



Geoenvironmental Report

Ickleford Mill, Ickleford SG5 3UN

For Hill

CRM.1027.189.GE.R.001.A



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Geoenvironmental Report

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Executive Summary

Proposed Development

The proposed scheme comprises a residential development at Ickleford Mill, Ickleford SG5 3UN

Investigation

Site works were undertaken by Enzygo Geoenvironmental Ltd. In July and August 2024.

Ground Conditions

Ground conditions comprise Made Ground over Alluvium and glacio fluvial materials over Lowestoft Formation (Clays). Groundwater was recorded at depths of between 0.38 and 1.27m bgl.

Contamination

Contamination has been identified and remediation is proposed.

Foundations

Piled foundations are recommended.

Pavement Construction

An equilibrium CBR value of 1% is recommended.

Ground Gas

No Radon has been identified.

Ground gas has been identified at the site and further analysis is recommended and if present gas protection measures are proposed.

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1.0 INTRODUCTION

1.1 Background

- 1.1.1 Enzygo Geoenvironmental Limited has been commissioned to prepare a Geo-Environmental Report for a proposed development at Ickleford Mill, Ickleford SG5 3UN.

1.2 Proposed Development

- 1.2.1 The proposed development comprises residential use consisting of houses and apartments. The proposed development layout is incorporated into the site plan presented as Drawing CRM.1027.189.GE.D.001.

1.3 Objectives

- 1.3.1 The objectives of the study are to:
- Review existing ground investigation reports which include a summary of the previous desk study undertaken by WSP in 2016;
 - Undertake a targeted supplementary ground investigation;
 - Assess the implications of any potential environmental risks, liabilities and development constraints associated with the site in relation to the future use of the site and in relation to off-site receptors;
 - Provide a factual and interpretative report relating to the desk study and site investigations. Provide a revised conceptual model and recommendations on any potential development issues and mitigation measures, where appropriate.

1.4 Risk Classification

- 1.4.1 Enzygo Geoenvironmental has utilised the available information, together with our experience to assess the likely risks to development from land quality issues. Definitions of the risk terms used are provided on the following table.

Table 1.4.1 Risk Classification

Risk	Description
Dismissed	No contamination risk has been identified which is likely to affect development.
Very Low	No significant contaminated land risks have been encountered affecting development and a low risk that remediation will be required.
Low-Moderate	There are unlikely to be significant contaminated land issue associated with the site which will adversely affect its re-development. However, minor or localised contamination may be present requiring remediation. Remediation should be possible under a discovery strategy and with a call out service.
Moderate	Some potential contaminated land risks have been encountered or identified which may affect re- development. The risks identified are unlikely to affect the entire site or preclude development. Remediation is considered feasible as part of the development process and no further investigation is considered necessary.
Moderate-High	Some potentially significant contaminated land risks have been identified at the property that requires remediation. It is recommended that a separate remedial methodology is prepared supported by a site-specific risk assessment
High	Significant potential contaminated land risks have been identified and remediation is required supported by further intrusive ground investigation, risk assessment and remedial design.

1.4.2 Where adverse risks from ground instability are identified these are discussed within the report.

2.0 SITE SETTING

Table 2.0 Site Description

Item	Description
Site Address	Ickleford Mill, Ickleford SG5 3UN
National Grid Reference	518218, 231295

2.1 Current Site Description

- 2.1.1 The following site description has been compiled from the site inspection undertaken by Enzygo Geoenvironmental Ltd, together with current maps, aerial photographs.
- 2.1.2 At the time of the investigation the site comprised an area of disused mill buildings, former offices, former plant rooms, former warehouses and former underground tanks and former tank bases, disused flour silos and a number of disused interceptors.
- 2.1.3 Access is via an access gate with a through lift up bar within the east of the site from
- 2.1.4 The southern part of the site comprised open grass land.
- 2.1.5 The river Oughton flows south west to north east across the site and is crossed by bridge in two locations to gain access to the southern part of the site.
- 2.1.6 A discharge point into the river was noted from the site and this contained bagging in the river to catch any spillages into the river.
- 2.1.7 A former mill race and pond are located to the south west of the site.
- 2.1.8 The majority of the site is covered in hardstanding however there are small pockets of overgrown landscaping around the perimeters of the site.
- 2.1.9 Scattered trees are noted around the perimeters of the river and site and around the north west of the site.
- 2.1.10 No significant spillages were noted on the overgrown concrete surfacing.

2.2 Surrounding Area

- 2.2.1 Land uses surrounding the site are summarised as follows:

Table 2.2.1 Land Use Surrounding the Area

Direction	Land Use
North	Field, Turnpike road and Residential development
West	Fields with scattered properties and Bedford road and fields beyond.
South	Open fields and allotments with residential estate beyond
East	Arlesey Road with residential house and new pound farm beyond.

- 2.2.2 No evidence of significant potential contamination sources were noted on or adjacent to the site.

3.0 PREVIOUS DESK STUDY INFORMATION

3.1 General

3.1.1 A Phase I Desk Study was undertaken by WSP and then summarised in the Phase II Ground Investigation undertaken by Groundtech. A copy of the Groundtech report is included in Appendix 1. A copy of the WSP report was not available.

3.1.2 Pertinent aspects are reported below:

3.2 Historical Maps

3.2.1 The previous Groundtech- report confirms that the site has been a mill since 1881 and no significant changes since then.

3.3 Ground Conditions

3.3.1 The British Geological Survey (BGS) indicates that the site is underlain by the following geological sequence:

Table 3.3.1 Geological Sequence

Geological	Type	Descriptions	Aquifer Classification
Drift (path of river)	Alluvium.	Silt, Sand, Clay and Gravel	Secondary A
Drift (Northern part of the site)	Glaciofluvial Deposits	Silt, Sand, Clay and Gravel	Secondary A
Deeper Drift materials	Lowestoft Formation	Chalky Glacial Till	Undifferentiated Secondary Aquifer
Solid	Gault formation	Mudstone	Unproductive

3.3.2 Made Ground (Artificial deposits) are not identified by the BGS on the site, however historical land use age of the site indicates that there will be Made Ground across the site associated with the former usage as a Mill.

3.3.3 BGS borehole records close to the site show soft organic clay, consistent with Alluvium over yellow brown clayey sand and gravel. Superficial deposits are underlain by firm to stiff grey clay consistent with the Weymouth Formation.

3.4 Hydrogeology

3.4.1 The site is not located within a Source Protection Zone.

3.4.2 There are no potable groundwater abstraction points within 500m of the site.

3.4.3 There are no discharge consents within 250m of the site.

3.5 Mining and Cavities

3.5.1 No mining or natural cavities are identified close to the site.

3.6 Hydrology

3.6.1 The nearest surface water course is the river Oughton flows south which flows west to north east across the site.

3.7 Sensitive Designations

3.7.1 Iffley Meadows, which is a Site of Special Scientific Interest (SSSI) is located to the east of the Weirs Mill Stream. It is considered that the water course will act as a barrier to prevent migration of potential contaminants from the site to the SSSI.

3.8 Radon Risk Potential

3.8.1 The desk study report indicates that the site is not situated within an area where radon protection measures are required. Based on the radon UK map between 1% and 3% homes and in a radon zone and therefore further investigation is required to confirm radon for site address. This can be address in the remediation strategy.

3.9 Environmental Data

3.9.1 No fuel stations are recorded within 250m of the site.

3.9.2 A Pollution incident on site comprised crude sewage discharge in the River Oughton (1996) minor incident.

3.9.3 A further pollution incident occurred 120m north east of the site (organic waste and suspended solids) into the River Oughton (Significant incident).

3.10 Landfill Sites

3.10.1 There are no landfills within 250m of the site.

3.11 Conceptual model outlined in the previous desk study

Potential Sources

3.11.1 The contamination sources outlined in the previous desk study are as follows:

- Made Ground associated with the infilling of the pond and mill race and the construction of the existing buildings on the site.
- Contamination sources associated with the historical land use as mill including workshops, boiler rooms, vehicle cleaning station, refuelling areas, and maintenance areas.
- Other contamination sources include the hazardous materials associated with the significant thickness of Made Ground including the infilled gravel pit 80m south of the site.

3.11.2 The potential contaminants of concerns associated with the above sources include: Heavy metals, PAHs, VOCs PCBs and Asbestos

3.11.3 The potential receptors have been identified previous in the desk study information and are given below:

Potential Receptors

- Development workers (dermal contact, inhalation, ingestion of soils and dusts).
- Future residential site users (dermal contact, inhalation, ingestion of soils and dust, consumption of produce from gardens).
- Off-site human health receptors and building structures/services (lateral migration of groundwater and ground gas).
- Controlled water receptors – groundwater (vertical migration to Secondary A Aquifer) and surface water (lateral migration of groundwater).
- Future building structures and services (direct contact with contaminated soils, ingress of ground gases into buildings, notably carbon dioxide, via voids and service entries).

3.11.4 The potential receptors have been identified previous in the desk study information and are given below:

Risk Assessment

- Direct contact/ingestion/inhalation of soil-bound contaminants and asbestos by construction workers, neighbouring site users, future site users and future maintenance workers. These are likely to be the dominant potentially complete pollutant linkages driving risks to human health from soil bound contamination in a future residential development.
- Inhalation of vapours associated with soil and/or groundwater contamination by construction workers, future residents and future maintenance workers.
- Inhalation and accumulation of hazardous ground gases associated with possible in-filled areas by construction workers, future residents and future maintenance workers.
- Migration of contaminants into surface water and underlying aquifers (including preferential pathways associated with on-site structures and services).
- Direct contact between contamination in soil / groundwater and future below ground services and structures.

3.12 Client Information

3.12.1 Information was provided to Enzygo Geoenvironmental Ltd in the form of one ground investigation report, a supplementary gas risk assessment and foundation plan and supplementary investigation. Copies of these reports are given in the Appendix 1.

3.12.2 Desk study information was supplied in the initial report and from a previously reviewed WSP report referenced (70027704-10579(1) and dated 2016. A copy of this report has not been supplied however pertinent information from the subsequent ground investigation report is given above.

3.12.3 The previous reports are summarised in Section 4.0:

4.0 PRELIMINARY GROUND INVESTIGATIONS

4.1 General

4.1.1 A preliminary ground investigation was undertaken by Groundtech during January 2020 which included a review of the unseen WSP desk study. A gas risk assessment and foundations assessment were also taken in January and March 2020 by the same company. A secondary spillage investigation was undertaken by Xplore in March 2024. Pertinent information for each investigation is provided in the sections below:

4.2 Site Works

4.2.1 The preliminary ground investigation was undertaken in January 2020th and comprised:

- 13 window sample boreholes and
- 9 Trial Pits;
- Installation of monitoring wells in 10 window sampler boreholes;
- Groundwater sampling visit. Gas monitoring is reported in the subsequent gas risk assessment.

4.2.2 Some areas of the site were not accessible at the time of the investigation.

4.2.3 Locations of the exploratory holes advanced by Xplore and Groundtech are included on the Site Plan presented as Drawing CRM.1027.189.GE.D.001.

4.3 Laboratory Testing.

4.3.1 Twenty five samples were tested for standard contamination suite.

4.3.2 Six groundwater/leachate samples were tested.

4.3.3 Geotechnical testing was undertaken.

4.4 Ground and Groundwater Conditions

4.4.1 Ground conditions encountered during the preliminary investigation by Xplore and Groundtech are summarised on the table below:

Table 4.4.1 Ground and Groundwater Conditions

Strata	Summary Description	Depth range (m)
Made Ground	Concrete (reinforced and hard) 0.15 to 0.2m thick	0.15 to 0.2
	Brown clayey topsoil with brick and rare ash from Ground Level to 0.90m bgl (WS01, WS21, WS23, WS24, TP01, TP02 and TP03).	0.0 to 0.9
	Light brown gravelly sand with brick from 0.15m to 1.2m bgl (WS02 to WS08, WS10, WS12 to WS15, WS18 to WS20, WS25 to WS30).	0.15 to 1.2
	Dark brown/black sand and gravel with ash from 0.18m to 1.75m bgl (WS02, WS11, WS16 and WS18).	0.18 to 1.75
	Soft to firm grey brown clay with brick from 0.2m to 1.4m bgl (WS03, WS05, WS09, WS14 and WS23).	0.2 to 1.4
Alluvium	Soft to firm Clay, interbedded with soft Silt and loose to medium dense Sand.	0.2 to 4.45
Glacial Fluvial materials	Medium dense to dense Sand and Gravel	0.6 to 2.45
Lowestoft Formation	firm to stiff Clay with gravel of chalk.	0.35 to 5.45
Groundwater.	Seepages from 1.00mbgl to 3.45mbgl	

4.5 Visual and Olfactory Evidence of Contamination

4.5.1 Ash was noted as a minor constituent of the Made Ground in eleven locations across the site. Furthermore a moderate hydrocarbon odour was noted within WS09, WS10 and WS11 in the vicinity of a former diesel Underground Storage Tank (UST).

4.6 Contamination Testing

4.6.1 Results of the soil testing were compared with GAC values for residential use with plant up-take. These showed exceedances of GAC values for Asbestos in 5 samples with a maximum quantification of 0.002%, various PAHs and TPH in 4 samples 25 samples tested.

4.6.2 Results of the ground water analysis were compared to freshwater EQS as the receptor is considered to be the adjacent River Oughton. Exceedances were recorded for Benzo(a)pyrene and TPH (C₈-C₃₅ Aromatic and aliphatic) in a maximum of 2 samples (former WS09, and WS17). Further analysis of these samples indicates that the source of the TPH is the degraded diesel and although the source has been removed the likely source is the previous UST based on the original plume from this former UST. The remaining minor exceedances have attributed to the ash within the Made Ground soils. The previous investigation for VOCs has been undertaken and the latest set of testing included VOCs and PCBS

4.6.3 Given the recorded TPH plume in WS09 close to the river surface water samples were recommended to be collected.

4.6.4 Given that TPHs and PAHs have been recorded an additional window sampling exercise was undertaken around the previous source (removed UST). Chemical analysis was undertaken from the soils and groundwater and from 5 boreholes surrounding the former tank positions. Faint hydrocarbons were noted between 0.5mbgl and 1.50mbgl. No soil exceedances were encountered and no WHO guideline exceedances were encountered for the groundwater. In addition no vapour exceedances were encountered. Based on the above no further risk to human health, surface water and controlled waters was encountered. The results of this exercise are documented in the Xplore supplementary report given in Appendix 1.

4.6.5 Ground gas monitoring identified from the limited testing (one round) has concluded that no gas protection measures are required and no radon protection measures are required. As part

of an additional gas risk assessment including 6 rounds of monitoring were undertaken with a maximum contraction of Carbon Dioxide of 1.8% vol. and no Methane recorded and no recorded significant flows which are not considered to be outliers associated with the groundwater suction. Based on the above the GSV has been calculated less than 0.07 and therefore no gas protection measures are required.

4.6.6 Ground gas results are consistent with what would be expected for natural Alluvium.

4.7 Foundation Assessment

As part of the investigation and geotechnical insitu testing and geotechnical testing a foundation options included traditional foundations across the northern part of the site and piled foundations around the river and the southern part of the site. Similarly, given the thickness of the Made Ground suspended floor slabs were recommended and the sulphate classification for the concrete should be designed in accordance with ACEC-2 and DS2.

5.0 PRELIMINARY ASSESSMENT

5.1 Preliminary Conceptual Model

5.1.1 Based on the information obtained the following Preliminary Conceptual Model has been prepared:

Table 5.1.1 Preliminary Conceptual Model

Source	Location	Exposure Pathway	Potential Receptor	Probability of Exposure	Details
Human Health					
PAH and hydrocarbons. And VOCs and PCBs	Made Ground	Ingestion dermal and inhalation.	Construction Workers.	Dismissed.	Normal construction practices and PPE will address risk.
			Site users.	Low	Contamination identified and remediation can be incorporated into the development NO VOC or PCB encountered previously.
			Off-site receptors	Dismissed	No significant mobile contaminants identified which may impact off-site users.
Asbestos, metals and hydrocarbons.	Unforeseen Contamination.	Ingestion dermal and inhalation.	Construction Workers.	Dismissed.	Normal construction practices and PPE will address risk.
			Site users.	Very Low.	Significant unforeseen contamination unlikely and remediation can easily be incorporated into the development.
			Off-site receptors	Dismissed	No significant mobile contaminants identified which may impact off-site users.
Asbestos	Identified asbestos below ground	Ingestion dermal and inhalation	Construction Workers.	Low	Quantification analysis has been undertaken for waste classification and appropriate control measures will mitigate risk to construction workers in these areas.
			Site users.	Dismissed	Areas not remediated and validated will be covered with 600m of clean cover or hardstanding which will break the pollutant linkage and therefore mitigating risk.
	Known asbestos above ground	Ingestion dermal and inhalation	Construction Workers.	Dismissed.	Further detailed assessment has identified all the above ground asbestos, and this has been registered and will require controlled removal.
			Site users.	Dismissed	Final development will remove any above ground asbestos via validation or cover therefore mitigating risk.
TPH (around the former tank)	Fuel spillages and plume	Ingestion dermal and inhalation	Construction Workers.	Dismissed.	Appropriate PPE to be worn within the TPH plume area around the former UST. Further detailed assessment has dismissed risk to construction workers.
			Site users.	Dismissed.	Further detailed assessment has dismissed risk.
Hydrocarbon and metals.	Migration from off-site sources.	Ingestion dermal and inhalation.	Construction Workers.	Dismissed.	No significant additional sources identified.
			Site users.		
Ground Gas.	Landfill.	Inhalation & Explosive.	Construction Workers.	Dismissed	No source
			Site users.	Dismissed	
			Off-site receptors	Very Low	
	Made Ground.	Inhalation & Explosive.	Construction Workers.	Dismissed	No confined space entry anticipated.
			Site users.	Dismissed	CS1 conditions identified no gas protection measures required.
			Off-site receptors	Very Low	Low permeability clay soils below landfill a shallow groundwater.

Source	Location	Exposure Pathway	Potential Receptor	Probability of Exposure	Details
Radon	Ground conditions	Inhalation & Explosive.	Site users.	Dismissed	No radon protection required based on previous desk study however recent records from the UK radon maps indicate between 1% and 3% of properties required radon protection measures which will result in Basic radon protection measures required. To be clarified in Remediation strategy.
Groundwater					
Hydrocarbon	Plume from former tanks	Vertical Migration	Groundwater.	Dismissed	Additional investigation dismissed risk to ground water and surface water from the UST plume
Hydrocarbon and metals.	Made Ground across the site.	Vertical Migration.	Groundwater.	Dismissed.	Secondary A aquifer in connectively with river. (No exceedances encountered above EQS guidelines apart from localised ash and the identified plume which has been dismissed previously
Hydrocarbon and metals.	Natural soils.	Vertical Migration.	Groundwater.	Very low	No deep water anticipated to be in contact with the Made ground and therefore limited risk. Further investigation and deep boreholes installations should be monitored to confirm.
Surface Water					
Hydrocarbon and metals.	Unforeseen Contamination.	Horizontal Migration.	River Network.	Low.	Elevated contaminants in Groundwater next and soils next to the river associated with plume could impact water course. Alluvium is considered a pathway rather than a receptor.
Environmental Receptors					
Asbestos, metals and hydrocarbons and ground gas		Direct.	Archaeology.	Dismissed.	None present.
		Direct.	Geology.	Dismissed.	None present.
		Phytotoxic.	Woodland.	Very Low.	Some trees are present on site.
		Phytotoxic.	Crops.	Dismissed.	None present.
		Ingestion dermal and inhalation.	Livestock.	Dismissed.	No receptor.
Building Services					
On site contaminants		Direct.	Historic Buildings.	Dismissed.	No receptors.
		Direct.	Proposed Buildings.	Very High	Proposed buildings
		Permeate into pipework.	Water Pipes.	Very Low.	Requirements of Water Authority to be followed.

6.0 SUPPLEMENTARY SITE INVESTIGATION

6.1 General

- 6.1.1 A supplementary site investigation was undertaken by Enzygo Geoenvironmental Limited between 18th July and 24th July 2024 and comprised fifteen window sample boreholes (WS101 to WS115) and four cable percussive boreholes (BH1 to BH4) to depths of between 20m
- 6.1.2 Locations of exploratory holes advanced by Enzygo Geoenvironmental Limited are presented on Drawing CRM.1027.189.GE.D.001. Locations were designed to provide coverage of the site and also supplement to the previous ground investigation locations and confirm the foundations requirements in relation to the extent of traditional footings and piled foundations.
- 6.1.3 Locations of each of the exploratory holes was scanned for services prior to drilling.

6.2 Site Works

- 6.2.1 Representative soil samples were collected for chemical and geotechnical testing. Soil samples destined for chemical analysis were collected in appropriate containers provided by the analytical laboratory. Samples were stored in cool boxes prior to dispatch to the laboratory for analysis. All samples were collected using appropriate sampling equipment that was cleaned at each sampling location.
- 6.2.2 Generally, soil samples were collected from Made Ground which is likely to be the source of potential contamination. In addition, any soils showing visual or olfactory evidence of contamination were sampled for laboratory testing.
- 6.2.3 Groundwater samples were collected from the standpipes and using slow flow techniques.
- 6.2.4 Surface water samples were collected from the river.

6.3 Laboratory Testing

- 6.3.1 Soil samples for chemical analysis were sent to I2 Ltd who are UKAS and MCERTS accredited. Samples were tested for the CLEA metal suite, pH, sulphate, cyanide, phenols, speciated Polycyclic Aromatic Hydrocarbons (PAH), organic carbon, Total Petroleum Hydrocarbon (TPH), VOC analysis and PCB analysis and asbestos.
- 6.3.2 Groundwater samples were also sent to I2 Ltd who are UKAS and MCERTS accredited. Samples were tested for the EQS suite together with attenuation properties analysis and alkalinity.
- 6.3.3 Two stage Waste Acceptance Criteria (WAC) tests were undertaken to assist with waste classification.
- 6.3.4 Result of the chemical testing is included in Appendix 3 and discussed in Section 8.
- 6.3.5 Geotechnical samples were sent to the laboratories of I2 Ltd who are UKAS and MCERTS accredited and were tested for:
- Laboratory California Bearing Ratio (CBR) testing;
 - Plasticity testing;
 - Particle size distribution Tests (PSD)

- Particle Density
- pH and sulphate.

6.4 Monitoring

- 6.4.1 Groundwater monitoring installations were placed within the cable percussive boreholes and window sample boreholes (10 number in total). The response zone was installed within the sand and gravel which underlies the Made Ground. A solid section of pipe was installed through the Made Ground and this was sealed using a cement/bentonite seal at the top of the gravels, extending into the overlying clay soils. The boreholes were installed to prevent the gravel pack forming a potential preferential pathway and also to allow discrete groundwater samples to be collected from the sand and gravel. In addition some of the installations were installed specifically in the Made ground and sealed when in the natural materials to specifically target any plume within the Made ground.
- 6.4.2 Groundwater and gas monitoring wells were installed within the window sampler holes and cable percussion boreholes. Monitoring wells were installed within the Made Ground and the natural materials. Where the window sampler boreholes were advanced into the underlying natural soils the lower 1m was sealed using a concrete/bentonite seal.
- 6.4.3 Groundwater and ground gas monitoring was undertaken. Groundwater samples were collected using low flow sampling methods.
- 6.4.4 During one of the visits potential Volatile Organic Compounds (VOC) were measured from window sampler installations using a Photo Ionization Detector (PID). The potential for Light Non-Aqueous Phase Liquid (LNAPL) was measured using a bailer. No sheens were encountered.

7.0 GROUND AND GROUNDWATER CONDITIONS

7.1 Summary of Ground and Groundwater Conditions

7.1.1 Ground and groundwater conditions have been assessed by Enzygo Geoenvironmental Limited from the various site investigations. The investigation undertaken identify the following strata:

Table 7.1.1 Ground and Groundwater Conditions

Strata	Summary Description	Thickness (m)
Made Ground	Concrete (0.14m to 0.48m thick) or Macadam (0.05m thick) locally over ballast/type one/crushed brick and concrete (subbase materials) (0.15 to 0.40m thick)	0.15 to 0.8
	Brown clayey gravelly SAND. Gravel is angular to rounded fine to coarse flint and concrete. Or firm brown slightly gravelly sandy CLAY. Gravel is subangular to rounded fine to coarse brick and concrete.	0.15 to 0.30
Deeper Made Ground	Brown slightly gravelly clayey medium SAND. Gravel is angular to subangular concrete and flint. Or soft brown sandy gravelly CLAY.	1.75 to 2.25
Made Ground - Soft landscaping areas.	Grass over brown slightly gravelly clayey medium SAND. Gravel is angular to subangular concrete and flint	2.00
Alluvium	Very soft greyish brown clayey gravelly SILT (WS109)	+6.0
	Very soft and soft locally firm with depth dark grey and brown slightly sandy slightly gravelly silty CLAY. Sand is fine to coarse. Gravel is angular and rounded fine to coarse flint.	1.1 to 5.0
	Medium dense locally dense with depth orange brown clayey gravelly SAND. Gravel is angular and rounded fine to coarse flint.	0.4 to 1.2
Glacio Fluvial materials (WS110, WS112, 114, WS115)	Medium dense to dense orange brown clayey sandy GRAVEL. Sand is medium to coarse. Gravel is angular and rounded fine to coarse flint.	0.7 to +1.0
Lowestoft formation	Firm becoming stiff and very stiff dark grey slightly sandy slightly gravelly silty CLAY. Sand is fine to coarse. Gravel is angular to subangular and subrounded fine to coarse chalk and flint.	>23
Groundwater.	Shallow Seepages.	1.4mbgl to 3.0m bgl
	Deep seepage	13.5m bgl to 14.1mbgl

7.1.2 The above ground conditions are consistent with the previous investigations.

7.1.3 Details of the ground and groundwater conditions encountered are given on the exploratory hole records included in Appendix 2 and are summarised in the sections below:

7.2 Made Ground

7.2.1 Across most of the site was a layer of Made Ground either in soft landscaping areas of concrete hardstanding.

7.2.2 Within soft landscaping the Made Ground comprised grass over brown slightly gravelly clayey medium sand. Gravel is angular to subangular concrete and flint. Generally this was between 0.6m and 2.0m thick, but was locally absent in areas of hardstanding which covers the majority of the site.

7.2.3 Within hard landscaping the Made Ground generally comprised a layer of either concrete (reinforced locally) or macadam 0.14m to 0.48m thick. These materials were general underlain

by ballast/type one/crushed brick and concrete (subbase materials) which were generally 0.15m to 0.40m thick.

- 7.2.4 Below the sub base materials general Made Ground was encountered and this comprised brown clayey gravelly sand. Gravel is angular to rounded fine to coarse flint and concrete. This was locally replaced by firm brown slightly gravelly sandy clay. Gravel is subangular to rounded fine to coarse brick and concrete. These materials were noted to range in thickness from 0.1m to 0.30m thick.
- 7.2.5 Within Boreholes WS106, WS107 and BH04 deeper Made Ground was encountered to a maximum depth of 2.75mbgl in BH04. These materials generally comprised brown slightly gravelly clayey medium sand. Gravel is angular to subangular concrete and flint. Or soft brown sandy gravelly clay.
- 7.2.6 No fuel related odours were noted during drilling.
- 7.2.7 Based on the above deeper Made Ground was noted in the south west of the development site close to the river.
- 7.2.8 The deep Made Ground/backfill materials for the pond and the mill race to the west of the site have been proved in in Boreholes WS106, WS107 and WS108 and are backfilled with deep Made Ground up to 2.80m thick. In Boreholes WS109 the deep Made Ground has been replaced with silt to in excess of 6.00mbgl. Other areas of Deep Made Ground are located in Borehole BH04 adjacent to the river (2.75m thick).

7.3 Alluvium

- 7.3.1 Generally the Alluvium comprised 2 layers of materials, however when the underlying materials are cohesive with no interbedded glacio fluvial materials the base of the Alluvium grades into the Lowestoft Formation with only a slight variation on colour to make any noticeable change (orange and brown to grey and dark grey).
- 7.3.2 Where disguisable from the underlying Lowestoft Formation the cohesive Alluvium comprised very soft and soft locally firm with depth orange brown and dark grey and brown slightly sandy slightly gravelly silty clay. Sand is fine to coarse. Gravel is angular and rounded fine to coarse flint. And very soft orangish greyish brown clayey gravelly silt (Borehole WS109). These materials were generally between 1.00m and 6.00m thick.
- 7.3.3 The granular alluvium comprised medium dense locally dense with depth orange brown clayey gravelly sand. Gravel is angular and rounded fine to coarse flint and were generally 0.4 to 1.2m thick.

7.4 Glacio Fluvial Materials

- 7.4.1 The Glacio Fluvial Materials generally comprised medium dense to dense orange brown clayey sandy gravel. Sand is medium to coarse. Gravel is angular and rounded fine to coarse flint and were in excess of 1.00m thick.

7.5 Lowestoft Formation

- 7.5.1 The Lowestoft Formation materials generally comprised firm becoming stiff and very stiff dark grey slightly sandy slightly gravelly silty clay. Sand is fine to coarse. Gravel is angular to subangular and subrounded fine to coarse chalk and flint and were in excess of 22m thick.

7.6 Soil Strength

- 7.6.1 Undrained shear strength of cohesive soils were calculated using the correlations of Stroud and Butler. These show the undrained shear strength values of the Alluvium to vary from 4kN/m² to 103kN/m² with a lower quartile value of 27kN/m².
- 7.6.2 The granular Alluvium is loose to medium dense with SPT values carrying from 4 to 11.
- 7.6.3 The granular Glacio fluvial Materials are very dense with SPT n values in excess of 50.
- 7.6.4 Undrained shear strength of the Lowestoft Formation increases from 35kN/m² at 4m bgl to over 490kN/m² at 20m bgl with lower quartile value of 100kN/m².
- 7.6.5 Made Ground is shown to be soft and loose to medium dense.
- 7.6.6 A shear strength verses depth plot is given in Appendix 2.

7.7 Visual and Olfactory Evidence of Contamination

- 7.7.1 No significant visual or olfactory evidence of contamination was encountered in this investigation, however previous investigations have identified faint hydrocarbons odours around the former tanks position, however these have been further analysed and the risk to human health, controlled waters and surface waters has been dismissed.

7.8 Groundwater

- 7.8.1 Groundwater was encountered as seepages at depth of between 1.4 to 3.00mbgl and 13.5 to 14.1mbgl. The depth to groundwater measured during the monitoring visit is summarised in the table below:

Table 7.8.1 Groundwater Depths

Exploratory Hole	Installation depth	Seepage depth drilling	Response zone		Depth (mbgl)		
		M bgl	Within materials	Depth (mbgl)	31.07.24	06.08.24	13.08.24
WS101	Shallow	3	Alluvium	2-5	1.22	1.15	1.3
WS103	Shallow	3	Alluvium	2-5	0.45	0.38	0.48
WS105	Shallow	3	Alluvium	2-5	0.66	0.58	0.76
WS107	Shallow	3	Made Ground	2-3	0.51	0.69	0.92
WS109	Shallow	3	(silt, backfilled pond, mill race)	2-4	1.17	1.1	1.28
WS110	Shallow	3	Alluvium	2-4	0.9	0.9	1.1
WS111	Shallow	3	Alluvium	2-4	0.71	0.6	0.94
BH01	Deep	13.5	Lowestoft clay	14-17m	1.4	1.2	1.43
BH03	Deep	2.2	Lowestoft clay	17-20m	0.7	1.09	0.85
BH04	deep	15	Lowestoft clay	17-20m	1.31	0.7	1.37

- 7.8.2 No LNAPL was detected during the monitoring.
- 7.8.3 Groundwater flow and hydraulic gradient have been assessed from the groundwater monitoring undertaken. The general pattern for the groundwater is flow to the south and towards the river.

7.8.4 Rising head permeability tests were not undertaken as the groundwater levels are very high, however as part of the DQRA assessment the permeability tests should be undertaken as constant head tests from the installations.

7.9 Ground Gas

7.9.1 Ground gas was monitored during the return visit to monitor groundwater levels and the results are summarised on the table below:

Table 7.9.1 Gas Monitoring Results

Exploratory Hole	Atmos pressure (Mb)	Flow (l/hr)	CH4		CO2		O2
			Concentration (%)	GSV (l/hr)	Concentration (%)	GSV (l/hr)	Concentration (%)
31.07.24							
WS101	1008 (F)	<0.1	<0.1	<0.0001	<0.2	<0.0002	19.3
WS103	1007 (F)	<0.1	<0.1	<0.0001	<0.1	<0.0001	19.4
WS105	1007 (F)	<0.1	<0.1	<0.0001	<0.2	<0.0002	19.2
WS107	1003 (F)	<0.1	<0.1	<0.0001	4.5	<0.0046	18.9
WS109	1004 (F)	<0.1	<0.1	<0.0001	<0.3	<0.0003	18.3
WS110	1004 (F)	<0.1	<0.1	<0.0001	<0.4	<0.0004	19.5
WS111	1004 (F)	<0.1	<0.1	<0.0001	<0.2	<0.0002	19.1
BH01	1006 (F)	<0.1	<0.1	<0.0001	<0.1	<0.0001	19.3
BH03	1004 (F)	<0.1	1.5	<0.0015	<0.8	<0.0008	15.5
BH04	1004 (F)	<0.1	<0.1	<0.0001	<0.2	<0.0002	18.4
06.08.24							
WS101	1001 (R)	<0.1	<0.1	<0.0001	<0.1	<0.0001	20.7
WS103	1001 (R)	<0.1	<0.2	<0.0002	<0.1	<0.0001	20.6
WS105	1001 (R)	<0.1	<0.1	<0.0001	<0.1	<0.0001	20.8
WS107	1001 (R)	<0.1	<0.1	<0.0001	4.2	<0.0046	17.3
WS109	1002 (R)	<0.1	<0.1	<0.0001	4.6	<0.0046	16.9
WS110	1001 (R)	<0.1	<0.1	<0.0001	<0.4	<0.0004	17.6
WS111	1001 (R)	<0.1	<0.1	<0.0001	<0.1	<0.0001	20.9
BH01	1000 (R)	<0.1	<0.1	<0.0001	<0.1	<0.0001	20.7
BH03	1002 (R)	<0.1	<0.1	<0.0001	<0.1	<0.0001	20.9
BH04	1001 (R)	<0.1	<0.1	<0.0001	<0.1	<0.0001	20.9
13.08.24							
WS101	1000 (F)	<0.1	<0.1	<0.0001	<0.1	<0.0001	19.4
WS103	1000 (F)	<0.1	<0.1	<0.0001	<0.1	<0.0001	19.4
WS105	999 (F)	<0.1	<0.1	<0.0001	<0.1	<0.0001	19.4
WS107	997 (F)	<0.1	14.0	0.0014	<0.2	0.0002	15.7
WS109	997 (F)	<0.1	<0.1	<0.0001	<1.9	<0.0019	18.0
WS110	998 (F)	<0.1	<0.1	<0.0001	<0.5	<0.0005	19.1
WS111	996 (F)	<0.1	<0.1	<0.0001	<0.1	<0.0001	19.8
BH01	1000 (F)	<0.1	<0.1	<0.0001	<0.1	<0.0001	19.3
BH03	1000 (F)	<0.1	<0.1	<0.0001	<0.1	<0.0001	19.4
BH04	1004 (F)	<0.1	<0.1	<0.0001	<0.3	<0.0003	19.1

8.0 CONTAMINATION ASSESSMENT

8.1 General

8.1.1 A Tier I risk assessment has been undertaken using available and current screening values for a residential end use. The risk assessment is undertaken based on the findings of the ground investigation undertaken by Enzygo Geoenvironmental Ltd and Groundtech and Xplore. Based on the contamination testing and Tier I assessment a Conceptual Model has been prepared, which is presented later in this section.

8.1.2 Where significant risks are identified remedial measures are recommended.

8.2 Human Health

8.2.1 Assessment of the risks to human health has been undertaken by comparing the soil quality data with reference values obtained from the Contaminated Land Exposure Assessment (CLEA), Soil Guideline Values (SGV) and General Acceptance Criteria (GAC) published by LQM/CIEH. The LQM/CIEH S4ULs values are used and summary tables of the reference values are included in Appendix 5.

8.2.2 Where an exceedance is identified the risk is assessed by considering the sensitivity of the proposed development and the potential pathway. The proposed development is for residential use and therefore the GAC values for Residential Use with plant uptake are considered suitable for an initial screening assessment.

8.2.3 Results of the chemical testing from the Enzygo Geoenvironmental Ltd investigation are included in Appendix 3.

8.2.4 Results of the chemical testing undertaken show exceedance of GAC values in samples of Made Ground across the site from Asbestos, PAH, TPH. Exceedances were recorded in recorded in the Made Ground and deep Made Ground in the vicinity of Borehole WS107 0.40m bgl and , 0.65m bgl and 1.90m bgl.

8.2.5 The exceedances are tabulated below.

Exploratory Hole	Determinant	Concentration (mg/kg)	
		Soil	GAC
WS107 (0.65mbgl)	TPH (c10-c12)	130	74
WS107 (0.65mbgl)	TPH (c12-c16)	550	140
WS107 (0.65mbgl)	TPH (c16-c21)	1500	250
WS107 (1.90mbgl)	Asbestos (amosite fibres)	confirmed	presence
WS103 (0.40mbgl)	Dibenz(a,h)anthracene	0.29	0.24
WS103A (0.70mbgl)	Dibenz(a,h)anthracene	0.26	0.24
BH01 (0.3-0.7mbgl)	Benzo(a)pyrene	14	2.2
BH01 (0.3-0.7mbgl)	Benzo(b)fluoranthene	19	2.6
BH01 (0.3-0.7mbgl)	Benzo(a)anthracene	16	7.2
BH01 (0.3-0.7mbgl)	Chrysene	17	15
BH04 (0.3-0.5mbgl)	TPH (c16-C21)	440	260

8.2.6 Asbestos was identified in one sample from Borehole WS107 at 1.90m bgl within the Made Ground which ranged in thickness from 1.60m to 2.80mbgl at this location.

8.2.7 An assessment of the TPH and PAH results has not identified any concentrations exceeding the threshold for indoor inhalation pathway only.

8.3 Controlled Waters

- 8.3.1 Where groundwater samples have been analysed the results are compared against reference values. These reference values are summarised in Appendix 5 and are taken from Fresh Water Environmental Quality Standards (EQS), UK Drinking Water Standards and World Health Organisation (WHO) values for Drinking Water. Where the controlled waters receptor is a surface water course then the EQS are used as the primary reference value. Drinking Water Standards and WHO values are used where EQS values are not available. An assessment of likely risk is then made based on a source-pathway-receptor model. Where the receptor is potable groundwater resources the Drinking Water Standards and WHO values are used.
- 8.3.2 It is considered that the receptor is the river ? in the centre of the site. It is considered that the alluvial materials present beneath the site are providing a pathway to the surface water receptor.
- 8.3.3 Groundwater analysis has therefore been compared against Freshwater EQS values and the following exceedances were recorded:

Table 8.3.3 EQS Exceedances

Exploratory Hole	Determinant	Concentration (ug/l)	
		Groundwater	EQS
WS107 (1.72mbgl)	Flouranthene	0.67	0.02

- 8.3.4 Exceedances are similar to those identified by previous report. This indicates that the local materials round the former mill pond (which have been infilled with Made ground to a depth of 2.80mbgl) are in hydraulic continuity with the surrounding materials and potentially the river. Based on the results it would appear that the TPH recorded in the same location is not fully leaching out into the river however is partially contained within this area. The same conclusions were drawn from the previous spillage report which indicated that the fuel related materials were confined in close proximity of the former tanks which is located to the north east of boreholes WS107.
- 8.3.5 In order to confirm the above conclusions it is recommended that a Detailed Quantitative Risk Assessment (DQRA) is undertaken to assess potential impacts on the Weirs Mill Stream.

8.4 Ground Gas

- 8.4.1 For the assessment of risk from ground gas reference has been made to CIRIA C665 and British Standard BS8485 Code of Practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings. Where significant potential risk from ground gas is identified from the Initial Conceptual Model and the ground gas monitoring is undertaken and the results of the monitoring are compared against the Gas Screening Values given in CIRIA Report 665. From this the Characteristic Situation is identified and remedial measures proposed.
- 8.4.2 When assessing the risk and type of remedial measures appropriate consideration is given to the likely construction of the development, the nature of the gas posing a risk and the nature of the likely source. The use of engineering judgement when determining risk from ground gas is consistent with the recommendations given in CIRIA C665 using a pollutant linkage model.
- 8.4.3 Gas monitoring was undertaken during return visits which has recorded elevated concentrations of Methane and Carbon dioxide and high flows however this was recorded were the pump failed due the water suction into the monitoring instrument. As a result this is not considered representative of the gas regime of the site. Based on this and the previous

investigation recommendations Gas Screening Value falls within Characteristic Situation 1 (CS1) which requires no gas protection measures.

8.5 Conceptual Model

8.5.1 A Conceptual Model is presented below based on the findings of the ground investigation.

Table 8.5.1 Conceptual Model

Source	Location	Exposure Pathway	Potential Receptor	Probability of Exposure	Details
Human Health					
PCB	Made Ground	Ingestion dermal and inhalation.	Construction Workers.	Dismissed.	No exceedances.
			Site users and off-site Receptors		
VOC	Made Ground	Ingestion dermal and inhalation.	Construction Workers.	Dismissed.	No exceedances.
			Site users and off-site Receptors		
PAH and hydrocarbons.	Made Ground	Ingestion dermal and inhalation.	Construction Workers.	Dismissed.	Normal construction practices and PPE will address risk.
			Site users.	Low	Contamination identified. GAC exceedance remediation recommended can be incorporated into the development.
			Off-site receptors	Dismissed	No significant mobile contaminants identified which may impact off-site users. DQRA recommended to provide remediation criteria.
Metals and hydrocarbons.	Unforeseen Contamination.	Ingestion dermal and inhalation.	Construction Workers.	Dismissed.	Normal construction practices and PPE will address risk.
			Site users.	Very Low.	Significant unforeseen contamination unlikely and remediation can easily be incorporated into the development.
			Off-site receptors	Dismissed	No significant mobile contaminants identified which may impact off-site users.
Asbestos	Identified asbestos below ground	Ingestion dermal and inhalation	Construction Workers.	Low	Quantification analysis has been undertaken for waste classification and appropriate control measures will mitigate risk to construction workers in these areas.
			Site users.	Dismissed	Areas not remediated and validated will be covered with 600mm of clean cover or hardstanding which will break the pollutant linkage and therefore mitigating risk.
	Known asbestos above ground	Ingestion dermal and inhalation	Construction Workers.	Dismissed.	Further detailed assessment has identified all the above ground asbestos, and this has been registered and will require controlled removal prior to development.
			Site users.	Dismissed	Final development will remove any above ground asbestos via validation or cover therefore mitigating risk.
TPH (around the former tank)	Fuel spillages and plume	Ingestion dermal and inhalation	Construction Workers.	Dismissed.	Dismissed the risk previously.
			Site users.	Dismissed.	Further detailed assessment has dismissed risk.
Made Ground with backfilled Mill race and Mill Pond	Made Ground - Metal, asbestos and Hydrocarbons	Ingestion dermal and inhalation	Construction Workers.	Dismissed.	Appropriate PPE to be worn when accessing materials below 0.60m depth as these materials are covered with clean inert materials 0.60m thick. Potential pathway generated with pile installation. Pile risk assessment recommended.
			Site users.	Dismissed.	Materials will be covered by 600m of clean cover no future access to these materials. Potential pathway generated with pile installation. Pile risk assessment recommended
Hydrocarbon and metals.	Migration from off-site sources.	Ingestion dermal and inhalation.	Construction Workers.	Dismissed.	No significant additional sources identified.
			Site users.		
Ground Gas.	Made Ground/Landfill.	Inhalation & Explosive.	Construction Workers.	Dismissed	No confined space entry anticipated.
			Site users.	Dismissed	CS1 conditions identified no gas protection measures required.

Source	Location	Exposure Pathway	Potential Receptor	Probability of Exposure	Details
			Off-site receptors	Very Low	Low permeability clay soils.
	Made Ground with backfilled Former Mill race and Pond	Inhalation & Explosive.	Construction Workers.	Low	Potential gas encountered. Gas bag analysis should be undertaken to clarify. In addition, a Pathway will be generated from pile installation therefore creating gas pathways through backfill materials. Pile risk assessment recommended.
			Site users.	Very Low	Potential gas generating materials CS2 conditions identified no gas protection measures required. Furthe gas bag analysis required for clarification.
			Off-site receptors	Very Low	Low permeability clay soils, however potential pathway to river through previous Mill race.
Radon	Ground conditions	Inhalation & Explosive.	Site users.	Very Low	As recommended in the previous desk study information no radon protection required, however 1% to 3% affected by radon based on the UK radon map. Further clarification recommended.
Groundwater					
Hydrocarbon	Plume from former tanks	Vertical Migration	Groundwater.	Low	Additional previous investigation dismissed risk to ground water and surface water from the UST plume. DQRA recommended to provide remediation criteria and confirm degradation over distance from the source to the receptor.
Hydrocarbon and metals.	Made Ground across the site.	Vertical Migration.	Groundwater.	Low	Secondary A aquifer in connectively with river. (One EQS exceedance in groundwater) localised ash and the identified plume which has been dismissed previously however DQRA recommended to provide remediation criteria and confirm degradation over distance from the source to the receptor.
Hydrocarbon and metals.	Natural soils.	Vertical Migration.	Groundwater.	Very low	No deep water anticipated to be in contact with the Made ground and therefore limited risk. DQRA recommended to confirm risk model.
Surface Water					
Hydrocarbon and metals.	Unforeseen Contamination.	Horizontal Migration.	River Network.	Low.	EQS exceedances in Groundwater next to river associated with plume and or backfilled Made ground within former pond and mill race. Mill race and Alluvium is considered a pathway and source. DQRA recommended.
Environmental Receptors					
Asbestos, metals and hydrocarbons and ground gas		Direct.	Archaeology.	Dismissed.	None present.
		Direct.	Geology.	Dismissed.	None present.
		Phytotoxic.	Woodland.	Very Low.	Some trees are present on site.
		Phytotoxic.	Crops.	Dismissed.	None present.
		Ingestion dermal and inhalation.	Livestock.	Dismissed.	No receptor.
Building Services					
On site contaminants		Direct.	Historic Buildings.	Dismissed.	No receptors.
		Direct.	Proposed Buildings.	Very High	Proposed buildings
		Permeate into pipework.	Water Pipes.	Very Low.	Requirements of Water Authority to be followed.

8.6 Assessment and Remediation

Proposed Development

8.6.1 The proposed development comprises residential use consisting of houses and apartments.

Contamination

- 8.6.2 Gross contamination has not been encountered however contamination has been identified within the general Made Ground and specially within the former backfilled pond and mill race. The Made ground is not considered suitable for re-use within soft landscape areas. Therefore remediation is proposed as part of the landscape works within soft landscape areas comprising 600mm of clean cover soils in domestic gardens and 400mm in communal gardens and areas of open space placed over a geotextile no dig barrier. The clean cover is to be validated.
- 8.6.3 Additional remediation is proposed to address the ground gas risk which is discussed in following section.
- 8.6.4 If unforeseen contamination is encountered during construction works such as localised spillage outside the areas investigated an Environmental consultant will be available on a 'call out' basis to undertake an assessment of risk. If 'unforeseen contamination' is encountered such as hydrocarbon contamination or solvent odours the discovery strategy will be to remove the source as it is likely to be very limited in extent or encapsulate it on site as appropriate and the Local Planning Authority advised.
- 8.6.5 A remediation method statement, detailing the remediation strategy that must be adopted will be required. The document should also detail requirements for verification to provide confirmation that suitable remediation has been undertaken that breaks all identified exposure pathways.

Management Procedures

- 8.6.6 Asbestos contaminated materials have been previously identified during the previous ground investigation and also confirmed in the supplementary investigation. It is therefore possible that further material could be encountered during construction works.
- 8.6.7 In addition, asbestos has also been encountered above ground within the buildings to be demolished and an approved register provided confirming that remediation and appropriate removal will be required prior to construction.
- 8.6.8 Buried asbestos has been encountered currently below 600mm of clean cover and therefore is currently protected from current site users. This does not apply to construction activities below the surface capping of 600mm.
- 8.6.9 Measures should be incorporated in to the Contractors Construction Stage Health and Safety Plan as required under the Construction Design and Management (CDM) Regulations to mitigate risk to construction works. Measures may include:
- Designing temporary works to minimise disturbance of the Back fill material;
 - Separating material and disposal of soils containing asbestos;
 - Wetting down during excavation;
 - Sheeting of stockpiles where asbestos is suspected;
 - Testing of soils and off-site disposal of any soils found or suspected of containing asbestos;
 - Preventing access to the construction site by members of the public;
 - Use of good hygiene measures, including washing down of plant; and

- Use of appropriate PPE, including face masks.

Ground Gas

8.6.10 Ground gas monitoring has identified that the site falls within CS1 condition with the exception of one elevated reading which is categorised as CS2 condition. It is recommended that gas bag analysis is undertaken as part of the remediation strategy and DQRA to confirm the methane and carbon dioxide from the Made Ground without being affected by groundwater suction.

8.6.11 The remaining current results and the previous set of gas monitoring (total 9 visits) have confirmed CS1 conditions which required no gas protection measures are required to be installed.

8.6.12 As a precaution, however, and after gas bag analysis or further assessment via a window sampling is undertaken to clarify the actual gas within the infilled Mill Race and pond (WS107,) it is recommended that within this area the characteristic situation is increased to CS2.

8.6.13 As detailed in BS8485 residential properties within this area and for CS2 conditions should achieve a minimum gas protection score of 3.5. It is proposed that gas protection measures are incorporated into the proposed structures comprising:

- Suspended floor slabs are used including a gas membrane sealed around service entry points and to the cavity tray; and
- Underfloor passive ventilation to suspended floor slabs achieving very good performance.
- All gas protection measures should be installed by a competent qualified contractor. Verification of the installation should also be undertaken

8.6.14 The CS2 conditions and gas protection measures are only recommended in the area of the former mill race and mill pond. Further detailed recommendations in relation to plot numbers will be recommended once a proposed layout has been finalised and this will be included in the remediation strategy.

8.6.15 No remediation of the ground water is expected however this will need to be confirmed by the DQRA. In addition, the DQRA will provide remediation criteria which can be used to validate any remediation areas.

8.7 Waste Classification

8.7.1 It is considered that the Made Ground will generally be classified as Stable Non-Reactive waste based on the chemical and WAC testing undertaken.

8.7.2 Final assessment will be undertaken by the receiving landfill based on the requirements of their permit.

9.0 GEOTECHNICAL ASSESSMENT

9.1 Proposed Development

9.1.1 The proposed development comprises residential use consisting of houses and apartments.

9.2 Ground Conditions

9.2.1 Ground conditions comprise Made Ground over soft and very soft alluvium clays and medium dense sands over glacio fluvial dense sand and gravels to the north of the site over Lowestoft Formaiton (Firm to stiff clays). Groundwater was recorded as two seepages (shallow seepage) between depths of between 1.4mbgl and 3.0mbgl and as a (deep seepage) at 15.00mbgl. Groundwater levels from the installations ranged from 0.38mbgl to 1.22mbgl for the shallow installations and 0.7mbgl to 1.43mbgl for the deep installations. There was no connectivity between the two seepages.

9.3 Preparation

9.3.1 The site is underlain by Made Ground including backfilling materials and is vegetated with trees and scrub vegetation together with concrete surfacing. During site preparation works the following should be undertaken:

- Removal or exiting vegetation and any root balls associated with existing trees should be grubbed out;
- Removal of the above ground asbestos within the buildings before these buildings are demolished using an appropriate licenced asbestos contractor and asbestos landfill.
- Removal of any obstructions identified including where appropriate concrete hardstanding and
- Removal of any redundant services.

9.4 Foundations

9.4.1 Traditional foundations are likely to be appropriate for the north of the site in the area of Boreholes WS113, WS114, WS115 and WS101 and BH01. At these locations the materials comprise either medium dense and dense sands or firm clays with an allowable bearing pressure of 100kN/m² and settlements less than 25mm. Given the potential variation in formation differential settlement may be expected and therefore reinforcement will be required. A foundation plan will be prepared as part of the remediation strategy.

9.4.2 In addition, if the formation is cohesive blinding will be required to protect the formation from strain softening. Should soft pockets be encountered at formation level during foundation excavation these should be removed and replaced with granular materials and proof rolled to differential settlement.

9.4.3 Trees have been encountered and the materials have been classified with a Plasticity index ranging from 20% to 22%, however once these have been modified to take account of the granular percentage within these materials the modified plasticity index ranges from 8% to 17%. An assessment of the soils modified plasticity index confirms that the Alluvium is either non plastic (medium dense sands) or of low volume change potential, depending on the clay content. It is therefore recommended that a Low volume change potential is used for all

foundations and all foundations are designed in accordance with Chapter 4.2 of NHBC Standards and specific with relation to the existing or proposed trees within this area.

9.4.4 For the remainder of the site and given the thickness of the Made Ground (backfilled pond and mill race materials) and soft alluvium and glacial fluvial materials piled foundations are recommended. For preliminary purposes and an initial pile assessment has been undertaken using the following assumptions:

- Upper 5 m is ignored due to the presence of Made Ground and soft clay.
- Soil properties have been taken from the ground investigation and laboratory testing.
- A global factor of safety of 3 has been used, together with factors of 1.5 on shaft resistance and 3 on base resistance.

9.4.5 The following preliminary pile working loads have been calculated:

Table 9.4.2 Preliminary Pile Loads

Pile depth (m bgl)	Working Load kN					
	200mm	250mm	300mm	350mm	450mm	600mm
10	75	100	120	150	215	320
15	200	270	330	400	550	750
20	380	500	600	700	1000	1300

9.4.6 Final design should be undertaken by a specialist piling contractor who can use case studies to negotiate more economic pile designs.

9.4.7 Given the nature of the site and the risk of foundations creating new pathways for gas and groundwater it is recommended that Continuous Flight Auger piling is used where possible. A detailed piling risk assessment is likely to be required.

9.4.8 An assessment of the soils modified plasticity index has been undertaken. This identifies that the Alluvium has a low to medium volume change potential. This identifies that the Lowestoft Clay has a low to medium volume change potential.

9.4.9 It is therefore recommended that a medium volume change potential is used for piled foundations in accordance with Chapter 4.2 of NHBC Standards.

9.4.10 Given the upper 5.00mbgl is being ignored due to soft and variable ground conditions any heave protection is considered to be minimal however consideration will need to be given to negative skin friction from the soft alluvial materials with SPT N values of 1 or less.

9.5 Floor Slab

9.5.1 Given the depth of Made Ground it is recommended that suspended floor slabs are used. Potential Gas protective measures are recommended in the area of the former mill race and pond. This will be clarified with further gas bag chemical analysis from the installations involves (WS107, WS108 and WS109) to confirm the presence of methane and carbon dioxide. Should gas protection measures these are outlined above in section 8.6.10 to 8.6.15 and will be confirmed in the remediation strategy.

9.6 Pavement Construction

- 9.6.1 It is recommended that an equilibrium CBR of 1% is used. Due to the potential for collapse and long term stability of the backfill materials (west of site -Boreholes WS107, WS108, WS109) it is likely that some form of ground improvement will be needed below areas of hardstanding.

9.7 Drainage

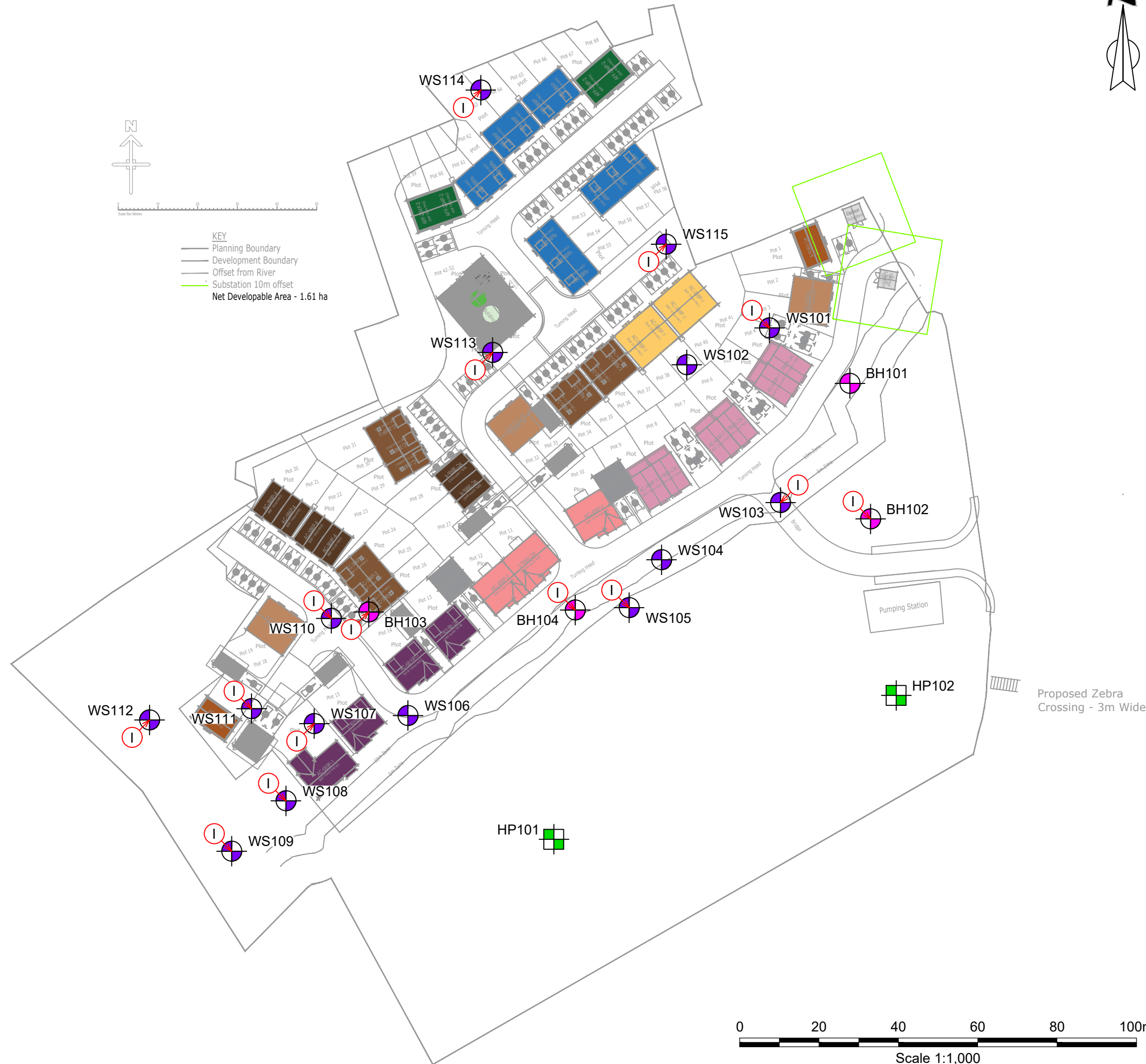
- 9.7.1 Soakaway drainage is not considered feasible due to the high groundwater levels and cohesive nature of the materials to the south of the site.
- 9.7.2 The report should be submitted to the Water Authority. Due to an elevated TPH value it is likely that barrier pipe may be needed.

9.8 Aggressive Soils

- 9.8.1 It is considered that buried concrete may be designed in accordance with ACEC Class AC-2s.

9.9 Excavation

- 9.9.1 Based on the various site observations it is considered that excavations should be feasible with normal plant. Assistance from a breaker will be required for excavation of obstructions encountered and previous foundations, tank bases and surface concrete. Potential backfilled interceptors have been encountered which will also require removal and validation.
- 9.9.2 Excavations where access is required should be supported in accordance with CIRIA RR97. Additional measures will also be required due to the risk from ground gas and asbestos which should be considered by the Principal Contractor.
- 9.9.3 Significant dewatering is unlikely to be required.



KEY:

Site Boundary

Window Sampler Borehole (WS01 - WS30)

Window Sampler Borehole (TP01 - TP03)

Window Sampler Borehole (WS101 - WS115)

Rotary Borehole (BH101 - BH104)

Trial Pit (TP101 - TP103)

Borehole Installation (WS111, 112, 113, 114, 115) 6m (WS101, 103, 105, 107, 108, 109, 110) 4-6m

NOTES:

DO NOT SCALE FROM THIS DRAWING

ALL DIMENSIONS ARE IN METRES UNLESS STATED OTHERWISE

THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT DRAWINGS AND DOCUMENTS ASSOCIATED WITH THIS PROJECT.

ALL EXISTING AND PROPOSED DIMENSIONS, LEVELS AND LOCATIONS TO BE CHECKED AND VERIFIED BY THE MAIN CONTRACTOR ON SITE PRIOR TO THE COMMENCEMENT OF THE WORKS AND ANY ANOMALIES REPORTED TO THE ENGINEER.

P02	16.07.24	Proposed Boreholes Added	LB	RH	RH
P01	16.07.24	Issued for comment / approval	LB	RH	RH
Rev	Date	Description	DRA	CHK	APP

Project

Ickleford Mill

Client

Hill Partnership Ltd

Drawing Title

Proposed - Borehole Location Plan - Site Layout

Scale 1:1,000 @ A3	Date 16.07.24	Status Preliminary
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DWG No.

CRM1027189-ENZ-XX-XX-DR-G-0001.1

Revision

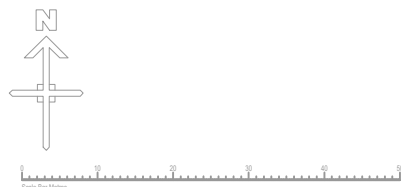
P02

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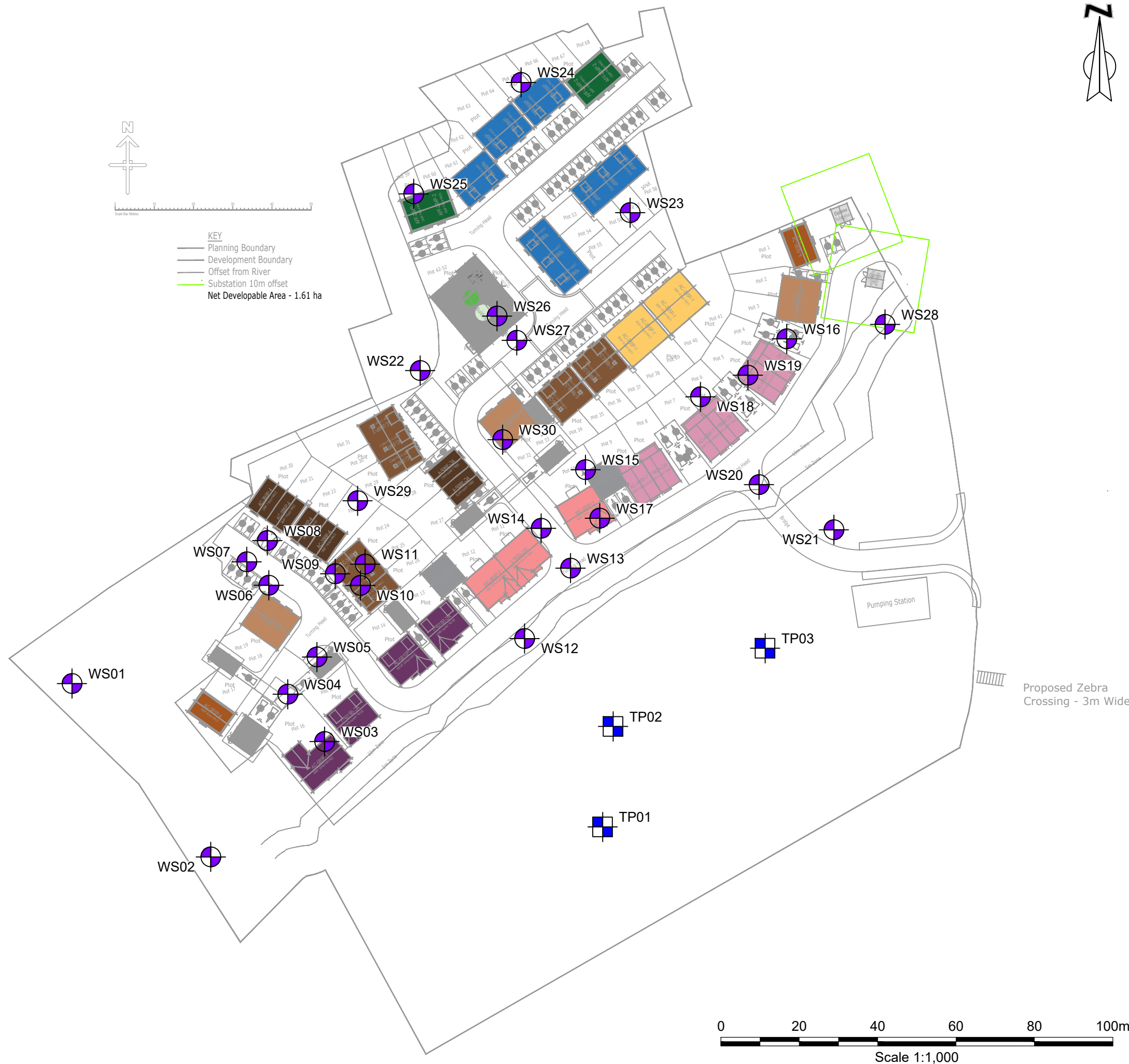
Cardiff02920 023 700Cambridge01799 542 473Belfast07377673948

enzygo

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- KEY
- Planning Boundary
 - Development Boundary
 - Offset from River
 - Substation 10m offset
 - Net Developable Area - 1.61 ha



KEY:

- Site Boundary
- Window Sampler Borehole (WS01 - WS30)
- Window Sampler Borehole (TP01 - TP03)
- Window Sampler Borehole (WS101 - WS115)
- Rotary Borehole (BH101 - BH104)
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AND ANY ANOMALIES REPORTED TO
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P02	16.07.24	Proposed Boreholes Added	LB	RH	RH
P01	16.07.24	Issued for comment / approval	LB	RH	RH
Rev	Date	Description	DRA	CHK	APP

Project

Ickleford Mill

Client

Hill Partnership Ltd

Drawing Title

Existing - Borehole Location Plan - Site Layout

Scale	Date	Status
1:1,000 @ A3	16.07.24	Preliminary

DWG No.	Revision
CRM1027189-ENZ-XX-XX-DR-G-0001.2	P02

Bristol
01454 269 237
Manchester
0161 413 6444
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0114 321 5151

Cardiff
02920 023 700
Cambridge
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KEY:

- Site Boundary
- Window Sampler Borehole (WS01 - WS30)
- Window Sampler Borehole (TP01 - TP03)

NOTES:

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P02	16.07.24	Proposed Boreholes Added	LB	RH	RH
P01	16.07.24	Issued for comment / approval	LB	RH	RH
Rev	Date	Description	DRA	CHK	APP

Project
Ickleford Mill

Client
Hill Partnership Ltd

Drawing Title
Proposed - Borehole Location Plan - Topo

Scale 1:1,000 @ A3	Date 16.07.24	Status Preliminary
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DWG No. CRM1027189-ENZ-XX-XX-DR-G-0002.1	Revision P02
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KEY:

Site Boundary

Window Sampler Borehole
(WS01 - WS30)

Window Sampler Borehole
(TP01 - TP03)

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Project
Ickleford Mill

Client
Hill Partnership Ltd

Drawing Title
Existing - Borehole Location Plan - Topo

Scale 1:1,000 @ A3	Date 16.07.24	Status Preliminary
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DWG No.
CRM1027189-ENZ-XX-XX-DR-G-0002.2

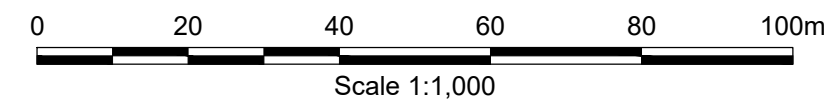
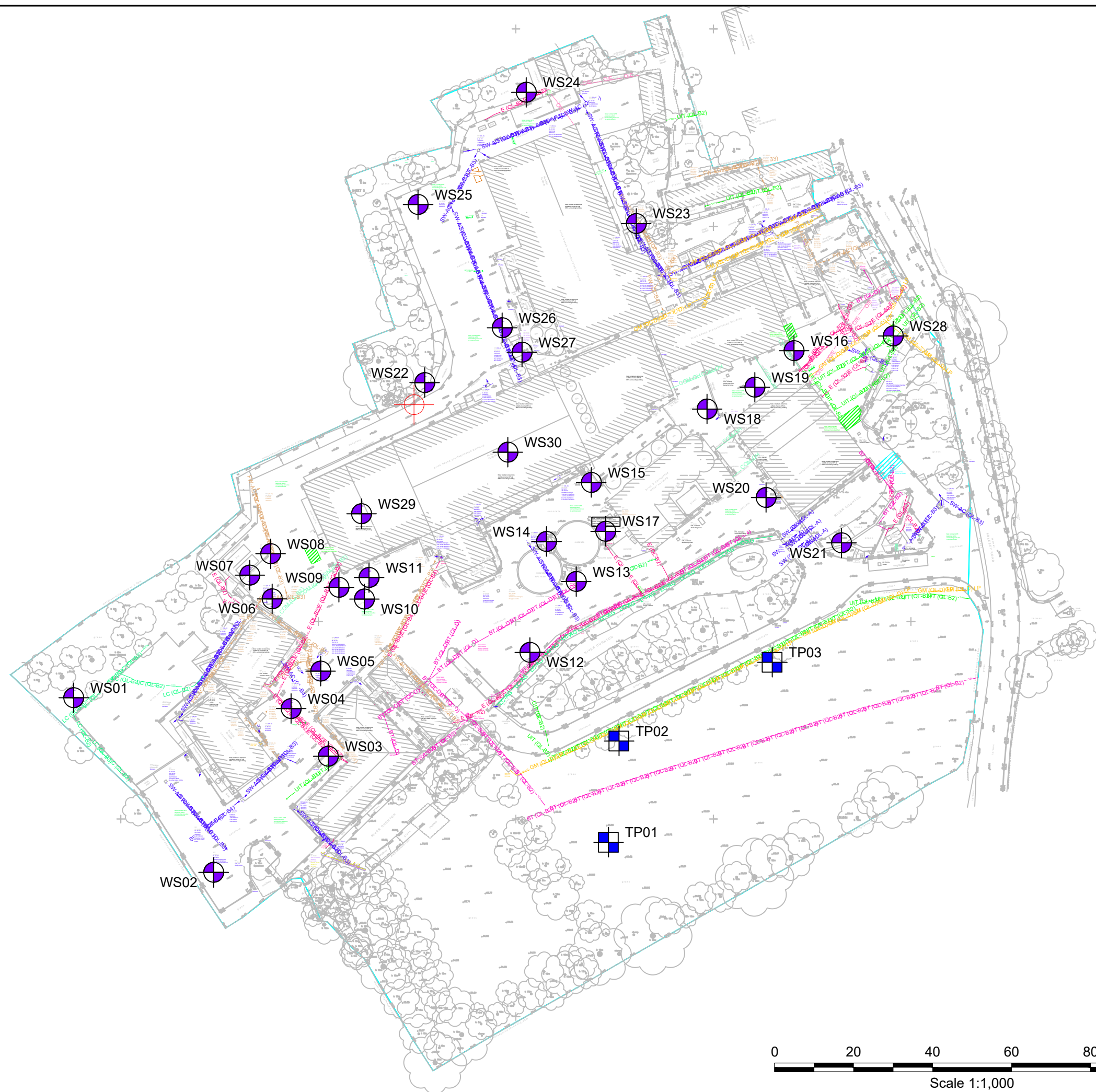
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P02

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Appendix 1 – Existing Information



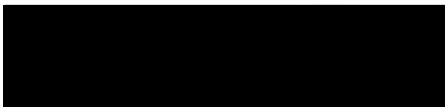
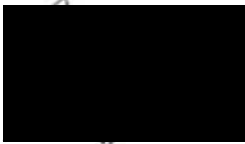
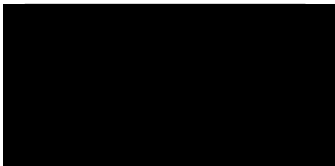
GROUNDTECH
CONSULTING

Job title: Bowman's Mill, Ickleford

Report type: Ground Gas Risk Assessment

Prepared for: Bowman's Ingredients Ltd

Date: March 2020

Document Control Form	
PROJECT	BOWMAN'S MILL, ICKLEFORD
REPORT NAME	GROUND GAS RISK ASSESSMENT
REPORT REFERENCE	19271/1341
STATUS	FINAL
ISSUE DATE	12 MARCH 2020
REVISION	
CLIENT	BOWMAN'S INGREDIENTS LIMITED
CLIENT CONTACT	ALEX MASIH
For and Behalf of Groundtech Consulting	
SIGNATURE	
AUTHOR	Sam Flaherty BSc (Hons) FGS
SIGNATURE	
CHECKED	Richard Wyatt MEng (Hons) FGS
SIGNATURE	
REVIEWED	James Doyle BSc (Hons) CGeol FGS

Introduction

We are pleased to present our findings following the completion of the gas monitoring programme undertaken at the above site for the proposed residential development.

Preliminary Risk Assessment Information

A Geo-Environmental Appraisal was carried out by Groundtech Consulting referenced 19271/1209, dated 06 January 2020.

No significant on-site sources of ground gas were identified during the Ground Investigation, deep Made Ground was generally not encountered across the site and no putrescible material was observed within the soils.

An infilled pond and mill race were identified by the Preliminary Risk Assessment undertaken by WSP Parsons Brinkerhoff (Report Ref: 70027704-10670(1)) in addition to an infilled gravel pit c.80m south of the site. Furthermore, a historic underground storage tank (UST) was present near the centre of the site.

The risk to site end users was considered to be moderate to low based on the PRA and Ground Investigation information.

Ground Model

Made Ground was encountered across the site to a maximum depth of 2.2m bgl but was generally less than 1.0m thick.

The Made Ground was generally granular containing ash and brick, however cohesive Made Ground was encountered in WS03, WS05, WS09, WS14 and WS23 to a maximum depth of 1.4m bgl.

Locally in the vicinity of WS09, WS10 and WS11, the Made Ground and natural strata had a hydrocarbon odour, these locations were drilled in the vicinity of the former UST. The Made Ground in the vicinity of WS11 was encountered to 2.2m bgl.

Made Ground was also locally deeper than 1.0m in the vicinity of WS02, WS03, WS05 and WS06 where the former pond and mill race was identified on the historic maps.

The natural strata were highly variable, comprising interbedded soft to firm Clay, soft Silt and loose Sand deposits. This was underlain by firm to stiff Clay.

Perched groundwater strikes were observed in most locations across the site from 1.0m to 3.45m bgl.

The exploratory hole positions are shown on the Exploratory Hole Location Plan 19271 03 and the logs are in Appendix 1.

Gas Monitoring

During the Ground Investigation works, monitoring standpipes were installed in the following holes and a summary of the installations is provided in the table below.

Location	Depth (m)	Response Zone (m bgl)	Targeted Strata	Reason
WS02	1.50	1.00 – 1.50	Made Ground	Ground Gas/ Groundwater
WS06	4.00	1.00 – 4.00	Sand, Silt and Clay	Ground Gas/ Groundwater
WS09	3.00	1.00 – 3.00	Made Ground, Sand and Clay	Ground Gas/ Groundwater
WS12	4.00	1.00 – 4.00	Clay	Ground Gas/ Groundwater

WS17	4.00	1.00 – 4.00	Clay	Ground Gas/ Groundwater
WS18	5.00	1.00 – 5.00	Clay	Ground Gas/ Groundwater
WS23	3.00	1.00 – 3.00	Sand and Clay	Ground Gas/ Groundwater
WS25	3.00	1.00 – 3.00	Clay	Ground Gas/ Groundwater
WS28	2.00	1.00 – 2.00	Sand and Clay	Ground Gas/ Groundwater
WS29	3.00	1.00 – 3.00	Silt and Clay	Ground Gas/ Groundwater

The standpipes consisted of polyvinyl chloride (pvc) pipe - a bentonite seal was placed around the plain pipe and a clean gravel pack was placed around the slotted pipe.

Six ground gas monitoring visits have been completed between 23rd December 2019 and 2nd March 2020. Monitoring of the weather conditions and predicted atmospheric pressures (Met Office Surface Pressure Charts) was carried out up to 72 hours in advance of proposed monitoring visits in order that a reasonable period of data was obtained to determine atmospheric trends, and also to target the 'worst case' scenario.

Permanent gas and flow rate monitoring was carried out using a GFM436 infrared gas monitor with integral electronic flow analyser. The measurements taken are listed below:

- Oxygen (O₂), carbon dioxide (CO₂) and methane (CH₄) as the percentage volume in air (%v/v).
- Hydrogen sulphide (H₂S) and carbon monoxide (CO) as the percentage volume in air (%v/v).
- Lower Explosive Limit (% LEL) of methane.
- Atmospheric and borehole pressure, including pressure trend.
- Flow measurements (l/hr).
- Weather and ground surface conditions.

Both peak and steady state conditions were monitored to understand the behaviour of the permanent ground gas, the steady state conditions were recorded by allowing the gas monitor to run for a minimum of 3 minutes.

Permanent gas and groundwater monitoring results are presented in Appendix 2.

Gas Monitoring Results

During the monitoring period, no concentrations of methane (CH₄) have been recorded within the standpipes. However, detectable levels of carbon dioxide (CO₂) were recorded within the standpipes, up to a maximum level of 1.7% v/v together with associated depleted oxygen (O₂) concentrations (minimum 15.0% v/v).

In addition, a maximum flow rate of 17.5 l/hr was recorded in WS17 however, high flows were only encountered in this location during one monitoring visit (visit 4). High flows of 7.1l/hr in WS18 and 16.7l/hr in WS06 were also recorded during visits 3 and 5 respectively. These results are considered to be outliers likely related to localised high-pressure environments created within the boreholes as a result of local changes in groundwater regime stemming from heavy downpours in recent months and gases being trapped above the response zone. The general range of flow results observe is <0.1l/hr to 2.7l/hr, therefore a maximum flow of 2.7l/hr will be used when calculating the GSV.

High groundwater levels were recorded within the standpipes ranging from ground level to 2.83m bgl during the monitoring period and groundwater was generally above the response zone of the standpipes. This appears to be characteristic of the site as groundwater was encountered at depths of between 1.00m and 3.45m bgl across the site during the Ground Investigation.

The atmospheric pressure ranged between 988mb and 1017mb during the monitoring period and was carried out during periods of steady, rising and falling barometric pressure.

Characterisation of the Gas Screening Value (GSV)

In accordance with CIRIA Report C665, November 2007 it is felt that an adequate risk assessment can be undertaken based on the following limiting factors:

- The proposed development has been considered as **high sensitivity** based on the site being developed with residential dwellings (Table 5.5 – Typical/Idealised frequency and period of monitoring, after Wilson et al, 2005).
- The risk associated with the generation potential of a source is considered as **low**, (assessment based on the environmental setting) as well as observations noted during the fieldworks.
- Relatively low flow rates have been recorded (Table 8.5 – Modified Wilson & Card classification) and the high anomalous positive flow rates are likely to be associated with groundwater being within the response zone. For this site, three of the monitoring visits were targeted to correlate with a falling atmospheric pressure trend. As a comparison, monitoring has also been undertaken during steady and rising atmospheric pressure trend.

Based upon the results recorded, in accordance with CIRIA Report C665, the risk to the site from ground gases has been assessed by converting the results to gas screening values (GSVs), calculated by multiplying the typical maximum gas concentrations with the recorded maximum positive flow rates. In addition, individual “hazardous gas flow rates” (Q_{hg}) have been derived for each monitoring point. As no levels of methane have been recorded a GSV for carbon dioxide only has been calculated.

$$GSV \text{ (l/hr)} = \text{max borehole flow rate (l/hr)} \times \text{max gas concentration (\%)}$$

For this assessment, the maximum recorded concentration of carbon dioxide of 1.7%v/v has been used together with the maximum flow rate of 2.7l/hr to calculate the GSV.

$$\text{Carbon Dioxide GSV} = 0.017 \text{ (1.7\%)} \times 2.7 = 0.0459 \text{ l/hr}$$

$$\text{Methane GSV} = 0.0 \text{ l/hr}$$

Assessment

Ground gas monitoring was carried out as potential on-site and off-site sources of ground gas were identified.

No methane has been detected and a maximum concentration of carbon dioxide of 1.7% v/v has been recorded.

Groundwater has been encountered within the response zone in a number of the boreholes and is likely to be high as a result of the recent poor weather which has resulted in higher groundwater levels. However, the groundwater seems to be characteristic of the site as similar levels were encountered during the Ground Investigation. A positive borehole pressure was noted in WS17 and WS18 which is likely to have caused the flow of gas.

In order to assess the ground gas regime beneath the site and the need to incorporate ground gas precautions, guidance was taken from CIRIA C665 ‘Assessing risks posed by hazardous ground gases to buildings’.

Based on the site being developed with low-rise housing, the Boyle and Witherington, 2006 method has been used to carry out the assessment. This is a risk-based approach that is designed to allow an identification of gas protection for a low-rise housing development by comparing the measured gas emission rates to generic ‘traffic lights’ scenarios. The traffic lights include ‘typical maximum concentrations’ and are provided for initial

screening purposes and risk-based gas screening values for consideration in situations where the typical maximum concentrations are exceeded.

When considering the results, in accordance with CIRIA C665 (Situation B – Low-rise housing with a ventilated underfloor void (min 150mm) and Table 8.7 – NHBC Traffic light system for 150mm void) it can be seen that the GSV value for carbon dioxide is below the assessment GSV of <0.78l/hr and falls within the Green traffic light zone.

NHBC - Green Traffic Light

An extract of the table is presented below.

Traffic Light Classification	Methane ¹		Carbon Dioxide ¹	
	Typical Maximum Concentration ³ (%v/v)	Gas Screening Value ^{2,4} (l/hr)	Typical Maximum Concentration ³ (%v/v)	Gas Screening Value ^{2,4} (l/hr)
Green	1	0.16	5	0.78
Amber 1	5	0.63	10	1.56
Amber 2	20	1.56	30	3.10
Red				
Notes: 1. The worst-case ground gas regime identified on the site, either methane or carbon dioxide, at the worst-case temporal conditions that the site may be expected to encounter will be the decider as to what Traffic Light is allocated; 2. Gas Screening Value is the Borehole Gas Volume Flow Rate, in litres per hour, as defined in Wilson and Card (1999), which is the borehole flow rate multiplied by the concentration in the air stream of the particular gas being considered; 3. The Typical Maximum Concentrations can be exceeded in certain circumstances should the Conceptual Site Model indicate it is safe to do so; 4. The Gas Screening Value thresholds should not generally be exceeded without the completion of a detailed ground gas risk assessment taking into account site-specific conditions.				

In addition, based on the site being developed with residential homes with potential for ground bearing floor slabs, an assessment in accordance with the Wilson and Card method has also been carried out.

When considering the results, in accordance with CIRIA C665 (Section A Development and Table 8.5 – Modified Wilson and Card Classification) it can be seen that the GSV value for carbon dioxide is below the assessment GSV of <0.07l/hr and falls within Characteristic Situation 1 resulting in no gas protection measures being required.

Characteristic Situation 1

An extract of the table is presented below.

Modified Wilson and Card classification

	Characteristic situation (CIRIA R149)	Comparable classification in DETR et al (1999)	Risk classification	Gas screening value (GSV) (CH ₄ or CO ₂) (l/hr) ¹ Threshold	Additional factors	Typical source of generation
	1	A	Very low risk	<0.07	Typically methane <1 % and/or carbon dioxide <5 %. Otherwise consider increase to Situation 2	Natural soils with low organic content "Typical" made ground
	2	B	Low risk	<0.7	Borehole air flow rate not to exceed 70l/hr. Otherwise consider increase to characteristic Situation 3	Natural soil, high peat/organic content. "Typical" made ground
	3	C	Moderate risk	<3.5		Old landfill, inert waste, mineworking flooded
	4	D	Moderate to high risk	<15	Quantitative risk assessment required to evaluate scope of protective measures.	Mineworking – susceptible to flooding, completed landfill (WMP 26B criteria)
	5	E	High risk	<70		Mineworking unflooded inactive with shallow workings near surface
	6	F	Very high risk	>70		Recent landfill site

Radon Gas

In accordance with BRE 211 'Radon Guidance on Protective Measures for New Buildings' 2015 and UKRadon the site falls in an area where <1% of homes are affected by radon gas, therefore no radon precautions are required within the proposed dwellings.

Conclusions

No gas protection measures are required within the proposed houses at the site.

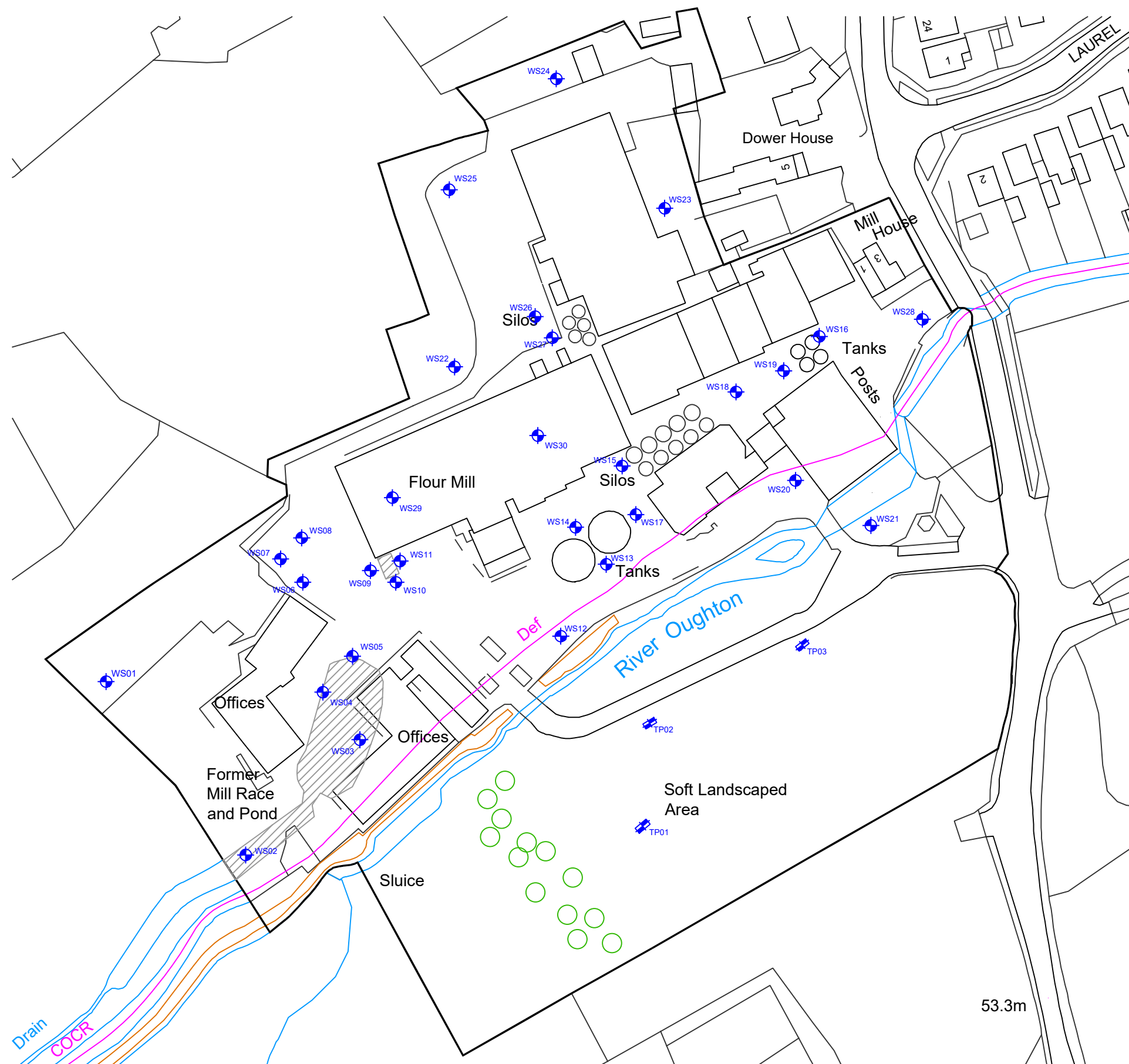
No radon precautions are necessary.

It is recommended that confirmation of these findings is made with the Local Authority prior to any irrevocable action being taken.

PLANS



 GROUNDTECH CONSULTING	CLIENT	DATE			Status		Notes  Location of the Site
	BOWMAN'S INGREDIENTS LTD	JANUARY 2020			Preliminary		
	PROJECT TITLE	SCALE			Draft		
	BOWMANS MILL, ICKLEFORD	NTS			Issued	●	
	PLAN TITLE	PLAN NUMBER			For Comment		
	PROJECT LOCATION PLAN	19271 01	Rev.	Details	Date	Approved	



	CLIENT	DATE			Status		Notes • Window Sample Borehole Locations • Trial Pit Locations
	BOWMAN'S INGREDIENTS LTD	JANUARY 2020			Preliminary		
	PROJECT TITLE	SCALE			Draft		
	BOWMAN'S MILL, ICKLEFORD	NTS			Issued	●	
	PLAN TITLE	PLAN NUMBER			For Comment		
	EXPLORATORY HOLE LOCATION PLAN	19271 03	Rev.	Details	Date	Approved	