alluvial soils to the southeast, which could form a potential off-site source.
7. Radon risk is low, and no protective measures are required.
8. The above risk evaluation is updated following the intrusive investigation and testing in Section 6.2.

4 Exploratory Investigation

4.1 Investigation Points

4.1.1 Introduction

The intrusive investigation of the farmyard area was undertaken between 27th and 28th July 2021 in accordance with BS5930:2015+A1:2020 and BS10175:2011+A2:2017 and was designed to investigate both geo-environmental and geotechnical hazards identified in the desk study (Section 2). It comprised windowless sample boreholes, Hand dug trial pits and gas/groundwater monitoring.

The exploratory holes were supervised and logged by an engineering geologist in general accordance with BS5930:2015+A1:2020, BS EN ISO 14688-1:2002, BS EN ISO 14688-2:2018, and BS EN ISO 14689:2018.

The investigation point positions are shown on Figure 2.

The ground levels and coordinates indicated on the investigation point records are approximate only and have been obtained with a handheld GPS (Garmin ETREK20 - +/-3m).

4.1.2 Investigation Strategy

The investigation strategy was generally designed in accordance with BS10175:2011+A2:2017, considering the additional potential for geotechnical hazards to be present.

The desk study identified several potential contaminant sources/geotechnical hazards at the site including:

- Potential Made Ground across the site.
- Potential for asbestos/asbestos containing materials at the surface and within the shallow soils.
- Potential for biologically contaminated soils within the slurry pit.
- Potential for hydrocarbon contamination from the diesel tank/generator.
- Potentially shrinkable/swelling soils across the site.
- Potential for running sands.

Therefore, the investigation points were selected to maximise the information obtained on these hazards, as well as obtaining a general overview of the general ground conditions present. In this regard, several of the investigation points were targeted at the above sources, as summarised in Table 3 below – the investigation point positions are shown on Figure 2.

Table 3: Placement Rationale for Investigation Points

Point ID	Location	Placement Rationale
HDP01	Southwest of slurry pit	In area of previously identified elevated pathogen levels. To collect shallow samples for hazard characterisation and WAC testing disposal options
HDP02 & HDP03	Within slurry pit	To collect shallow samples for hazard characterisation and WAC testing disposal options
WS207	Southeast.	In area of diesel engine to collect shallow soil samples and install gas monitoring well.
WS206	Central East.	In area closest to off-site oil storage tank to collect shallow soil samples and install gas monitoring well.
WS201	Central North.	In area closest to off-site pond to collect shallow soil samples and install gas monitoring well.
Notes: 1. Investigation Point positions shown on Figure 2. 2. HDP = Hand Dug Trial Pits. WS = Windowless sample boreholes.		

4.1.3 Hand Dug Trial Pits

3no. hand dug trial pits (HDP01, HDP02 and HDP03) were excavated on 28th July 2021. The trial pits were excavated to depths of between 0.30 and 0.60m. The pits were excavated using hand tools within the area of the former slurry pit. The trial pit records are presented as Appendix G, and their positions are shown on Figure 2.

Disturbed samples were collected from the trial pits for laboratory testing as shown on the trial pit records.

On completion, the trial pits were backfilled with arisings and compacted at the surface.

4.1.4 Windowless Sampling

9no. windowless sample drillholes (WS201 to WS208) were constructed between 27th and 28th July 2021 to depths between 0.50 and 3.0m. The borehole records are presented as Appendix H, and their positions are shown on Figure 2.

A hydraulically powered rig was used to drive plastic lined sampling tubes into the ground, with the soil recovered within the tubes, which are then split to allow sampling and logging. Disturbed samples were obtained throughout the boreholes for identification and laboratory testing purposes, as shown on the borehole records. The windowless sampling provided generally good recovery to the depth of refusal. At the commencement of each borehole, the surface concrete was broken out using a hydraulic breaker and a service inspection pit excavated by hand to a depth of 1.2m.

Standard Penetration Tests (SPT) were carried out using a split spoon (SPT) and solid cone (SPT-C) in the boreholes in accordance with BS EN ISO 22476-3 (2005) and BS5930:2015+A1:2020 to assess the relative density of the coarse-grained soils encountered in the borehole and to provide a correlated assessment of the likely undrained shear strength of fine-grained soils using relationships published by Stroud (1975). As required in BS5930:2015+A1:2020, the SPT N-values shown on the borehole records are the direct, uncorrected results obtained in the field.

Depending on the nature of the test undertaken and the soils subjected to testing, field SPT N-values may require correction before using in design.

On completion, selected boreholes were installed with monitoring wells (see Section 4.2). Where no well was installed, the boreholes were backfilled with arisings/gravel, with the concrete reinstated at the surface.

4.2 Instrumentation

4.2.1 Gas Well Installations

A 50mm diameter monitoring well was installed in selected boreholes in accordance with BS8576:2013 in order to allow monitoring of hazardous ground gases. The wells, comprising slotted plastic pipe with a gravel surround (the response zone), bentonite seals above and below the response zone, and a lockable vandal proof cover, were installed as detailed on the borehole records and summarised in the table below.

Table 4: Gas Well Installations

Well ID	Date of Installation	Response Zone depth	Response Zone Stratum	Rationale
WS201	27/7/2021	0.5 – 2.5m	MG & BHC.	2
WS202	27/7/2021	0.5 – 2.0m	MG & BHC.	3
WS206	28/7/2021	0.5 – 2.0m	MG & BHC.	3
WS207	28/7/2021	0.5 – 2.5m	MG & BHC.	4
WS208	28/7/2021	0.5 – 3.0m	MG & BHC.	3
Notes: 1. Details of each monitoring well are presented on the individual borehole records (Appendix H). 2. Well installed in area of dry pond 3. Well installed in general areas and Made Ground. 4. Well installed in shallow soils adjacent to diesel engine/generator. 5. MG = Made Ground. BHC = Moyne Hollow Chert Member.				

4.2.2 'Spot' Gas Monitoring

Monitoring of the installed gas wells has been undertaken on a 'spot' monitoring basis (periodic visits to monitor gas levels at the time of the visit). CIRIA C665 (Wilson et al, 2007) provides guidance on the number and frequency of monitoring visits required for installed gas wells. These depend on the gas generation potential of the source and the sensitivity of the development to gas risk and are designed as a typical minimum only.

As discussed in Section 3.1.4, the most significant source in the vicinity of the site in terms of gas risk (the slurry pit) would likely be classified as of moderate to very high gas generation potential.

Therefore, based on the guidelines in CIRIA C665, a minimum of 6 monitoring visits are required over a 12-week period.

During each visit, Gas Data LMSxi G3.18e portable monitoring equipment was used to measure levels of the following ground gases within the airspace in the wells and the flow rates from the wells:

- Methane - total and percentage of Lower Explosive limit (LEL).
- Carbon dioxide.
- Oxygen; and
- Hydrogen sulphide.

The percentage of nitrogen is also calculated by difference. The equipment uses infra-red methane (CH₄) and carbon dioxide (CO₂) detectors, coupled with pressure (barometric and well), temperature and flow sensors. A photo-ionisation detector (PID) with a 10.6eV lamp was used during the monitoring to measure the levels of volatile organic compounds present in the well.

Following measurement of gas levels and flow rates, the well cap was removed, and groundwater levels were measured using a dipmeter from the site surface.

The ground gas assessment is presented in Sections 5.6 and 7.3.

4.3 Sampling Strategy

4.3.1 Soil Sampling

Soil samples were collected from the exploratory holes as discussed in the previous sections. The sampling procedures were selected based on the suitability for the laboratory testing proposed.

The hand pits constructed were to specifically collect shallow samples of the previously identified pathogen impacted soils to the southeast of the slurry pit and from within the slurry pit itself (see

Section 3.1.3). These samples were collected specifically to identify the waste hazard rating of the soils and to undertake Waste Acceptance Criteria Testing (WAC) to determine disposal options.

The general site sampling was focused on the contaminant sources identified in Section 3.1.2. Further soil samples were also taken randomly from non-targeted areas to provide a general indication of the variability in concentrations of possible diffuse source contamination across the site as a whole.

Environmental samples (denoted as ES on the exploratory holes records) were collected for possible geo-environmental laboratory testing and generally comprised a plastic tub, an amber glass jar and an amber glass vial. The sample containers provided clean by the testing laboratory appropriate for the proposed testing to be scheduled. Immediately after collection the samples were placed in sealed cool boxes with ice packs where they remained during storage and transport to the laboratory.

Samples for logging and geotechnical laboratory testing purposes were collected at regular intervals within the exploratory holes.

4.4 Evidence of Site Contamination Found During Site Works

Regarding potential hazards identified in the desk study and Preliminary Risk Assessment, the following observations were made.

Made Ground was encountered across the site, with direct visual or olfactory evidence of contamination identified in the exploratory holes as summarised in the table below.

Table 5: Site Evidence for Contamination

Hole ID	Stratum	Comment on contamination encountered
WS207	Made Ground	Asbestos Containing Materials (Roof Tile)
WS208	Made Ground	Asbestos Containing Materials (Roof Tile)
Notes: 1. Large pieces of tile were noted in the Made Ground.		

4.5 Geotechnical Laboratory Testing

Geotechnical laboratory testing was undertaken on samples from the suitable quality classes recovered from the exploratory holes to obtain information on the geotechnical properties on the soils beneath the site.

The following tests were undertaken by a UKAS accredited laboratory on samples selected by ESP in accordance with the methodologies presented in BS1377:1990. The results are presented in Appendix K.

- Natural moisture content.
- Atterberg limits.
- Particle size analysis.

Selected samples were also analysed for soil sulphate and pH value in accordance with the analytical methods specified in BRE Special Digest SD1 (BRE, 2005).

The results of the sulphate testing are included with the geo-environmental test results in Appendix L.

4.6 Geo-environmental Laboratory Testing

4.6.1 Soils Testing

Laboratory testing has been undertaken to identify the levels of selected contaminants within samples of soil recovered during the investigation. The geo-environmental analyses were carried out by a UKAS accredited testing laboratory with detection limits being generally compatible with the relevant guideline values adopted in the assessment (see Sections 5.4).

To allow an assessment of the potential chronic risks posed to human health, a total of 10no. selected samples of the near-surface natural soils have been analysed for the contaminants identified in Section 3.1.3, plus other determinands typically present on brownfield sites in the UK.

The general suite of geo-environmental laboratory testing undertaken comprised:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, chromium VI, copper, lead, mercury, nickel, selenium, vanadium, zinc.
- US EPA 16 polycyclic aromatic hydrocarbon (PAH) compounds.
- Total monohydric phenols.
- Total cyanide, asbestos qualitative screen (presence or absence).
- Soil organic content, pH value.
- Petroleum hydrocarbons (CWG ali/aro carbon banded C₅ to C₃₅).
- Pathogens

4.6.2 Leachate Samples

To allow an assessment of the potential pollution risks to controlled waters, samples of leachate have been generated from six samples of soil (three samples of Made Ground and three samples of the natural Boyne Hollow Chert Member) recovered from the exploratory holes. The results of the leachate tests are presented in Appendix L.

The leachate preparation was carried out in accordance with BS EN 12457, at a 10:1 eluate ratio.

The resulting leachate was analysed for the following determinants:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, copper, iron, lead, mercury, nickel, selenium, vanadium, zinc.
- US EPA 16 polycyclic aromatic hydrocarbon (PAH) compounds.
- Total monohydric phenols.
- Cyanide, soluble sulphate, pH value.
- Petroleum hydrocarbons (CWG ali/aro carbon banded C₅ to C₃₅).

4.6.3 Pathogens – Soil Samples

Samples of shallow soils collected from soils within, and adjacent to, the existing slurry pit. (HDP01 to HDP03), have been analysed for the presence of pathogens. The results are also included within Appendix L.

The testing suite comprised the following determinands:

- Total coliforms
- Faecal coliforms
- E. coli.

4.6.4 Waste Acceptance Criteria (WAC) Testing

To assess the disposal options for the soils adjacent to and within the slurry pit in term of landfill, the soils have been classified in terms of hazardous/inert waste by analysing leachate generated from three samples of Made Ground soils (two within the slurry pit and one to the south east) likely to require excavation and removal from the site, in accordance with the Landfill Directive (2004) – Waste Acceptance Criteria (WAC) testing.

Two leachate is generated from the soils at a 10:1 concentration and are analysed and analysed for the following determinands:

- Total organic carbon, loss on ignition, pH, acid neutralisation capacity, total dissolved solids, dissolved organic carbon.
- BTEX, PCBs (7 congeners), mineral oil (C₁₀-C₄₀), PAHs, phenol index.
- Arsenic, barium, cadmium, chromium, copper, mercury, molybdenum, nickel, lead, antimony, selenium, zinc.
- Chloride, fluoride, sulphate (as SO₄).

The results of the WAC testing are presented in Appendix L.

5 Development of the Revised Conceptual Model

The previous assessment (ESP, 2016) identified the wider site to be generally underlain by a thin veneer of Topsoil overlying weathered Boyne Hollow Chert Member and Shaftesbury Sandstone Member bedrock (both Upper Greensand formation). Probable Made Ground was identified around the slurry pit and beneath the north-west of the site.

5.1 Conceptual Ground Model – Geology

The hand excavated trial pits constructed within the slurry pit have been separated from the general ground model of the farmyard area (Section 5.1.1) and presented in Section 5.1.2.

5.1.1 Farmyard Area

The exploratory holes have identified the farmyard area to be generally underlain by variable thicknesses of Made Ground, overlying natural Boyne Hollow Chert Member bedrock. Shaftesbury Sandstone Member bedrock was also identified in some areas. These strata are discussed in more detail in the following sections.

Made Ground: Generally, the Made Ground comprised concrete hardstanding around 0.2m to 0.3m in thickness, directly underlain by natural soils (WS203 to WS206).

In WS201, no concrete hardstanding was present, however Made Ground was identified to a maximum depth of 0.6m below surface levels as a reddish-brown clay, with fractions of gravel and cobbles and frequent anthropogenic materials of brick, metal, and wood.

In WS202, no concrete hardstanding was present, however Made Ground was identified to a maximum depth of 0.6m below surface level as a dark grey gravel with fractions of slit/clay, sand, and cobbles. Rare metal wiring was identified within the Made Ground.

In WS207, concrete hardstanding was present to a depth of 0.25m, followed by dark grey/brown clay, with fractions of sand and gravel. Frequent anthropogenic materials were identified of brick, metal and wood and possible asbestos containing materials in the form of concrete tiles were identified.

In WS208, no concrete hardstanding was present, however Made Ground was identified to a maximum depth of 1.9m below surface levels as a dark grey/black gravel, with fractions of sand and clay. Frequent metal and rope were noted and possible asbestos containing materials in the form of concrete tiles were identified.

One SPT-N value of 7 was obtained in WS208 at 1.2m depth, indicating the density of these Made Ground soils to be loose.

Boyne Hollow Chert Member: encountered to a maximum depth of 3.0m below surface level in varying weathered states, as detailed below.

Fine-Grained Boyne Hollow Chert Member

Identified in WS202, WS203, WS204, WS206 and WS207 only to a maximum depth of 1.3m below surface level as an orange/brown and occasionally green clay, with fractions of silt, sand, and gravel. Occasional grey/red mottling was also noted.

Laboratory testing within the fine-grained Boyne Hollow Chert Member indicated liquid limits between 44% and 62%, plasticity indices between 24% and 39%, and natural moisture contents between 27% and 38%. The modified plasticity indices (after the coarse-grained particles have been removed) suggest that the soils are generally of medium volume change potential.

Coarse-Grained Boyne Hollow Chert Member

Identified beneath the fine-grained Boyne Hollow Chert member (locally absent) in all windowless sample positions investigation point to a maximum depth of 3.0m below surface level, generally as a green sand, occasionally with brown/grey mottling, with occasional fractions of silt/clay and gravel becoming less frequent with depth. Cobbles were also noted in some areas, generally increasing with depth.

Particle size analyses within the laboratory have indicated the coarse-grained Boyne Hollow Chert member soils to comprise between 64% and 80% sand, between 7% and 8% gravel and between 12% and 29% silt/clay. Cobbles were also noted within the soils but were not samples for analysis. Based on our observations on site, these proportions would appear representative of the in-situ soils.

Field SPT N-values within the coarse-grained Boyne Hollow Chert member soils varied between 8 and 38. N-values more than 50 were also identified at the base of WS201, WS206 and WS207 (possibly terminated on the Shaftesbury Sandstone Formation).

Shaftesbury Sandstone Formation: identified in WS202, WS203 and WS205 only, underlying the coarse-grained Boyne Hollow Chert Member to a maximum depth of 2.0m below surface level. These soils were identified to generally comprise a light grey sand with gravel.

Field SPT N-values within this stratum were all more than 50.

5.1.2 Slurry Pit

During the previous investigation (ESP, 2016), Boreholes WS6 and WS8 (see Figure 2) were constructed around the slurry pit and identified Probable Made Ground. Within Borehole WS6, around 1.7m of probable reworked natural soils (Made Ground) were identified above a 200mm suspected Buried Topsoil layer. In Borehole WS8, 2.5m of possible predominantly fine-grained Made Ground was identified. It was thought that this Made Ground could be associated with previous excavations for the slurry pit.

During the recent investigation of the farmyard area, 1no. hand pit (HDP01) was constructed near the previously constructed WS6 (ESP, 2016). A further 2no. hand excavated pits (HDP02 and HDP03) were constructed within the slurry pit where access was possible (see Figure 2).

HDP01 identified similar shallow conditions as were identified in WS6 previously, with soft silt/clay identified to 0.6m depth, noted to be probable re-worked natural soils (Made Ground).

HDP02 and HDP03 within an accessible portion of the slurry pit identified a soft brown clay with black mottling, to a maximum depth of 0.6m below the surface level. Occasional glass, plastic and wood were also noted. In HDP02, brown/green reworked sand was also noted from 0.35m to 0.6m.

5.2 Conceptual Ground Model - Hydrogeology

The investigation did not identify any groundwater to a depth of 3.0m. The monitoring to date has identified all the wells to be dry to a maximum depth of 3.0m.

The previous investigation of the wider site area (generally at a lower elevation) identified the main groundwater body beneath the site appears to be located within the coarse-grained Shaftesbury Sandstone Formation, generally at between 1.0 and 3.0m depth.

The yard area is noted to be in the order of 1.5m to 2.0m above the wider site (at its highest elevation). The wider site also falls to the southeast and southwest, with the topography then rising further southwest.

5.3 Site Instability

No evidence was identified of potential landslides or unstable ground in the Preliminary Geotechnical Risk Register, and we identified no evidence of any global instability issues on the site.

No significant side wall instability was experienced during the excavation of the hand trial pits or during the construction of the windowless sample boreholes.

5.4 Chronic Risks to Human Health – Generic Assessment of Risks

5.4.1 Assessment Methodology

The long-term risks to health have been assessed using methodologies and frameworks determined by the Environment Agency within documents SR2, SR3, SR4 and the CLEA Technical Review published to support the Contaminated Land Exposure Assessment Model (CLEA). Where applicable, reference has been made to the supporting toxicological reports (TOX Series) and the Soil Guideline Value reports (SGV Series). It is assumed that the reader is familiar with the above documents, and it is not intended to repeat these described methodologies in detail, for further information, please refer directly to the specific documents.

To provide an initial 'screen' to identify elevated levels of contaminants, a Generic Quantitative Risk Assessment (GQRA) has been undertaken using the most appropriate Generic Assessment Criteria (GAC) determined by assessment of exposure frequency/duration relevant to the critical receptor.

5.4.2 Assessment Criteria

In 2013, CL:AIRE published the Category 4 Screening Levels (C4SL – CL:AIRE, 2013) for use in Part 2A determinations. The C4SL are designed to be more pragmatic, but still strongly precautionary, assessment criteria compared to the previous assessment criteria (SGV – see below) used to assess chronic human health risks. The C4SL have been calculated for a limited number of contaminants at this stage, and range of land uses including residential, commercial, and public open space, but are based on a 'low level' of risk rather than the 'minimal level' of risk adopted by the Environment Agency in preparing their Soil Guideline Values (SGV). The C4SL have also only been published for a limited number of contaminants commonly identified in contaminated land risk assessments at present (arsenic, cadmium, chromium VI, lead, benzene, benzo[a]pyrene). However, the C4SL have been published for a range of land uses, including residential, commercial, allotments and two types of public open space.

The C4SL are designed for use in deciding whether land is suitable for use and definitely not contaminated, and DEFRA and the Welsh Government have recommended that they be used in assessing human health risks during the planning regime (i.e., as part of standard development investigations). The Welsh Local Government Association and Natural Resources Wales (WLGA/NRW) have confirmed that, *'where the site conditions are applicable to the land use scenarios adopted in their calculation, the C4SL levels can be used as screening tools'* for development site risk assessments (WLGA/NRW, 2017). The C4SL have also been accepted by the NHBC for use as generic screening levels on residential developments in England and Wales (NHBC, 2014). Given this, where available and applicable, the C4SL have been adopted as the Generic Assessment Criteria in this assessment.

Where no C4SL is currently available, the Suitable For Use Levels (S4ULs) published in January 2015 by the Chartered Institute of Environmental Health (CIEH) and Land Quality Management (LQM) (Nathanail et al, 2015) have been adopted. These assessment criteria adopt updated toxicological data and exposure models, and the same 'minimal level' of risk as the SGV (i.e., unlike the C4SL). The S4ULs have been published for many contaminants typically found on brownfield sites in the UK, and for the same range of land uses as the C4SL, i.e., including public open space scenarios.

Where no C4SL or S4UL is available, the Soil Guideline Values (SGV) published by the Environment Agency have been adopted as the Generic Assessment Criteria (GAC) – note several SGV have been withdrawn since originally published. However, the SGV are only available for a limited number of contaminants for three proposed land uses (residential, commercial and allotments – and not public open space).

For more exotic, predominantly organic, compounds no SGV, S4UL or C4SL assessment criteria have been published. In this instance, GAC published by CL:AIRE and the Environmental Industries Commission (CL:AIRE/EIC, 2010) have been adopted. These GAC have also been developed using the CLEA UK software based on a 'minimal level' of risk and for the same land use scenarios as the SGVs (i.e., not public open space).

Details of the Generic Assessment Criteria (GAC) adopted for each contaminant are presented on the assessment tables in the following section.

The proposed development comprises conventional residential properties with private gardens. Therefore, the GAC appropriate for the residential land use with plant uptake have been adopted in this assessment.

The GAC for most organic compounds are dependent on the organic content of the soil. Analysis has shown that the soil organic content in the soils analysed ranged from 0.5% to 6.7%. Therefore, for the purposes of this assessment, GAC for a soil organic content of 1% has been adopted. This again is considered a conservative approach for most of the soils at the site.

5.4.3 Generic Quantitative Risk Assessment

The samples analysed for soil contaminants comprised four samples of Made Ground and four samples of natural Boyne Hollow Chert soils. At this stage, all samples have been considered across the site as one averaging area. If any exceedances are identified, a statistical analysis based on particular averaging areas may be undertaken to further assess the risks. The risks from asbestos are considered further in Section 5.4.5. The risks from biological contamination have been considered further in Section 5.4.6.

The results of the Generic Quantitative Risk Assessment for the proposed development are presented in the table below. It should be appreciated that if the development were to change, the following assessment should be reviewed and, if necessary, updated.

Table 6 - Generic Assessment of Human Health Risks

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	2.9 – 8.2mg/kg	37mg/kg	C4SL ²	None of 8
Barium ⁶	33 – 150mg/kg	1,300mg/kg	CL:AIRE/EIC ⁵	None of 8
Beryllium	0.2 – 1.1mg/kg	1.7mg/kg	S4UL ⁴	None of 8
Boron	0.3 – 0.7mg/kg	290mg/kg	S4UL ⁴	None of 8
Cadmium	<0.1 – 0.7mg/kg	26mg/kg	C4SL ²	None of 8
Chromium (total) ⁷	7.4 – 28mg/kg	910mg/kg	S4UL ⁴	None of 8
Chromium (hexavalent)	<1.0mg/kg	21mg/kg	C4SL ²	None of 8
Copper	6.5 – 15mg/kg	2,400mg/kg	S4UL ⁴	None of 8
Lead	15 – 310mg/kg	200mg/kg	C4SL ²	None of 8
Mercury ⁸	<0.05 – 0.08mg/kg	40mg/kg	S4UL ⁴	None of 8
Nickel	4.5 – 15mg/kg	130mg/kg	S4UL ⁴	None of 8
Selenium	<0.5 – 1.2mg/kg	250mg/kg	S4UL ⁴	None of 8
Vanadium	9.3 – 36mg/kg	410mg/kg	S4UL ⁴	None of 8
Zinc	28 – 110mg/kg	3,700mg/kg	S4UL ⁴	None of 8
Polyaromatic Hydrocarbons (PAH)				
Acenaphthene	<0.03 – 0.15mg/kg	210mg/kg	S4UL ^{4,9}	None of 8
Acenaphthylene	<0.03 – 0.57mg/kg	170mg/kg	S4UL ^{4,9}	None of 8
Anthracene	<0.03 – 0.59mg/kg	2,400mg/kg	S4UL ^{4,9}	None of 8
Benzo(a)anthracene	<0.03 – 5.8mg/kg	7.2mg/kg	S4UL ^{4,9}	None of 8
Benzo(a)pyrene	<0.03 – 8.8 mg/kg	5mg/kg	C4SL ^{2,9}	1 of 8
Benzo(b)fluoranthene	<0.03 – 11 mg/kg	2.6mg/kg	S4UL ^{4,9}	1 of 8
Benzo(ghi)perylene	<0.03 – 4.8mg/kg	320mg/kg	S4UL ^{4,9}	None of 8
Benzo(k)fluoranthene	<0.03 – 4.9mg/kg	77mg/kg	S4UL ^{4,9}	None of 8
Chrysene	<0.03 – 4.6mg/kg	15mg/kg	S4UL ^{4,9}	None of 8
Dibenzo(a,h)anthracene	<0.03 – 0.94 mg/kg	0.24mg/kg	S4UL ^{4,9}	1 of 8
Fluoranthene	<0.03 – 8.4mg/kg	280mg/kg	S4UL ^{4,9}	None of 8
Fluorene	<0.03 – 0.12mg/kg	170mg/kg	S4UL ^{4,9}	None of 8
Indeno(123-cd)pyrene	<0.03 – 3.4mg/kg	27mg/kg	S4UL ^{4,9}	None of 8
Naphthalene	<0.03 – 0.03mg/kg	2.3mg/kg	S4UL ^{4,9}	None of 8
Phenanthrene	<0.03 – 1.7mg/kg	95mg/kg	S4UL ^{4,9}	None of 8
Pyrene	<0.03 – 8.9mg/kg	620mg/kg	S4UL ^{4,9}	None of 8
BTEX Compounds				
Benzene	<0.01mg/kg	0.87mg/kg	C4SL ^{2,9}	None of 8
Toluene	<0.01mg/kg	130mg/kg	S4UL ^{4,9}	None of 8
Ethyl benzene	<0.01mg/kg	47mg/kg	S4UL ^{4,9}	None of 8
Xylene ¹⁰	<0.01mg/kg	56mg/kg	S4UL ^{4,9}	None of 8
Aliphatic Petroleum Hydrocarbons (Equivalent Carbon Number)				
Ali EC 5-6	<0.01mg/kg	42mg/kg	S4UL ^{4,9}	None of 8
Ali EC 6-8	<0.01mg/kg	100mg/kg		None of 8
Ali EC 8-10	<0.01mg/kg	27mg/kg		None of 8
Ali EC 10-12	<1.5mg/kg	130mg/kg*		None of 8
Ali EC 12-16	<1.2mg/kg	1,100mg/kg*		None of 8
Ali EC 16-35	<10 – 81.3mg/kg	65,000mg/kg*		None of 8

Continued Over.

Table 6 (Continued) - Generic Assessment of Human Health Risks

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Aromatic Petroleum Hydrocarbons (Equivalent Carbon Number)				
Aro EC 5-7	<0.01mg/kg	70mg/kg	S4UL ^{4,9}	None of 8
Aro EC 7-8	<0.01mg/kg	130mg/kg		None of 8
Aro EC 8-10	<0.01mg/kg	34mg/kg		None of 8
Aro EC 10-12	<0.9 – 1.2mg/kg	74mg/kg		None of 8
Aro EC 12-16	<0.5 – 3.5mg/kg	140mg/kg		None of 8
Aro EC 16-21	<0.6 – 21mg/kg	260mg/kg		None of 8
Aro EC 21-35	<1.4 – 320mg/kg	1,100mg/kg		None of 8
Other Organic Compounds				
Phenol	<0.3 – 0.8mg/kg	280mg/kg	S4UL ^{4,9}	None of 8
Notes:				
1. Assessment for residential land use <u>with home-grown produce uptake</u> (apart from barium – see Note 6 below).				
2. C4SL: Category 4 Screening Level, published by CL:AIRE.				
3. SGV: Soil Guideline Value published by Environment Agency.				
4. S4ULs Suitable 4 Use Levels. Copyright Land Quality Management Limited, reproduced with permission; Publication No. S4UL3156. All Rights Reserved.				
5. CL:AIRE/EIC GAC published by CL:AIRE and Environment Industries Commission.				
6. GAC for barium for residential use without plant uptake. No GAC published for plant uptake risk drivers.				
7. In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted.				
8. GAC for inorganic mercury adopted.				
9. GAC for organic compounds based on 1% soil organic content.				
10. GAC for xylene based on p-xylene (lowest S4UL).				
11. Exceedances highlighted in red and bold.				
12. Laboratory results presented in Appendix L.				
* GAC exceeds solubility or vapour saturation limit.				

5.4.4 Summary

As shown in the table above, except for elevated PAH levels in one sample, the levels of all determinands were below the adopted GAC.

The elevated levels of Benzo(a)pyrene (8.8mg/kg), Benzo(b)fluoranthene (11mg/kg) and Dibenzo(a,h)anthracene (0.94mg/kg) were all identified from one sample, from WS208 at 0.45m within the Made Ground. This is discussed further in Section 7.1.2.

5.4.5 Asbestos

A qualitative analysis has identified chrysotile asbestos in visible cement and loose bundles present in WS07 (0.55m) within the Made Ground and chrysotile asbestos as loose bundles present in WS08 (0.45m) within the Made Ground.

Further quantitative testing has been undertaken and identified that the level of this asbestos varies between 10.725% mass (WS207, 0.55m) and 0.002% mass (WS208, 0.45m). This is discussed further in Section 7.1.1.

5.4.6 Biological Soil Contamination

Samples of shallow soils collected from soils within, and adjacent to, the existing slurry pit. (HDP01 to HDP03), have been analysed to assess the potential for biological contamination of the shallow soils on site within the slurry pit and in the area previously identified to have elevated pathogens.

There are currently no assessment criteria for evaluating risks from biological contaminants. Therefore, the assessment is of a qualitative nature only.

The samples were analysed for total coliforms, faecal coliform, and e coli (parameters commonly found to be elevated in sewage).

In HDP02 within the slurry pit, the results for E.coli, faecal coliforms and Total coliforms were all below detection limits.

In HDP01 (southeast of the slurry pit), the level of E. coli was 90cfu/g (colony forming units per gramme), the level of faecal coliforms was 90cfu/g, and the total coliforms was 90cfu/g.

In HDP03 (within the slurry pit), the level of E. coli was 240cfu/g, the level of faecal coliforms was 240cfu/g, and the total coliforms was 740cfu/g.

The previous assessment identified similar levels.

We have no information on the construction of the slurry pit, but from site observations, we consider that it is likely to be contained within a simple soil bund, with no basal liner. The results of the above testing (and previous testing) suggest that there may have been some contamination of the soils around the slurry pit from effluent leaking from the pit. The above is discussed further in Section 7.1.2.

5.5 Risk to Controlled Waters - Level One Assessment

5.5.1 Methodology

The potential impact of contamination originating at the site on controlled waters around the site (i.e., groundwater and surface water) has been initially evaluated in line with the Environment Agency guidance (Carey et al, 2006).

Levels of leachable contamination within the soil samples recovered at the site have been analysed, which represents a 'Level One' risk assessment (Carey et al, 2006).

5.5.2 Assessment Criteria

As for the assessment of human health risks above, the results of the contamination testing have been compared to assessment criteria appropriate to the controlled water receptors in the area.

The Preliminary Risk Assessment has identified that the following controlled water receptors are potentially at risk from contamination originating at the site:

- The groundwater within the Upper Greensand strata beneath the site (classified as a Principal Aquifer and within a Zone 3 SPZ around a potable groundwater abstraction).

Given the available information, we consider that the most vulnerable receptor with regards to leachable and mobile contamination would be the groundwater beneath the site and our assessment has concentrated on this receptor.

Potable Groundwater:

To assess the potential risk to potable groundwater beneath the site, and in particular the abstraction well some 1km to the east of the site (within the town centre of Warminster), the published Prescribed Concentration Values (PCV) of the Water Supply (Water Quality) Regulations (WSR, 2016), which relate to the use of groundwater as a potable resource, have been adopted as the assessment criteria.

Where no PCV is published, the '*concentrations of hazardous substances within groundwater below which the danger of deterioration of the groundwater quality is avoided*' published by UKTAG (2016) have been adopted as assessment criteria. These UKTAG concentrations have been calculated from thresholds designed to be protective of drinking water.

Hazardous Substances:

Some contaminants which can impact on controlled waters have been classed as hazardous substances (JAGDAG, 2019) and include arsenic, lead, mercury, and some of the polyaromatic and petroleum hydrocarbon compounds. Natural Resources Wales (NRW) require that the entry of hazardous substances into controlled waters is phased out, or at least any further entry should be minimised. The remaining contaminants are classed as non-hazardous. The classification of each determinand analysed is presented in Table 7.

Petroleum Hydrocarbons:

There are currently no EU or UK guidelines for ethylbenzene and the World Health Organisation criteria (WHO, 2011) have been adopted for this compound. Similarly, except for the BTEX compounds, there are no published assessment criteria for petroleum hydrocarbons within controlled waters. The Environment Agency/NRW have previously stipulated an assessment criterion of 10µg/l for all bands of petroleum hydrocarbons, and this has been used tentatively as the assessment criteria. However, it should be appreciated that this only represents a preliminary, broad-brush appraisal of the levels of contamination present and an exceedance does not necessarily define an unacceptable risk.

The actual assessment criteria adopted are shown in the following table(s), and further details on them can be found in the respective published documents.

5.5.3 Assessment of Leachate Test Results

The results of the leachate testing and their comparison to the relevant assessment criteria are presented in Table 7 below, based on the Potentially Potable Groundwater as the most vulnerable receptor.

Table 7: Level One Controlled Waters Risk Assessment – Leachate Results (Potable Groundwater)

Compound	Range Recorded	PCV ⁶	UKTAG ⁷	Exceedances
Metals				
Arsenic ¹	1.1 - 18 µg/l	10µg/l	5.0µg/l	1 of 6 (PCV & UKTAG)
Boron ²	<12 - 150µg/l	1,000µg/l	-	None of 6
Cadmium ²	<0.03 - 0.04µg/l	5.0µg/l	-	None of 6
Chromium VI ^{1,3}	<0.25 - 1.6µg/l	50µg/l	5.0µg/l	None of 6
Copper ²	0.9 - 6.6 µg/l	2.0µg/l	-	1 of 6 (PCV)
Lead ¹	0.15 - 3.6µg/l	10µg/l	5.0µg/l	None of 6
Mercury ¹	<0.01 - 0.01µg/l	1.0µg/l	0.5µg/l	None of 6
Nickel ²	<0.5 - 2.0µg/l	20µg/l	-	None of 6
Selenium ²	<0.25 - 0.71µg/l	10µg/l	-	None of 6
Polyaromatic Hydrocarbons				
Anthracene ¹	<0.01 - 0.04µg/l	-	0.05µg/l	None of 6
Benzo[a]pyrene ¹	<0.01 - 0.3 µg/l	0.01µg/l	0.005µg/l	1 of 6 (PCV & UKTAG)
BbF ¹	<0.01 - 0.42 µg/l	-	0.05µg/l	1 of 6 (PCV & UKTAG)
BghiP ¹	<0.01 - 0.32 µg/l	-	0.05µg/l	1 of 6 (PCV & UKTAG)
BkF ¹	<0.01 - 0.15 µg/l	-	0.05µg/l	1 of 6 (PCV & UKTAG)
IDP ¹	<0.01 - 0.42 µg/l	-	0.05µg/l	1 of 6 (PCV & UKTAG)
Petroleum Hydrocarbons				
Benzene ¹	<1.0µg/l	1.0µg/l	0.5µg/l	None of 6
Toluene ¹	<1.0µg/l	-	350µg/l	None of 6
Other Contaminants				
Cyanide ²	<40µg/l	50µg/l	-	None of 6
Notes: - Hazardous substance (JAGDAG, 2019). - Non-hazardous substance (JAGDAG, 2019). - All chromium present assumed to be chromium VI (conservative approach). - All four PAH compounds classed as hazardous. - Assessment based on potable groundwater beneath the site. - PCV – Prescribed Concentration Value, drinking water only – measured at consumers tap (WSR, 2016). - UKTAG – UK TAG concentration below which the danger of deterioration in the groundwater quality is avoided. For hazardous substances only. - Exceedances indicated in bold, and colour coded as shown. - Test results presented in Appendix L. Key to PAH compounds: BbF: benzo[b]fluoranthene BghiP: benzo[ghi]perylene BkF: benzo[k]fluoranthene IDP: indeno[123-cd]pyrene				

As shown by table 7 above, two marginally elevated levels of metals were identified, and five marginally elevated levels of PAH's were identified.

The elevated level of arsenic and copper were identified from the same sample collected from WS207 a 0.55m within the Made Ground.

The elevated PAH levels were identified from the same sample collected from WS08 at 0.45m within the Made Ground.

This is discussed further in Section 7.2.

5.6 Hazardous Ground Gas

The following section is an assessment of the ground gas monitoring undertaken across the site as a whole and includes the results of the previous monitoring undertaken following the first phase of works (Ref: ESP.6271t.2676) as well as the recent monitoring of wells installed in previously inaccessible areas.

The following assessment supersedes the Ground gas addendum (GGA) report previously issued in 2017 (Ref: aw/6271t.2720.GGA).

5.6.1 Summary of Gas Well Installations

A 50mm diameter monitoring well was installed in selected boreholes during the 2017 and 2021 works in accordance with BS8576:2013, to allow monitoring of hazardous ground gases.

During the 2017 works, areas within the farmyard were inaccessible and therefore no investigation (or gas wells) could be undertaken in this area. The farmyard area has now been investigated during these recent works.

The wells, comprising slotted plastic pipe with a gravel surround (the response zone), bentonite seals above and below the response zone, and a lockable vandal proof cover, were installed as detailed on the borehole records and summarised in the table below.

Table 8: Gas Well Installations

Well ID	Date of Installation	Response Zone depth	Response Zone Stratum ⁵	Rationale
WS1	18/10/2016	0.7 – 3.0m	RA, BHC & SSM.	2
WS2	18/10/2016	0.7 – 2.9m	RA, BHC & SSM.	2
WS3	18/10/2016	0.7 – 3.8m	RA & SSM.	2
WS6	18/10/2016	0.7 – 4.9m	MG & SSM.	4
WS7	18/10/2016	0.7 – 2.8m	MG, BHC & SSM.	5
WS8	18/10/2016	0.7 – 3.0m	MG & SSM.	4
WS201	27/7/2021	0.5 – 2.5m	MG & BHC.	3
WS202	27/7/2021	0.5 – 2.0m	MG & BHC.	4
WS206	28/7/2021	0.5 – 2.0m	MG & BHC.	4
WS207	28/7/2021	0.5 – 2.5m	MG & BHC.	5
WS208	28/7/2021	0.5 – 3.0m	MG & BHC.	4
Notes: - Details of each monitoring well are presented on the individual borehole records (Appendix E & H). - Well installed in area of River Alluvium. - Well installed in area of dry pond - Well installed in general areas and Made Ground. - Well installed in shallow soils adjacent to diesel engine/generator. - RA = River Alluvium. BHC = Boyne Hollow Chert Member. SSM = Shaftesbury Sandstone Member. MG = Made Ground.				

5.6.2 Degradation of Organic Materials

The installed gas wells have been monitored for hazardous gases on six occasions over a 12-week period during the 2016/2017 monitoring (of the wider site) and the 2021/2022 monitoring (of the farmyard area). The monitoring results are presented in Appendix I and J and are summarised in the table below:

Table 9 - Summary of Gas Monitoring Data (Visits 1 to 6)

Well	Response Zone Depth ¹ (m)	No visits	Maximum Methane (%)	Maximum Carbon dioxide (%)	Minimum Oxygen (%)	Maximum Gas Flow (L/hr)	Shallowest Water depth (m)	Atmospheric pressure
WS1	0.7 – 3.0m	6	ND	6.0	14.3	2.3	1.69	980-1019
WS2	0.7 – 2.9m	6	ND	4.5	13.6	4.0	1.85	
WS3	0.7 – 3.8m	6	ND	0.90	20.4	0.6	0.52	
WS6	0.7 – 4.9m	6	ND	6.3	9.7	0.3	1.81	
WS7	0.7 – 2.8m	6	ND	12.0	3.1	1.0	DRY	
WS8	0.7 – 3.0m	6	ND	4.7	15.0	0.4	2.46	
WS201	0.5 – 2.5m	6	ND	4.8	6.3	0.3	DRY	977 - 1016
WS202	0.5 – 2.0m	6	ND	4.1	16.5	0.1	DRY	
WS206	0.5 – 2.0m	6	ND	6.5	7.5	0.1	DRY	
WS207	0.5 – 2.5m	6	ND	9.2	3.2	0.1	DRY	
WS208	0.5 – 3.0m	6	ND	12.8	0.1	0.1	DRY	
Notes: 1. ND – none detected with instrument (<0.2% for methane, <0.1% for carbon dioxide). 2. Full monitoring results presented in Appendix I and J.								

The monitoring to date has indicated levels of methane between below the limit of detection (0.2%) and carbon dioxide levels between 0.9% and 12.8%. Oxygen was depleted where the levels of carbon dioxide were elevated, most notably in WS208, where a level of 0.1% oxygen was recorded during monitoring visit 3 (coinciding with a low atmospheric pressure). Maximum gas flow rates of 4.0L/hr were recorded. Levels of volatile organic compounds were recorded as between below the limit of detection and 0.4%.

5.6.3 Gas Screening Values

The below assessment is undertaken for the site as a whole, including the site wide monitoring (2016/2017) and the farmyard monitoring (2021/2022). The results of monitoring undertaken to date have been used to calculate Gas Screening Values (GSV) appropriate for the site using the methodology published in CIRIA C665 (Wilson et al, 2007).

The calculated GSV for the site are presented in in the table below. As no levels of methane were recorded above detection, we have used the limit of detection (0.2%) as a conservative approach.

Table 10 - Gas Screening Values (based on 6no. site wide visits and 6no. farmyard visits)

	Maximum Recorded Level (%)	Maximum Gas Flow Rate (L/hr)	GSV (L/hr)
Methane	0.2 ²	4.0	0.008
Carbon dioxide	12.8	4.0	0.512
Notes: 1. GSV calculated using method derived in CIRIA 665 (2007). 2. Levels of methane recorded below detection throughout monitoring (<0.2%). GSV calculated using 0.2% as a conservative approach.			

Based on the above calculated GSV, we consider that the site would be classified as Characteristic Situation CS-2 for a residential development (CIRIA C665:2007). This is in line with the previous sitewide assessment undertaken in 2017 (which did not include the farmyard area at the time).

5.7 Sulphate Attack

The assessment of the concrete protection against sulphate attack has been undertaken in accordance with BRE SD1 (2005).

5.7.1 Classification of Site

Due to the presence of Made Ground on the site, we consider that it should be considered as 'brownfield' in terms of concrete classification.

5.7.2 Groundwater Setting

No groundwater was encountered in the exploratory holes to a depth of 3.0m. However, no long-term monitoring (more than 24 hours) of groundwater levels has been undertaken. Therefore, in accordance with the BRE guidelines, we recommend that groundwater be considered as 'mobile' in terms of foundation concrete assessment.

5.7.3 Sulphate Levels

At this stage, the below assessment combines samples of the Made Ground (2no. samples) and samples of the natural Boyne Hollow Chert Member (6no. samples).

Laboratory test results indicate the levels of water-soluble sulphate (as SO₄) in the Made Ground and natural Boyne Hollow Chert Member soils to be between 13mg/l and 380mg/l. As levels of water-soluble sulphate are less than 3,000mg/l, there is no need to consider the levels of magnesium present in the soils.

Levels of acid soluble sulphate varied between 0.02% and 0.11% and total sulphur between <0.01% and 0.04%. From these results, the calculated levels of total potential sulphate are between 0.03% and 0.12%, and oxidisable sulphides are between -0.02% and 0.04%. As the levels of oxidisable sulphide are well below 0.3%, pyrite is unlikely to be present.

pH values varied between 7.3 and 8.8, indicating near neutral/slightly alkaline soil conditions to exist. As the pH levels all exceed 5.5, there is no need to further assess the soils for the types of acids present (e.g., hydrochloric, and nitric acids).

5.7.4 Foundation Concrete Design:

Using the above results, we consider that the following characteristic values are applicable for the shallow soils at the site (all as SO₄):

Water soluble sulphate:	235mg/l.
Total potential sulphate:	0.11%.
pH value:	7.4.

6 Phase Two Geo-Environmental Risk Assessment

6.1 Discussion on Occurrence of Contamination and Distribution

The farmyard site history has indicated that it has been developed as a farm which has areas of potentially contaminative use, all located around the farm buildings and slurry pit in the centre of the site. No contamination sources have been identified in the wider site.

From the available information, we consider that the following features on site could prove point sources of contamination that could impact on the development, environment, or site users:

- Made Ground.
- Spills of fuel/oils around the steel diesel storage tank and engine.
- Probable asbestos cement within farm building construction.
- Slurry pit and outfall pipe.

The farm buildings are generally of brick or concrete block construction with asbestos cement roofs, and some asbestos cement panel side cladding.

Made Ground was encountered across the yard area and was notably deeper in WS207 and WS208 in the southeast, likely due to historical filling during the development of the farm buildings and yard.

Probable asbestos cement roof tiles were identified within the made Ground soils in WS307 and WS208.

Quantitative testing of asbestos identified within the laboratory analysis has been undertaken and identified that the level of this asbestos varies between 10.725% mass (WS07, 0.55m) and 0.002% mass (WS08, 0.45m). This is discussed further in Section 7.1.1.

Laboratory testing has identified that, except for elevated PAH levels in one sample, the levels of all determinands were below the adopted GAC.

Elevated levels of Benzo(a)pyrene (8.8mg/kg), Benzo(b)fluoranthene (11mg/kg) and Dibenzo(a, h)anthracene (0.94mg/kg) were all identified from one sample, from WS208 at 0.45m within the Made Ground.

Two marginally elevated levels of metals were identified, and five marginally elevated levels of PAH's were identified.

Variable levels of biological contamination have been identified within samples taken from within the slurry pit and to the southeast, around the outflow pipe and previously identified elevated levels of biological contamination.

6.2 Revised Risk Evaluation & Relevant Pollutant Linkages

As discussed in detail within Section 3.2.1, the methodology set out in CIRIA C552 (2001) has been used to assess whether risks are acceptable, and to determine the need for collating further information or remedial action.

The risks evaluated at the desk study stage of this report (Table, Section 3.2.2) have been updated and revised in Table 11 following information learned from the exploratory works and results of monitoring and laboratory testing.

Table 11 - Revised Risk Evaluation & Relevant Pollutant Linkages (RPL)

Source	Pathway	Receptor	Classification of Consequence	Classification of Probability	Risk Category	Further Investigation or Remedial Action to be Taken
Potential general contaminants in shallow soils	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users (residents)	Medium – potential for chronic levels.	Low likelihood ²	Moderate/Low Risk	See Section 7.1.2.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	Low likelihood ²	Very Low Risk	
	Leaching of soil contaminants	Impact on Groundwater /Potable Water	Medium – Principal Aquifer and Zone 3 SPZ.	Low likelihood ²	Moderate/Low Risk	See Section 7.2.
Pathogens in slurry pit	Direct contact/ingestion of contaminated soil	Site Users (residents)	Medium – potential for chronic levels.	Likely ³	Moderate Risk	See Section 7.1.2.
	Direct contact/ingestion of contaminated soil	Construction/ Maintenance Workers	Medium – additional PPE may be required	Likely ³	Moderate Risk	
Asbestos in existing buildings	Ingestion of fibres	Demolition Workers/ Ground Workers	Medium – potential for chronic levels	High Likelihood ⁴	High Risk	Asbestos survey of buildings.
Asbestos in shallow soils	Ingestion of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	High Likelihood ⁴	High Risk	See Section 7.1.1.
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	Low likelihood ⁵	Low Risk	See Section 7.4.2.
Hazardous ground gas/vapours	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	Low Likelihood ⁶	Moderate Risk	See Section 7.3.1 & 7.3.2
	Damage through explosion.	Building/Property	Severe – acute risk.		Moderate Risk	
	Asphyxiation/poisoning. Injury due to explosion.	Construction and Maintenance Workers.	Severe – acute risk.		Moderate Risk	
Radon gas	Migration into Buildings	Site Users (residents)	Medium – potential for chronic levels	Unlikely ⁷	Low Risk	See Section 7.3.2.

Notes:

1. Methodology and details of risk consequence, probability and category based on CIRIA C552 (2001) and presented in Section 3.2.1.
2. Except for elevated PAH levels in one sample, the levels of all determinands were below the adopted GAC.
3. Previous investigations identified potential risk from biological contamination. Recent testing has identified similar levels.
4. Probable asbestos roofing and cladding noted on existing farm buildings and possible asbestos cement stockpile identified in the centre of the yard area (see Figure 1). Quantitative testing of asbestos identified within the laboratory analysis has been undertaken and identified that the level of this asbestos varies between 10.725% mass (WS07, 0.55m) and 0.002% mass (WS08, 0.45m).
5. Low levels of soils sulphate identified in the testing undertaken.
6. Elevated levels of carbon dioxide have been identified historically across the wider site and recently within the farmyard monitoring. Based on the calculated GSV, we consider that the site would be classified as Characteristic Situation CS-2 for a residential development (CIRIA C665:2007).
7. Radon risk is low, and no protective measures are required.

7 Remedial Strategy for Contamination Risks

The following recommendations are based on interpretations made from the relatively limited site investigation data obtained to-date, and do not form the full Options Appraisal stage of CLR11. If at any stage of the construction works, contamination or a potential for such contamination is identified that is different to that presented within this report, all the following should be reviewed, and the advice of a geo-environmental specialist sought immediately.

7.1 Risks to Health

7.1.1 Asbestos

As indicated in Section 5.4.5, a qualitative analysis has identified chrysotile asbestos in visible cement and loose bundles present in WS207 (0.55m) within the Made Ground and chrysotile asbestos as loose bundles present in WS208 (0.45m) within the Made Ground.

Further quantitative testing has been undertaken and identified that the level of this asbestos varies between 10.725% mass (WS07, 0.55m) and 0.002% mass (WS08, 0.45m). This is discussed further in Section 7.1.1.

To provide an initial analysis of the potential risk from asbestos, we have undertaken a preliminary risk assessment in line with the Joint Industry Working Group (JIWP) 'Decision Support Tools for Qualitative Risk Ranking of Working Activities and Receptors Involved in or Exposed to Asbestos in Soil or Construction & Demolition Materials'. This tool is designed to provide a consistent decision-making format to further assess the potential risk from asbestos. Based on the current available information, the risk for the groundworkers during construction is likely to be at a medium level, with the risks to the site end users likely to be high.

There is no clear UK guidance on what would constitute an acceptable concentration of asbestos in soil. Working with asbestos (even within soils) is governed by the Control of Asbestos Regulations (2012). This requires that the excavation and removal of the asbestos contaminated soils must be undertaken by a licensed contractor.

An asbestos specialist may be employed to undertake further assessment of the risk from the asbestos present in the soils beneath the site with a view to investigating whether there would be an alternative risk mitigation method to prevent the expensive and non-sustainable removal and disposal of soils.

Prior to the demolition of the farm buildings on site, an asbestos survey should be undertaken by a specialist and any asbestos materials found removed by a licensed contractor.

On any historic farmland such as the site, it cannot be discounted that former hollows in the site surface may have been infilled in the past, and asbestos containing materials (ACM) may have been included in the backfill materials.

The following sections presume that any risks from asbestos materials at the site are mitigated.

7.1.2 Site End Users

7.1.2.1 General Contamination

Assuming an end use as a residential development, generally, the identified levels of soil contamination in the farmyard area site are not considered to pose a risk to future site users. Mitigation measures/source removal will be required around WS208, where elevated levels of contamination have been identified (discussed further below).

Notwithstanding the above, as discussed in Section 7.1.1, it cannot be discounted that former hollows in the site surface may have been infilled in the past with contaminated materials. If any evidence of Made Ground or other contaminated soils is identified during development, further geo-environmental specialist advice should be sought.

As discussed in Section 5.4.3, the levels of Benzo(a)pyrene (8.8mg/kg), Benzo(b)fluoranthene (11mg/kg) and Dibenzo(a,h)anthracene (0.94mg/kg) are elevated above the generic assessment criteria and, therefore, are present at unacceptable levels with respect to the users of the proposed residential development. The elevated levels were identified from one sample, from WS208 at 0.45m within the Made Ground.

Appropriate measures would need to be taken prior to development to break the pollutant linkage in this area of Made Ground and mitigate these risks in areas of soft surfacing (e.g., gardens, public landscaping etc.).

In areas of hard surfacing (e.g., beneath structures, driveways, roads, and other hardstanding), the hard surface would break the pollutant linkage and no further risk mitigation would be required in terms of risks to human health.

Dependant on any earthworks proposals/finished ground levels, one option could be to remove the Made Ground soils in this area. However, at this stage, we cannot be certain of their extent/volume and additional testing would be required to confirm waste category and disposal options.

Alternatively, and provided that finished site levels allow, another option of mitigating risks posed by non-volatile contaminants could be to isolate the contaminated soils beneath a surface cover layer of clean, inert soil. This could be localised to the area of Made Ground identified around WS208 (delineation of this area will be required during the works). The thickness and make up of this layer would need to be agreed with the regulators. For preliminary design and costing purposes, we consider that the clean cover layer would need to be at least 600mm in thickness (to include placed Topsoil) and would need to be proven to be 'suitable for use' by an appropriate scale of validation testing.

One possible and cost-effective option could be to utilise site won materials, such as the natural soils in the wider site. Previous testing has suggested that the levels of contaminants within these soils are below assessment criteria and, hence they may be suitable for use, however, further validation testing would be required.

If imported to site, appropriate validation testing would also be required to ensure that the materials used for the cover layer are suitable for use. Depending on the source site, these imported soils may also need to be moved under waste legislation – see Section 7.5.

In accordance with CLR11, the preferred risk mitigation strategy should be detailed within a remediation strategy and implementation plan and supervised and validated by a geo-environmental specialist. On completion, a validation report should be prepared to demonstrate to regulators and insurance providers that the risk has been successfully mitigated.

It may be necessary to remove some of the contaminated soils to provide sufficient space to allow a minimum 600mm thickness of clean cover to be constructed.

7.1.2.2 *Biological Contamination*

There are currently no assessment criteria for evaluating risks from biological contaminants.

Pathogens are anticipated within the slurry pit materials as these originate partly from animal waste products. Historical and recent testing indicates that there may have been some contamination of the soils around the slurry pit, possibly from effluent leaking from the pit.

Given the likely potential for biological contamination and the likely poor geotechnical properties of the materials within the slurry pit and the re-worked soils immediately southeast, we recommend that they are excavated and removed from site prior to the development works.

Confirmatory testing of the remaining soils will likely be required to demonstrate that any biologically contaminated soils have been removed.

7.1.3 New Service Connections

The current water industry guidance for the suitability of pipe materials on potentially contaminated sites (Blackmore et al, 2010) has onerous requirements and it is likely/possible, based on this guidance, that the levels of contaminants on site may prevent the use of plastic pipework. We recommend that enquiries are made to the local water authority to confirm their requirements for underground service materials for this development.

7.1.4 Risk to Construction and Maintenance Workers

Ground workers should be aware of the potential risks posed by asbestos within the shallow soils across the farmyard area. All potential risks associated with asbestos should be addressed prior to the commencement of the groundwork, however, it is likely that a residual risk will remain and a watching brief for any potential asbestos or asbestos containing materials should be upheld throughout the works.

Similarly, during any works within the slurry pit and the surrounding area, suitable measure should be in place, including appropriate personal protective equipment and disposal/wash-down areas, to ensure that any biologically impacted soils are handled appropriately and contained to ensure no cross-contamination of the surrounding areas.

Short term (acute) risks to construction and maintenance workers are generally poorly understood within the industry, certainly when compared to the volume of research undertaken on long term risks. However, we anticipate that the levels of general contamination at the site are not likely to pose a severe acute risk to construction workers or future maintenance workers. Ground workers would need to undertake their own assessment of the risks to their workers.

We recommend that construction workers adopt careful handling of the potential contaminants and good standards of personal hygiene should be adopted to reduce the risk of possible ingestion and skin contact should any hotspots be encountered. The contractor should comply with the appropriate current Health and Safety at work legislation.

7.1.5 General Public/Neighbouring Properties

We do not anticipate any significant risks to the public from the development of the site. However, careful dust control measures should be adopted during construction to minimise the risk (and nuisance) to the public and neighbouring residents.

7.2 Risks to Controlled Waters

The historic and recent Level One assessment of risks to controlled waters has indicated that the levels of most contaminants within the shallow soils beneath the site are unlikely to pose an unacceptable risk to controlled waters.

However, elevated levels of metals (ESP, 2021) and elevated levels of polyaromatic hydrocarbon contamination have been recorded (ESP, 2016 and ESP, 2021) in samples of leachate tested.

As detailed in our proposal (dt/ESP.6271t.02.lt1.Proposal), we recommended that if further assessment was required, groundwater samples could be collected from the historical wells, if still serviceable.

If acceptable, we will locate and develop the historical wells during the next gas monitoring visit in order that water samples can be collected for testing and a level two controlled waters assessment can be undertaken.

7.3 Risks from Ground Gas

7.3.1 Risk to the Development – Degradation of Organic Material

Based on the above calculated GSV, we consider that the site would be classified as Characteristic Situation CS-2 for a residential development (CIRIA C665:2007). This is in line with the previous sitewide assessment undertaken in 2017 (which did not include the farmyard area at the time).

The requirements for gas protection have been assessed in accordance with BS8485:2019, which considers gas protection in terms of a ranking 'score' for various types of property.

The proposed development comprises residential dwellings with some likely small room sizes, and there is unlikely to be any building management control on alterations to the internal structure or ventilation. Therefore, we consider this to be classified as a Type A building of BS8485:2019.

Based on Characteristic Situation CS-2, and a Type A Building, the required gas protection score would be 3.5. This may be made up of several elements included within the structure whose individual 'scores' add up to the required total. The best combination of elements will depend to a large degree on the design of the building. Further advice can be provided by this office once the design of the buildings has been finalised.

The slurry pit may act as a confined space and elevated levels of methane/carbon dioxide could be present during its excavation. As detailed in Section 7.1.2.2, we recommend that all slurry pit materials are excavated and removed from site prior to the development works.

7.3.2 Risk to the Development – Radon

No radon protection measures are required.

7.3.3 Risk to Construction and Maintenance Workers

The presence of elevated levels of carbon dioxide and depleted oxygen could pose a risk to construction workers, and lead to asphyxiation in confined spaces.

Most notably, in WS208 a level of 0.1% oxygen was recorded during monitoring Visit 3 (coinciding with a low atmospheric pressure). Elevated levels of carbon dioxide (and corresponding depleted levels of oxygen) were also notably recorded in WS6, WS7, WS201, WS206 and WS207.

The slurry pit may act as a confined space and elevated levels of methane/carbon dioxide could be present during its excavation (as well as the levels identified above, outside of the slurry pit area). This area could pose a risk to construction workers, and lead to asphyxiation in confined spaces. As detailed in Section 7.1.2.2, we recommend that the slurry pit materials are excavated and removed from site prior to the development works.

All excavations should be treated as confined spaces and suitable precautions taken prior to man entry.

7.4 Risks to Property

7.4.1 Spontaneous Combustion

No evidence of combustible materials has been identified in the shallow soils. Therefore, the risk from spontaneous combustion is considered to be low.

7.4.2 Sulphate Attack on Buried Concrete

The following characteristic values are applicable for the shallow soils at the site (all as SO₄):

Water soluble sulphate:	235mg/l.
Total potential sulphate:	0.11%.
pH value:	7.4.

Based on these characteristic values, we consider that the site would be classified as Design Sulphate Class DS-1 and Aggressive Chemical Environment for Concrete Class AC-1, allowing for mobile groundwater.

The previous assessment identified that the wider site would be classified as Design Sulphate Class DS-1, and Aggressive Chemical Environment for Concrete Class AC-2z, allowing for mobile groundwater.

7.5 Re-Use of Materials/Disposal of Excess Arisings

7.5.1 General Comments on Re-use/Disposal

All soils or other materials excavated from any site are generally classified as waste under the Waste Framework Directive (European Union, 2008) and their re-use is controlled by this legislation.

If the soils are to be re-used on site (e.g., within the red-line planning boundary), provided that they are 'uncontaminated' or other naturally occurring deposits and they are certain to be used for the purposes of construction in their natural state on the site from which they are excavated, they may be excluded from waste regulation (Duckworth, 2011). A Materials Management Plan (MMP) may be required – further guidance can be provided by this office once proposals have been finalised. However, if they are man-made or contaminated materials, their use on the site may be limited.

If the soils are to be removed from site, they are automatically classified as waste, and they may only be:

- Disposed at a licensed landfill.
- Disposed at a licensed, permitted soil treatment centre; or
- Removed to a Receiver Site for beneficial re-use.

In Scenarios 1 and 2, the materials must be transferred by a licensed waste carrier and the waste producer (the developer) must ensure that the destination landfill or treatment centre is a legitimate operation (e.g., by requesting a copy of the Environmental Permit before releasing the soils). Prior to removal from site, the excavated arisings would need to be classified as either 'hazardous' or 'non-hazardous' waste based on the hazard that they pose – a WM3 assessment (note that this is a different assessment to the risk assessments reported on in earlier sections of this report). This can commonly be undertaken on the results of soils testing undertaken during the investigation, although further sampling and testing may be required. Only once the soils have been classified under the WM3 assessment, would Waste Acceptability Criteria (WAC) testing then be required to determine the type of landfill in which the arisings could be disposed in Scenario 1. Further testing and assessment may also be required by the soil treatment centre in Scenario 2.

In Scenario 3, management of soils could be undertaken via an Environmental Permit or Exemption. However, these can take time and are costly to arrange. Therefore, in certain circumstances, it is permissible to use the protocols laid down in the CL:AIRE Definition of Waste, Development Industry Code of Practice (DoWCoP, Duckworth, 2011) to classify the arisings and put a management plan in place to control the use. This involves approval of the proposals by a Qualified Person and is generally more efficient (in terms of time and cost) to implement.

The stockpile of possible asbestos containing roof tiles present on site (see Figure 1) would be initially classified as waste and cannot be managed under the DoWCoP protocols. This stockpile should be assessed by an asbestos specialist. If it can be demonstrated (by further testing and assessment) that the materials are compliant with the WRAP protocols, they may be de-classified as waste. Exemptions from the waste legislation may also be applicable.

Further guidance on the legislative requirements of the re-use/disposal of materials generated by the development can be provided by this office once the development proposals have been finalised.

7.5.2 WM3 Assessment – Slurry Pit Materials

A WM3 assessment has been undertaken on two samples of the slurry pit materials and one sample of the shallow, re-worked soils immediately to the southeast adjacent to an outflow pipe (previously identified to likely be impacted by biological contamination). The samples have been assessed to initially inform potential disposal options, if required.

To determine the hazardous nature of waste soils, the current legislation requires that they are classified under the European Waste Catalogue 2000/532/EC (EWC), part of the Waste Framework Directive 2008/98/EC (WFD). The EWC contains 846, six-digit waste codes arranged in twenty chapters, where each chapter is based on a generic industry or process that generated the waste or upon the type of waste. The EWC is based on a hazard assessment, rather than an assessment of risk, i.e., a different approach to when evaluating the impact on human health or controlled waters.

The EWC differentiates between hazardous and non-hazardous by identifying hazardous waste entries with an asterisk.

Soils excavated from development sites would normally be classified as one of two 'mirror' entries:

- **17-05-03***: soil and stones containing dangerous substances - hazardous waste (note the asterisk).
- **17-05-04**: soils and stones other than those mentioned in 17 05 03 - non-hazardous waste.

The class into which soils fall depends on the levels of contaminants, and the likely form of the compound present. The available test data has been assessed for the soils to be removed and the output from the WM3 model is summarised in the table below and presented in full in Appendix M.

Soils	Waste Classification	EW Code
HDP02, HDP03	Non-Hazardous Waste	17-05-04
HDP01	Hazardous	17-05-03*

Based on the results of the WM3 assessment, the soils which require removal from site may be considered generally non-hazardous. However, the sample from HDP01 is being classified as hazardous due to the levels of lead. It should be noted that the assessment assumes that all the lead is lead chromate and is therefore a conservative approach.

Based on the above and considering the results as a whole, we consider the slurry pit materials will likely be classified as non-hazardous, however, it should be noted that the WM3 assessment is based on the presence of general brownfield contaminants and not biological determinands or pathogens.

We recommend that the chosen receiver site is provided the WM3 assessment alongside all results, including biological test data, for them to confirm the classification of the soils. We cannot discount that they may require additional assessment/testing. The assessment report is presented in Appendix M.

As on any development site, the potential for localised contamination cannot be discounted and if any are found during ground works, these would need further classification in terms of waste prior to disposal.

An assessment for disposal options has been undertaken below.

7.5.3 Landfill Disposal

WAC testing has been undertaken on two samples of the slurry pit materials and one sample of the shallow, re-worked soils immediately to the southeast adjacent to an outflow pipe (previously identified to likely be impacted by biological contamination). The 'Test Results on Leachate' indicate that all three samples would generally satisfy the criteria for 'inert' disposal. The results are presented in Appendix M.

We consider it likely an inert facility would accept the soils; however, this needs to be checked with the chosen receiver and we recommend that the receiver site is provided with WAC testing result and our WM3 assessment.

7.5.4 Imported Materials

Any soils or materials to be imported to site (including Topsoil) should be certified clean and inert, and suitable for use. An appropriate number of samples (depending on the volume of soils imported) should be analysed for an appropriate suite of contaminants, and verification certificates should be provided. Further guidance can be provided by this office if required.

8 Geotechnical Comments

8.1 Site Preparation and Earthworks

8.1.1 Unexploded Ordnance

As discussed in Section 2.10.5, a specialist preliminary assessment has concluded that ‘a detailed desk study, whilst always prudent, is not considered essential in this instance’.

Therefore, although no special precautions are considered necessary, a careful watch should be maintained during all excavation and any suspected ordnance identified should be investigated further by specialists. Ordnance awareness is recommended during site inductions.

8.1.2 Invasive Plants

No evidence of invasive plants such as Japanese Knotweed/Himalayan Balsam etc. was identified on the site during the site works. However, their growth is seasonal and therefore their presence cannot be discounted.

8.1.3 Existing Foundations and Services

The site has previously been developed as a farmyard, and old foundations and underground structures are anticipated beneath the site.

These sub-structures and any others identified during development should be grubbed up within the zone of influence of the development as part of the site preparation works.

Live services have been identified on site as described in Section 2.1. Considering the presence of these services, an allowance for diversion/a suitable exclusion zone should be made when planning the development and site works. Further details and permissions should be obtained from the provider.

A network of land drains is likely to be present and may provide a seepage path into excavations. The land drains should be diverted where they enter foundation excavations.

8.1.4 New Services

For new services, flexible pipework and connections should be provided as a safeguard against potential settlements. Consideration could be given to increasing the gradients on sewage connections to mitigate against possible settlements.

8.1.5 Earthworks

We have not been advised that the development requires any significant earthworks. However, given the current changes in elevation across the site, particularly around the slurry pit and margins of the farm buildings, we consider that some earthworks will be required to create suitable development platforms.

Any permanent cuttings or embankment surcharges associated with earthworks or landscaping within the site should be kept to a minimum to avoid any possible adverse effects on the existing stability of the site.

In particular, the stability of any filling above very soft or soft soils, and the possible presence of very shallow groundwater in areas of cutting should be carefully considered. Any proposed changes to the topography should be reviewed by a geotechnical engineer.

8.2 Geotechnical Risk Register

8.2.1 Updated Geotechnical Risk Register

Following the site investigation, the potential geotechnical hazards have been re-assessed as described in the following section. This includes construction risks identified by the intrusive investigation.

For risk associated with poor temporary stability of excavations and groundwater ingress see Section 8.7. For risks associated with sulphate attack see Section 7.4.2.

8.2.2 Shrinkage and Swelling

8.2.2.1 Updated Overview

Laboratory testing has indicated, based on the modified plasticity index (which excludes the non-plastic coarser fraction within the soil), that the fine-grained soils at shallow (probable foundation) depth are of medium volume change potential.

Based on this volume change potential, the minimum foundation depth would need to be 0.9m across the site, however this depth would need to be increased to 1.25m depth in accordance with NHBC/BRE guidelines within the zone of influence of recent, existing, or future planting. It is essential that a tree survey (including current tree heights and species) is undertaken prior to any removal of trees to allow an assessment of the most economical foundation design.

8.2.2.2 Recommendation

As detailed in Section 5.1.1, the fine-grained soils were identified to a maximum depth of 1.3m below surface level and were locally absent in some areas. Given this, we recommend that all foundations are extended through any fine-grained soils encountered and placed within the coarse-grained Boyne Hollow Chert or Shaftesbury Sandstone bedrock (see Section 8.3).

The use of trench fill foundations in these circumstances should be used with great caution as lateral swelling pressures on such large foundation surfaces can lead to rotation or other movement which could lead to failure of the foundation, and they may be subject to uplift forces from the soil swelling.

Swelling pressures can be reduced with the use of suitably dimensioned compressible layers, such as Clayboard or similar, on the sides of the foundations. BRE report 298 provides further guidance on other methods which may be adopted. In addition, the use of deep spread footings (strips or trench fill) can also initiate swelling in the fine-grained soils where roots are severed.

Once the design proposals have been finalised; further advice can be provided by this office as to the required safe depth of foundations across the development.

It should be appreciated that the timing of construction will have an impact on the likelihood of shrinkage and swelling affecting the development. As such, consideration should be given to the proposed construction programme and then the need to carry out further testing and analysis of the potential and scale of movements.

8.2.3 Running Sand

Although no running sands were noted during the investigation in the farmyard area, horizons of sand are present within the shallow soils. No groundwater was observed during the works and the monitoring to date has identified the wells to be dry to a maximum depth of 3.0m below surface level. Monitoring over the winter period will continue during the remaining gas monitoring visits, so seasonally, if any shallow groundwater is present, it should be identified.

Given the above, we consider that the risk from running sands in the yard are likely to be low. However, the previous investigation (ESP, 2016), identified thick horizons of sand present and groundwater was identified at depths as shallow as 0.5m (the wider site is some 2.5m to 2.0m below the farmyard area). Therefore, the potential for running sand in the wider site could not be discounted. In the wider site area, a precautionary note was included that there is the potential that any open excavation below 1.0m depth or greater could experience significant instability and/or collapse (under the right conditions) and this should be considered during the development stages.

8.3 Foundation Design and Construction

The below assessment relates to the yard area only. Foundation recommendations for the wider site are presented in our previous assessment report (ESP, 2016).

The below assessment relates to existing ground levels. If earthworks are undertaken to create suitable development plateaus, then foundation depths are likely to change. The potential risk from shrinkage and swelling should also be considered, regarding lateral pressures where fine-grained soils are present.

We understand that the site is being considered for potential development for residential purposes and the comments and recommendations in this report assume that the development will involve the construction of typical two-storey structures of conventional load-bearing brickwork construction.

Based on the available investigation information, we consider that mass concrete spread foundations could be used at the site, constructed in the coarse-grained natural soils (of both the Boyne Hollow Chert Member and Shaftesbury Sandstone Formation), and placed at a minimum depth of around 1.3m below (existing) surface level. Deeper foundations will be required locally, where thicker Made Ground/fine-grained soils are present (e.g., around WS208). Measures should be in place to ensure that the foundations are placed into the coarse natural soils. We consider that for foundations placed in this stratum, a presumed bearing value of around 75kPa should maintain total and differential settlements to less than 25mm. This is in line with the previous recommendations (ESP, 2016) in the area adjacent to the yard area to the west.

Shallower foundation options (such as a raft) could also be used at the site, following suitable excavation and replacement of compacted fill.

For all spread foundation options, the formations should be cleaned, and subsequently inspected by a suitably qualified engineer prior to placing concrete. Should any soft, compressible, or otherwise unsuitable materials be encountered they should be removed and replaced by lean mix concrete or suitable compacted granular material. We recommend that a blinding layer of concrete be placed on the formation after excavation and inspection to protect the formation against softening and disturbance.

Once design proposals and any earthworks/finished ground levels have been finalised, the foundation recommendations across the site should be reviewed.

8.4 Floor Slab Foundations

The use of cast in-situ ground bearing floor slabs is considered suitable for most of the development in the yard area. However, where Made Ground is deeper in the southeast portion (WS207 and WS208), we consider that ground bearing floor slabs would not be suitable for the development, and floor slabs should be suspended.

Once the hardstanding and any shallow Made Ground has been removed, the underlying natural ground should be compacted for a depth of at least 300mm below slab formation level. Based on the materials observed, we anticipate that four passes of a vibratory roller with mass of five tonnes per metre width should achieve this. The formation should be inspected for any soft spots, which if found should be excavated and replaced with compacted, suitable, granular fill.

8.5 Retaining Wall Design

We are not aware of any retaining structures being required in the development.

8.6 Pavement Design

We understand that vehicle access roads/hardstanding are proposed at the site.

8.6.1 Design CBR Value

The previous assessment (ESP, 2016) of the wider site identified that, based on the testing undertaken, a Design CBR value of 3% would be suitable for preliminary design purposes.

California Bearing Ratio (CBR) tests have not been carried out at the farmyard site, but based on experience and published guidelines, a CBR value of 2.5% is considered appropriate for preliminary design purposes, for the near surface coarse-grained/fine-grained soils. Actual design values should be determined for designated areas as required.

8.6.2 Susceptibility to Frost Action

The near surface soils are considered to be non-frost susceptible.

8.7 Excavation and Dewatering

It is anticipated that excavation throughout most of the site will be within the capabilities of conventional mechanical excavators. Old foundations will require higher capacity machines for their removal.

For shallow excavations where there is no danger to life, support of excavation sides is unlikely to be necessary. Should any indication of excavation instability be noted at any depth, support should be provided as appropriate.

Based on our understanding of the proposed development, no significant groundwater ingress is anticipated above 2-3m depth. Where water ingress occurs, it is likely that pumping from screened sumps within shallow excavations will be adequate.

8.8 Soakaway Drainage

8.8.1 Soakaway Design

No soakaway infiltration testing has been undertaken at the site.

Soakaway testing was undertaken across the wider site as part of the previous assessment (ESP, 2016) and this should be referred to for soakaway drainage recommendations.

9 Recommendations

We consider that the following further investigation and assessment would be required or prudent prior to development:

Required Further Actions:

- Asbestos survey of all farm buildings and existing stockpile. Advice on future demolition and removal should be sought from specialist.
- Removal of slurry pit materials and reworked soils identified around the slurry pit. Confirmatory testing following removal will likely be required.
- Collection of water samples to allow further assessment of the risk to controlled waters.

Recommended Further Actions:

- Re-measure CBR values at sub-grade prior to pavement construction.
- Assessment of sensitivity of CBR value with changes in moisture content.
- Verification testing of any soils imported to site.
- WM3 assessment of any soils to be disposed of/re-used off-site, followed by WAC testing if disposal to landfill.
- Confirm any earthworks requirements/final ground levels and review associated recommendations (foundations, floor slabs, pavement design, soakaways etc).

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