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ROBROYSTON NORTH, ROBROYSTON

GROUND INVESTIGATION REPORT

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ROBROYSTON NORTH, ROBROYSTON

GROUND INVESTIGATION REPORT

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EXECUTIVE SUMMARY

Johnson Poole & Bloomer Limited (JPB) were commissioned by Barratt Homes West Scotland, to prepare a Ground Investigation Report for the site at Robroyston North, Robroyston. The site is centred on National Grid Reference NS 642 689 and occupies an area of approximately 31.5ha. The purpose of the report was to appraise the ground conditions at the site and to determine what impact these may have on proposed residential land use for the site.

Due to the presence of existing stockpiles, dense vegetation, services and areas of earthworks investigations were not undertaken in some areas of the site. Consequently, the findings of this report are only for the areas accessible during this investigation. Additional investigations will be required once these areas are accessible.

This section provides a brief summary of the investigation findings in relation to the geotechnical, mining, chemical contamination and gas emissions constraints at the site.

Historical Background

On Site	Off Site
Greenfield	Residential development/agricultural land/landfill

Invasive Plants

Other than the area discussed below, no invasive plants were recorded on the date of the inspection.

A fenced off area was noted in the western area of the site, with signs noting that Japanese Knotweed was present and currently undergoing treatment within this area.

Geology

The investigation has indicated the site to be underlain by topsoil, between 0.1m to 0.8m in thickness, though limited made ground was recorded. The underlying natural soils were found to comprise generally silty, sandy, gravelly clay and are interpreted to represent the anticipated glacial deposits.

Along with the glacial deposits noted above, within trial pits TP312, TP312A, TP312C, TP312D, and TP321 a soft consistency, low strength, sandy, gravelly peaty clay was recorded. Decaying vegetation was also noted in trial pit TP321. This was recorded from depths between 1.3m to 2.5m to depths between 1.8m to 3.1m and was between 0.2m to 0.7m in thickness. **It should be noted that peat may extend beyond the locations shown on site.**

In the eastern area of the site, several of the trial pits and boreholes from both the current and previous investigation encountered potential rockhead at depths between 0.7m to 2.35m. Within the central area of the site this was recorded at depths between 1.8m to 3.8m, while in the western area of the site, two trial pits encountered possible bedrock at depths between 1.5m to 1.7m.

The rotary drilling encountered rockhead at between 13m and 15.2m. The strata were recorded as a sequence of sandstone and mudstones. These strata were proven up to a maximum of 30m depth which is consistent with the anticipated Carboniferous strata.

The stockpiles that were present across the site were also investigated, with shallow pits being excavated into these. The material within the stockpiles were recorded as a silty, sandy, gravelly clay with cobbles, and also recorded ceramics, plastic, occasional brick fragments, and rootlets. This appears to be reworked natural deposits with some construction materials present.

Foundation Solution

Deposit Type	Foundation Option	Allowable Bearing Capacity based on a 0.6m wide foundation
Made Ground/Peat/Peaty Clays	Not suitable for strip founds.	N/A
Cohesive glacial till	Shallow Strip foundation. Deep trench foundation	60kPa
Granular glacial deposits	Shallow Strip foundation. Deep trench foundation	36kPa

Mining & Mine Entries

The table below summarises the potential risks associated with former mining legacy for the proposed development site, identified from list sources of information, in compliance with "Risk Based Approach to Development Management – Resources for Developers" published by the Coal Authority.

Mining Issue	Yes/No	Risk Assessment
Underground mining (recorded at shallow depths)	No	Previous work by others in August 2001 concluded that mining was not a development constraint. This conclusion was felt to be accurate, though additional rotary work was undertaken to ensure that no mining had been undertaken off the nearby quarry. These works confirmed no evidence of shallow mining.
Underground mining (recorded at depth)	No	The Coal Authority Coal Mining Report indicates that according to the records in their possession, the property is not within the zone of likely physical influence on the surface from past underground workings.
Mine entries (shafts and adits)	No	During the study no evidence of any mineshafts or adits being present within the site was encountered.
Coal mining geology (fissures)	No	CA report indicates no evidence of any issues.
Record of past mine gas emissions	No	CA report indicates no evidence of any issues.
Recorded coal mining surface hazard	No	CA report indicates no evidence of any issues.
Surface mining (opencast workings)	No	CA report indicates no evidence of any issues.

As with any coalfield/former mining area, there is the potential for unrecorded mine entries to be present. As in the development of all sites in former mining areas, vigilance should be maintained by all site workers during any ground excavations to identify any features suspected to be possible mine entries.

Chemical Contamination and Gas Emissions

Based on the risk assessments carried out and in recognition of the validated conceptual site model the following measures are required to address risks posed by chemical contamination and gas emissions.

The following recommendations are based on current site levels, it is recommended that they are reviewed, and if necessary revised, should significant earthworks be envisaged at the site, or once the cut/fill balance has been identified.

Receptor		Measures required
Chemical Contamination		
Human Health	Contact with soil	No remedial measures are required.
Human Health	Inhalation of Dust and Vapours	*General site* No remedial measures are required. *Stockpiles* Asbestos was detected within a sample from SP07, which was located within the stockpiles. It is recommended that this stockpile be segregated and further testing be carried out to determine if asbestos contamination is prevalent throughout the stockpile.
Plant Growth		No remedial measures are required.
Invasive Plants		No additional remedial measures are required. A fenced off area in the western area of the site was noted in which Japanese Knotweed was undergoing treatment.
Building/ Services	Concrete	pH values and sulphate concentrations indicate that the ground conditions fall within design sulphate class DS-1 and ACEC class AC-1s as defined in BRE Special Digest 1. Therefore, an appropriate concrete specification is required to protect building elements in contact with these conditions.
Building/ Services	Water supply pipes	No contaminant concentrations were identified which are considered to permeate water pipes or impact on their integrity. Therefore, no restriction is made on the type of water pipes which can be used on the site.
Surface Water		No remedial measures required.
Groundwater		No remedial measures required.
Ground Gas Emissions		

Receptor	Measures required
Chemical Contamination	
Human Health & Buildings/ Services	Elevated concentrations of gas emission were identified in some of the boreholes on the site as shown on JPB Drawing TG276-22/R/F/06. Remedial measures including passive venting and the incorporation of a ground gas resistant membrane and passive venting of the building solums, underslab voids/upfill and wall cavities is required.
Radon	
Human Health	New buildings within the north western area of the site as shown on JPB Drawing TG276-22/R/F/06 require **full** radon protection measures. Radon-proof membrane in building solum and passive venting of building solums, underslab voids/upfill and wall cavities are required. **However it is understood that the gas protection measures for Characteristic Situation 2 will also be considered sufficient for this.**

Road Construction

Prior to the construction of any adoptable roads CBR testing would be required at 25m centres along the route of these in order to ascertain the requirements for a capping layer. It should be noted, however, that any road built on areas of made ground or any upfilled areas would require a full capping layer.

The recorded CBR values were below 2.5% and therefore the material is a soft sub-grade as per Interim Advice Note 73/06 Revision 1 (2009) Design Guidance for Road Pavement Foundations (Draft Hd25) then the measures outlined in that document should be undertaken to address these issues.

Where the peat and peaty clays were recorded these will require to be removed and replaced with acceptable material. Any material beneath the road will require to be placed in accordance with the Specification of Highway Works Series 600 and appropriate testing carried out to confirm the acceptability of the material.

Site Verification

If Local Authority/NHBC certification is to be sought for the proposed development, then the following remedial works which can be supervised by JPB are likely to require verification.

Constraint	Action
Additional Investigations	Additional sampling of the contaminated stockpile is recommended.
Remedial Strategy	Produce Remedial Strategy based on the findings of the site investigation in accordance with CLR11 and obtain approval from the Local Authority.
Ground Gas Emissions	Ground gas and/or radon impermeable membrane in building solum in the area shown on JPB Drawing TG276-22/R/F/06. Passive venting of building solums, underslab voids/upfill and wall cavities.
Gas Monitoring Standpipes	As part of the development all boreholes must be decommissioned in accordance with SEPA guidance "*Decommissioning Redundant Boreholes and Wells*".
Verification Statement	Produce verification statement in accordance with CLR11 and obtain approval from the Local Authority.

PART ONE – INTRODUCTION

1.0 INTRODUCTION AND OBJECTIVES

1.1 Introduction

Barratt Homes West Scotland are assessing the potential of a site located at Robroyston North, Robroyston (JPB Drawing TG276-22/R/F/01). It is understood that the intended land use is for houses with domestic gardens. A client supplied drawing showing the current development proposals is given in Appendix 1.

Due to the presence of existing services, soil bunds, and flooding in areas, investigations were not undertaken in some areas of the site. Consequently, the findings of this report are only for the areas accessible during this investigation. Additional investigations will be required once these areas are accessible.

This report has been prepared and written on behalf of Barratt Homes West Scotland in the context of the purpose stated above and should not be used in any differing context. No duty of care extends to any third party that may make use of the information unless written confirmation has been provided by Johnson Poole & Bloomer. In addition, new information, improved practices and legislation may necessitate an alteration to the report in whole or in part after its submission. Therefore, with any change in circumstances, or after the expiry of one year from the date of the report, it should be referred to us for reassessment and, if necessary, amendment. No action or proceedings can be commenced against the JPB after the expiry of 12 years from the date of this report.

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1.2 Objectives

JPB were commissioned by Barratt Homes West Scotland to undertake site investigation works. The aim of the investigation was to provide information to identify environmental and geotechnical constraints which may have consequences in the design of the development and to provide information to be submitted as part of the planning process and in obtaining regulatory approvals.

Therefore, the investigations had the following objectives:

- To identify any chemical contamination constraints;
- To characterise the groundwater regime and identify any risks posed to water resources;
- To examine the ground gas regime and any constraints posed by gas emissions;
- To determine a foundation horizon and potential foundation solution; and
- To identify any mining constraints.

The investigation of the geotechnical, mining, chemical contamination and gas emission conditions is now complete and this report presents the factual investigation data and JPB's interpretation of the existing ground conditions. Potential development constraints are identified and appropriate remedial actions are recommended. Foundation design considerations are also discussed.

It is anticipated that during the course of any redevelopment works various local authority departments will become involved. We, therefore, advise that, where appropriate, our report and associated information are submitted to the regulatory bodies and approval obtained before detailed design, site works or other irrevocable actions are embarked upon.

PART TWO – STAGE 1 INVESTIGATION

2.0 SITE RECONNAISSANCE

2.1 Site Walkover

The site is located in the eastern area of Robroyston and is approximately centred on Ordnance Survey National Grid Reference NS 642 689 and covers an area of approximately 31.5 hectares. A selection of site photographs is presented in Appendix 2.

At the time of the site walkover on 21st January 2020 the site comprised of generally greenfield and earthworks, in the form of construction of a road and a SUDS pond, had started on the centre area of the site. The site was bounded by the current construction site and greenfield to the north, woodland to the east, the M80 motorway to the south and residential housing to the west.

The site was predominantly flat but had steep slopes to the west and eastern area of the site. The centre of the site was predominantly flat wherever earthworks had commenced.

The site was greenfield in the western area, with a densely vegetated area being located on the western and southern boundary. A flooded area was situated in the north-eastern corner of the site and was surrounded by soft ground and marshland. A small track bounded the southern boundary of this area.

The central area of the site had been stripped of topsoil and earthworks had commenced in this area. A treeline split this area into a northern and southern area with a large flooded area being located in the northern area. Large stockpiles of topsoil were located throughout this area. The northern area of this central portion also contained a newly constructed road and some stockpiling for the current construction site. A newly constructed SUDs pond was also located in the northern area of this portion. This portion of the site was bounded to the west by a small road, previously identified as Saughs Road although numerous trees were blocking this road. A wooded area separated the site from the residential housing in the western and north-western boundary.

The western area of the site comprised of greenfield. This contained a steep slope towards the centre of the area. An area of Japanese Knotweed was identified in the far west which was currently undergoing treatment and was fenced off from the rest of this area. There was a small track in the north-west of this area which led to the residential housing to the north. The site was bounded by the current Miller construction site to the north.

2.2 Invasive Plant Survey

An invasive plant survey was carried out during the works prior to commence of the investigation. The report is included in Appendix 3. The report's main findings are summarised below.

- No Japanese Knotweed, Giant Hogweed or Himalayan Balsam plants were identified during the walkover.

Not noted in the report was the presence of a fenced off area in the western area of the site, with signs noting that Japanese Knotweed was present and currently undergoing treatment within this area.

3.0 APPRAISAL OF EXISTING INFORMATION

3.1 General

Initial research undertaken prior to the site investigation works included a routine examination of available geological maps, past and present editions of the Ordnance Survey and relevant in-house data. A summary of information obtained from our researches is presented in the following section.

3.2 UXO Assessment

A Zetica Map has been obtained with regards to the assessment of any risks which may or may not be posed by Unexploded Ordnance (UXO) at the site. The map indicates the site to be in an area of low risk which are areas indicated as having 15 bombs per 1000acre or less. A copy of this map can be found in Appendix 5.

3.3 History of Land Use

An investigation of the past usage of the site can often provide an indication of the presence of potentially contaminated soils arising from processes associated with former land uses. These researches can help to identify any potential constraints to developments upon which physical investigations can then concentrate. Past copies of Ordnance Survey Maps and air photos were examined, with particular attention being given to the industrial heritage of the study area and the changing land use of the site. The summary of the historical land uses identified on and adjacent to the site are described below.

Ordnance Survey Edition (Appendix 4)	On Site	Surrounding Area
1859-1864	Site is greenfield, split into several fields. A small road runs north to south in the central area of the site	Essentially rural with the Garnkirk Burn present approximately 450m to the south east, and the Auchinleck well present approximately 450m to the north. Auchinleck Farm is approximately 80m to the north of the site. An old quarry is present approximately 430m to the north.
1896-1899	As 1859-1864	Robroyston Coal pit is present approximately 450m to the west of the site, though this is noted as disused. Cadder Coal Pit No. 16 is present approximately 750m to the north of the site. A disused mineral railway is noted approximately 400m to the south of the site, running east to west, connecting to Robroyston Coal pit. An old quarry is present approximately 550m to the south east. A small burn is noted approximately 500m to the north. Auchinleck well is renamed Wallace's Well.
1912-1914	As 1896-1899. A drain is marked flowing east in the central area of the site.	The Cadder Coal Pit is now marked as an old colliery. The Robroyston Coal Pit is no longer present, with several larger buildings present. Just to the south of these, approximately 450m to the west of the site, an old quarry, and old gravel and clay pit is present. The Robroyston Branch of the Caledonian Railway is present approximately 450m to the south, running roughly east to west. The old quarry to the north of the site is no longer present. A tank is noted on a nearby farm, approximately 100m to the south of the site.
1922-1923 (1:10,000 only, northern area only)	What can be seen of the site on this map appears as 1912-1914	What can be seen of the site on this map appears as 1912-1914.
1932-1935 (Limited coverage of surrounding area)	As 1912-1914.	To the west the disused quarry, clay pit and gravel pits are no longer present, and the larger industrial buildings are no longer present. A large number of buildings are present at the south western corner, which are noted as Robroyston Hospital.
1946 (aerial photograph)	Site appears as 1932 -1935, still remaining as farmland	Surrounding area is still generally agricultural, with Robroyston hospital still present, though it appears to have

Ordnance Survey Edition (Appendix 4)	On Site	Surrounding Area
		expanded to the north.
1954-1958	As 1932-1935	The old colliery to the north has now expanded and is marked as a mine, possibly denoting it is active again.
1967	As 1954-58	The spoil heaps in the mine to the north have expanded.
1980-83	As 1967	The mine to the north is now marked as disused, and the majority of the buildings are no longer present. The railway line to the south of the site is no longer present and is marked as dismantled.
1990-1994	As 1980-83	Robroyston Hospital is no longer present, and it has been replaced by a residential housing estate. On the 1:2,500 maps the M80 motorway is now shown adjacent to the southern boundary of the site.
1999	As 1990-94	Generally as 1990-94, though the housing estate to the south west has seen some expansion.
2005-2006	As 1999	The housing estate to the south west has expanded, with the addition of more housing and a superstore.
2020	As 2005-2006	The housing in the surrounding area has expanded, with housing now to the west, and north west, and approximately 50m to the north of the site.

3.4 Geology and Mining

The objective of this part of the assessment was to undertake a desk study review of the indicated site geology and the underlying mining conditions with a view to assessing the risk to the proposed development arising from the possible presence of mining. The report takes cognisance of the information contained in the guidance documents "Risk Based Approach to Development Management – Resources for Developers" published by the Coal Authority and CIRIA C758"Abandoned Mineworkings Manual".

An initial appreciation of the general geological conditions underlying the site was made from the available Geological Survey sheets (JPB Drawings TG276-22/R/F/02 and 03), geological and mining memoirs, mine plan catalogues and the Coal Authority Mining report (Appendix 5). The following is a summary of the indicated conditions as interpreted from the above information by JPB.

Made Ground	As the site is indicated to have been greenfield no significant made ground deposits are anticipated to be present. Earthworks have been undertaken in part of the site, and this may be a potential source of made ground.
Natural Superficial Deposits	Glacial till is indicated to be present across the site. This material is likely to comprise sandy clay with variable amounts of gravel, cobbles and boulders. Irregular bands or lenses of sand and gravel may occur in the till. Peat deposits are shown to be present adjacent to the north eastern boundary of the site, which may encroach into the site area. The anticipated depth to rockhead is unknown, however there are several quarries surrounding the site, and previous site works indicate that bedrock may be at or near surface.
Rock Strata	Within the northern area and eastern areas, the underlying rock strata are indicated to belong to the Carboniferous Upper Limestone Group. These typically comprise sandstones, siltstones and mudstones with limestones and coals. Running through the centre of the site, the east-west trending Robroyston Fault is present which downthrows to the south causing the younger Carboniferous Passage Group to be at shallow depth. The Garnkirk fault is also present in the north of the site, running roughly east to west. In the western portion of the site the Calmy Limestone, the Plean Limestone, and Upper Hirst Coal are present at outcrop with this strata generally dipping to the north east at shallow angles.
Quarrying	There is no indication of quarrying on site. There are however several quarries present in the surrounding area, with the closest approximately 430m to the north of the site.
Mining	The site is located in an area of known previous mining activity. There is no current mining within influencing distance, and although reserves of coal and related minerals may exist beneath the site, the possibility of future exploitation is at present considered to be unlikely. Our researches have encountered records of abandoned mineworkings within the area of the site. However, it did not become a statutory requirement to maintain and preserve plans of abandoned mines until 1872, by which date much unrecorded mining had taken place. Therefore, some further workings could exist which have not been recorded.

	The historical researches indicated a history of mining in the area including shallow workings in the Calmy Limestone. These are likely to be present beneath the site and have the potential to affect the surface. **Therefore, there is a potential for mining constraints at the site.** Previous rotary investigations by others (David R Murray in August 2001) concluded *British Geological Survey and Coal Authority reports suggested that the area maybe undermined at shallow depth. Rotary boreholes have found no indications of mining and in the absence of abandonment mineplans it is reasonable to assume the site is minerally stable.* Based on the information this would appear to be a reasonable conclusion. However some extension of mining from the base of the quarry has been known in other areas. Recent rotary drilling by JPB on the site to the immediate north indicated no evidence for this, however, rotary drilling was carried out to confirm this in the current area. These works confirmed no evidence of shallow mining.
Mine Entries	During the study no evidence of any mineshafts or adits being present within the site was encountered. However, as in any areas of past mining activity, the presence of unrecorded mineshafts and adits cannot be discounted.

Summary of Mining Risks

The table below summarises the potential risks associated with former mining legacy for the proposed development site, identified from list sources of information, in compliance with "Risk Based Approach to Development Management – Resources for Developers" published by the Coal Authority.

Mining Issue	Yes/No	Risk Assessment
Underground mining (recorded at shallow depths)	No	Previous work by others in August 2001 concluded that mining was not a development constraint. This appears to be a reasonable, however rotary work will be undertaken to confirm that no mining was carried out from the quarry within the current area. These works confirmed no evidence of shallow mining.
Underground mining (recorded at depth)	No	The Coal Authority Coal Mining Report indicates that according to the records in their possession, the property is not within the zone of likely physical influence on the surface from past underground workings.
Mine entries (shafts and adits)	No	During the study no evidence of any mineshafts or adits being present within the site was encountered.
Coal mining geology (fissures)	No	CA report indicates no evidence of any issues.
Record of past mine gas emissions	No	CA report indicates no evidence of any issues.
Recorded coal mining surface hazard	No	CA report indicates no evidence of any issues.
Surface mining (opencast workings)	No	CA report indicates no evidence of any issues.

3.4 Hydrology and Hydrogeology

The available information, including SEPA's online water environment data for the site vicinity (Appendix 6), indicates that the following hydrological and hydrogeological conditions are present at the site.

Surface Water Features	There are no major surface water features within influencing distance of the site. There are several drains at the northern and western site boundary. SEPA's Draft River Basin Management Plan online holds no information for the surface water drains. No surface water abstractions were recorded within 1km of the site.
Superficial Deposits	Made ground deposits are unlikely to be present. If present these may comprise granular materials. It is considered that these will have a medium to high permeability and are therefore susceptible to contamination. Glacial till may be present which is often noted to be stiff, silty, sandy clay with rock clasts and irregular bands or lenses of sand and gravel. This is considered to be of low permeability, to have a low susceptibility to contamination and may afford some protection to the underlying strata from the downward percolation of mobile contaminants.

Rock Strata	SEPA River Basin Management Plan online maps indicate that within the northern and eastern area of the site the groundwater belongs to the Glasgow and Motherwell groundwater. These are reported to be have an overall status of "Poor" and to be of "Good" quality under the quantitative classification but of "Poor" quality under the qualitative classification with diffuse source pollution pressures due to mining and quarrying and past land contamination. SEPA River Basin Management Plan online maps indicate that within the southern and western area of the site the groundwater belongs to the Stepps groundwater. These are reported to be have an overall status of "Good" and to be of "Good" quality under the quantitative classification and "Good" quality under the qualitative classification with no diffuse source pollution pressures.
Groundwater Abstraction	The Envirocheck report (Appendix 7) indicated there are no groundwater abstraction records with 1km of the site.

3.5 Regulatory Search

Johnson Poole & Bloomer commissioned an "Envirocheck" UK regulatory authority database search (Appendix 7) to obtain information on various operations within a 1 km radius of the centre of the site. A plan showing the location of these operations is included in the Appendix. The key findings of regulatory database search are summarised below. JPB's default distance for commenting on features in the vicinity of the site is 250m with the exception of COMAH and landfills for which it is 1km.

Licence/Data Type	Distance from site measured to the registered location (i.e. centre of the site)	Operation
Regulators		
Contaminated Land Register Entries and Notices	None within 250m	-
Discharge Consents to Controlled Waters	None within 250m	-
Enforcement and Prohibition Notices	None within 250m	-
Integrated Pollution Controls	None within 250m	-
Integrated Pollution Prevention And Control	None within 250m	-
Local Authority Integrated Pollution Prevention And Control	None within 250m	-
Local Authority Pollution Prevention and Controls	None within 250m	-
Local Authority Pollution Prevention and Control Enforcements	None within 250m	-
Pollution Incidents to Water Environment	None within 250m	-
Prosecutions Relating to Authorised Processes	None within 250m	-
Prosecutions Relating to Water Environment	None within 250m	-
Registered Radioactive Substances	None within 250m	-
Waste		
BGS Recorded Landfill Sites	None within 1km	-
Integrated Pollution Control Registered Waste Sites	None within 250m	-
Licensed Waste Management Facilities (Landfill Boundaries)	None within 250m	-
Licensed Waste Management Facilities (Locations)	None within 250m	-
Local Authority Recorded Landfill Sites	Five within 1km	Five landfills are recorded by the Local Authority within 1km. The closest of these is adjacent to the eastern boundary of

Licence/Data Type	Distance from site measured to the registered location (i.e. centre of the site)	Operation
		the site, noted as North Wood, Stepps. The type of waste is not noted, though is noted to be closed.
Registered Landfill Sites	None within 250m	-
Registered Waste Transfer site	None within 250m	-
Registered Waste Treatment or Disposal Sites	None within 250m	-
Hazardous Substances		
Control of Major Accident Hazards Sites (COMAH)	None within 1km	-
Explosive Sites	None within 250m	-
Notification of Installations Handling Hazardous Substances (NIHHS)	None within 250m	-
Planning Hazardous Substance Consents	None within 250m	-
Planning Hazardous Substance Enforcements	None within 250m	-
Industrial Land Use		
Contemporary Trade Directory Entries	None within 250m	-
Fuel Station Entries	None within 250m	-
Summary	The database search has confirmed that no industrial processes have been identified around the site, and therefore significant impact on the site is unlikely.	

As no evidence was present on the historical maps for the landfill adjacent to the site, North Lanarkshire Council, in whose area the possible landfill falls, were contacted. In a telephone conversation, they noted that they have records of this being a landfill, though no records exist of what material was landfilled here. They also note that this has not been monitored by the council for anytime that the Environmental Officer could recall.

3.6 Previous Site Works

JPB have previously undertaken two phases of investigations of a larger site which included the area within the existing site boundary. The findings of previous investigations, JPB report references AG632-07/MAK, July 2001, have been included in Appendix 9. A brief summary of the findings as they relate to the existing site is given below, for further information refer to the original reports.

Investigations reported in 2001 were directed by David R Murray Limited and relevant information for this site includes;

- Trial pitting across the current site
- Sinking of twelve boreholes, BH14-17, BH22, BH24-28, and BH30-31 across the current site.
- Gas monitoring using spike probes and at standpipes installed in boreholes.

The previous investigation concluded that no significant contamination was encountered within the current site area and that water environment receptors were not at significant risk. In addition, rotary investigations indicated that limestone workings do not extend to the current site. Therefore, no remedial actions were recommended at that time. Where relevant, the findings and results of previous investigations have been included in the current assessment and updated to current requirements.

3.7 Chemical Contamination and Gas Emissions

Our researches have indicated that the site has been occupied by agricultural land throughout its history. It is less likely, therefore, that any significant chemical contamination will be present on site. However, testing for pesticide residues together with general contamination should be carried out to confirm ground conditions. Any made ground encountered should be tested for a suite of chemical contaminants commonly encountered on brownfield sites.

Ground Gas

On Site Source

It is unlikely that made ground or other sources of ground gas emissions will be present on site and, as a result, elevated ground gas concentrations are not expected.

Deep Seated Gas

The site is in an area where there is the potential for ground gases from a deep-seated source including mining which could impact the whole site, therefore, investigations are required to determine the level of risk posed by this gas source.

Off Site Source

The site is adjacent to a landfill and potentially ground gases could migrate from this source towards the site, therefore, investigations are required to determine the level of risk posed by this off-site gas source.

Radon

Risks posed by radon have been assessed in accordance with current authoritative guidance as detailed in JPB's methodology (Appendix 8).

Inspection of the BR 211 Appendix A radon map indicates that the site may be within an area where radon protection is required and, therefore, a further assessment of the risks posed by radon has been undertaken and is detailed in the Gas Emissions section of this report.

4.0 STAGE 1 PRELIMINARY QUALITATIVE RISK ASSESSMENT

4.1 Stage 1 Preliminary Qualitative Risk Assessment

In assessing the research information a Stage 1 Preliminary Qualitative risk assessment has been carried out in order to develop an Initial Conceptual Site Model for the site. The Conceptual Site Model (CSM), is generated in accordance with Guide to Good Practice for the Development of Conceptual Models and the Selection and Application of Mathematical Models of Contaminant Transport Processes in the Subsurface - National Groundwater & Contaminated Land Centre report NC/99/38/2 – Environment Agency 2001.

Based on the Stage 1 Preliminary Quantitative Risk Assessment the next step in assessing environmental risks and constraints for the site is to use the available research information to develop a Conceptual Site Model (CSM). The CSM describes how potential chemical sources at the site could contribute to increased levels of risk to potentially sensitive receptors. The CSM identifies the sources of contamination, the likely receptors and the potential pathways present which may link them. Where it appears that a pathway links a source to a receptor, this potential significant pollutant linkage should be the focus of site investigations.

The CSM is developed at an early stage and constantly reassessed in light of investigative findings. The first step in producing such a model is to identify whether there are potential hazards on site through desk top research together with the application of professional expertise and judgement. In addition, information regarding the site-specific environmental setting including geology, hydrogeology, hydrology etc., is gathered to identify the environmental resources which could be impacted by potential contaminants at the site. Within this context, a hazard is defined as a property that has the potential to cause harm to a receptor group.

A summary of this preliminary assessment in presented in the following ICSM table which summarises the individual source, pathway and receptors considered to be present.

SPR item	SPR item present based on desk study (Yes/No)	Comment
Sources		
S1 – Contamination from former land use	**Yes**	Site recorded to be greenfield. Significant made ground not anticipated, therefore, no major source of contaminants anticipated. However, potential for pesticide residues.
S2 – Contamination from adjacent land use	**Yes**	An area adjacent to the eastern site boundary is noted as a landfill. Further investigations required.
S3 – Ground gas	**Yes**	Made ground and peat beneath site could contain biodegradable material and could degrade to produce elevated levels of gas. Landfill present at eastern boundary. While considered unlikely, there is the potential for mine gas. Risks posed by radon require to be considered. Further investigations required.
S4 – Leachable contaminants	**Yes**	Some potential made ground contaminants may be leachable or mobile. Further investigations required.
Pathways		
P1 – Contact with soil	**Yes**	Site is to be a residential with gardens and, therefore, there is the potential for site occupiers to come into contact with the soils.
P2 – Ingestion of vegetables	**Yes**	Site is to be a residential with gardens development and, therefore, there is the potential for site occupiers to grow their own produce.
P3 – Inhalation of dusts/vapours	**Yes**	Site residents may be exposed to dusts or vapours from any contaminants present.
P4 – Ingestion of groundwater	**Yes**	Potential for contact with groundwater.
P5 – Building contact with soil	**Yes**	Site is to be developed and, therefore, buildings will be present on site.
P6 – Migration via services	**Yes**	Site is to be developed and, therefore, buildings and associated infrastructure will be present on site.
P7 – Perched groundwater	**Yes**	Researches indicate the potential presence of contaminated made ground overlying cohesive soils, therefore, perched groundwater may be present.
P8 – Vertical migration	**Yes**	Granular deposits may be present allowing vertical contaminant migration.
P9 – Migration of gas	**Yes**	Potentially elevated levels of gas could migrate through granular soils or made ground.
Groundwater flow through mineworkings	No	No mineworkings present beneath the site.
Receptors		

SPR item		SPR item present based on desk study (Yes/No)	Comment
Human Receptors			
R1	Children & adults	**Yes**	Site is to be a residential with gardens and, therefore, there is the potential for site occupiers to come into contact with the soils.
R2 – Workers & trespassers		**Yes**	The site is to be developed and, therefore, workers and potentially trespassers on site
R3 – Adjacent land users		**Yes**	Adjacent developments include residential developments.
Plant Receptors			
R4 – Plants		**Yes**	Site is to be a residential with gardens and, therefore, there is the potential for plant growth.
Buildings/services receptors			
R5 – Buildings and infrastructure		**Yes**	The site is to be developed and, therefore, buildings will be present on site.
Water environment – surface waters			
Major River		No	There are no major surface water features within influencing distance of the site. In view of the distance to a major surface water, the localised nature of the made ground on site and the presence of intervening very low permeability glacial till soils which significantly retard contaminant migration, it is considered that there is no significant pathway present. In the absence of a significant pathway there is no significant pollutant linkage present and no further assessment is necessary.
R7 – Drains		**Yes**	Several small surface water drains are present at the site boundaries.
Water environment – groundwater abstraction			
Shallow perched groundwater		No	No groundwater abstractions recorded within 1km. In addition, any perched water in the made ground on site is unlikely to meet the criteria outlined in the WAT-PS-10-01 (Assigning Groundwater Assessment Criteria for Pollutant Inputs) and UKTAG (i.e. that in order to qualify as a body of groundwater an aquifer must be capable of supplying $10m^3$/day or 50 people on a continuous basis). **Therefore, in the absence of a receptor or water body no further assessment is required.**
Continuous groundwater in soil		No	No groundwater abstractions recorded within 1km. Natural superficial deposits are very low permeability glacial till, groundwater within which does not constitute a water body, **in the absence of a receptor no further assessment is required.**
Continuous groundwater in rock		No	No groundwater abstractions recorded within 1km. Although the underlying rock is noted to be sedimentary and groundwater within these strata may be classed as a water body**, in the absence of an abstraction receptor no further assessment is required.** Researches indicate that rock is overlain by very low permeability glacial till soils which significantly retard downward contaminant migration. **It is considered that there is no significant pathway present and in the absence of an intact pathway no further assessment is required.**
Water environment – groundwater resource			
Shallow perched groundwater		No	Any perched water in the made ground on site is unlikely to meet the criteria outlined in the WAT-PS-10-01 (Assigning Groundwater Assessment Criteria for Pollutant Inputs) and UKTAG (i.e. that in order to qualify as a body of groundwater an aquifer must be capable of supplying $10m^3$/day or 50 people on a continuous basis). **The perched water in the made ground is not considered to be a groundwater body and as such is not a receptor.**
R9 – Continuous groundwater in soil		**Yes**	Researches/investigations indicate the potential existence of significant thickness of very low permeability glacial till soils, groundwater within which does not constitute a water body. However, as some granular soils may also be present, any groundwater present in these strata may meet the criteria outlined in the WAT-PS-10-01 (Assigning Groundwater Assessment Criteria for Pollutant Inputs) and UKTAG (i.e. that in order to qualify as a body of groundwater an aquifer must be capable of supplying $10m^3$/day or 50 people on a continuous basis). **Further investigations are required to confirm the level of risk to this receptor.**
R10 – Continuous groundwater in rock		**Yes**	The rock strata are indicated to be sedimentary though are overlain by low permeability glacial till. As such any water in the deeper aquifer may meet the criteria outlined in the WAT-PS-10-01 (Assigning Groundwater Assessment Criteria for Pollutant Inputs) and UKTAG (i.e. that in order to qualify as a body of groundwater an aquifer must be capable of supplying $10m^3$/day or 50 people on a continuous basis). **Further investigations are required to confirm the level of risk to this receptor.**
Water environment – groundwater dependent terrestrial ecosystem (GDTE or wetland)			
GDTE/Wetland		No	No GDTE/Wetland within 250m of the site.

4.2 Objectives of the Site Investigation and Methodology

The initial conceptual site model was used to inform the design of the site investigation. Where chemical analysis data has been obtained for soils and waters, JPB's risk assessment methodology comprises an initial comparison of potential contaminant concentrations with Stage 2 Risk Assessment generic assessment criteria. The concentrations of contaminants exceeding these criteria and contaminants for which authoritative Stage 3 Risk Assessment criteria were not available are assessed in Stage 3 Risk Assessment, a site-specific quantitative risk assessment.

The Stage 3 Risk Assessment comprises a quantitative risk assessment of contaminant concentrations performed using appropriate risk assessment models and tools. These assessments are discussed in more detail in the later sections of this report.

In order to test and develop the initial CSM, the site investigations had the following objectives:

- To identify the extent of any made ground at the site (potential contaminant source)
- To identify the nature, extent and concentration of contaminants in soil, groundwater and ground gases.
- To determine if contaminants are leachable or otherwise mobile.
- To examine the ground gas regime at the site.
- To determine what threat the site poses to off site water receptors.
- To determine what threat the site contaminants pose to off site human receptors (occupants of adjacent properties).
- To determine what threat the site poses to on site human receptors (workers and occupants).
- To determine geotechnical properties of soils.
- To determine foundation solutions for development.
- To confirm the mining conditions noted in the previous report, and in particular the depth to and condition of the Upper Hirst Coal and the Calmy Limestone, to ensure that no mining was undertaken from the nearby quarry

In order to achieve these objectives, the investigation was designed to include the following; trial pitting, cable percussive boreholes with standpipes installed, rotary openhole boreholes and specialist laboratory testing of recovered soil and water samples for geotechnical and chemical characteristics. Monitoring of ground gas concentrations and groundwater levels in standpipes was also undertaken. These investigations are described in more detail in the following section of this report.

PART THREE – SITE INVESTIGATIONS

5.0 SITE INVESTIGATIONS

5.1 Programme of Works and Investigation Rationale

The design and performance of this site investigation takes cognisance of the guidance given in BS 10175 – Investigation of Potentially Contaminated Sites – Code of Practice – BSI 2011 and BS5930. Investigation points were located where access, ground conditions and underground services allowed. It should be noted that soil and rock conditions are highly variable and may differ between sampling points and under stockpiles and within flooded areas and this may affect interpolation. Additional features may exist buried at depth and undetected by investigation. The surveyed locations of all trial pits and boreholes are shown on JPB Drawing TG276-22/R/F/04.

2020 investigation

Work Item	Description	Appendix
Trial pit excavations	Ninety six trial pits, to between 0.5m and 3.5m depth on a 50m grid, undertaken by a Johnson Poole & Bloomer Engineering Geologist between 22nd and 28th January 2020.	Appendix 10
Rationale	To investigate the nature, extent and engineering properties of the soils underlying the site and recover soil samples for chemical analysis.	
Cable Percussive Boreholes	Thirty four soils boreholes (S301-S309A, S312, S314-S316, and S319-S332 including re-drills), to depths of between 1.10m and 5.00m, were sunk by Aitken Laboratories Limited across the site between 21st January and 18th February 2020.	Appendix 11
Rationale	To investigate the nature, extent and engineering properties of the soils underlying the site and recover soil samples for geotechnical and chemical analysis.	
Geotechnical testing	**Geotechnical laboratory** testing of soil samples was performed by Aitken Laboratories Limited and included the following: i) Bulk Density. ii) Moisture Content and Atterberg Limits. iii) Undrained triaxial compression testing. iv) One dimensional consolidation testing. v) Particle Size Distribution (PSD). vi) California Bearing Ratio (CBR) value.	Appendix 11
Rationale	To determine engineering properties of the soils underlying the site.	
Rotary drilling	Two rotary open hole boreholes (R1 to R2), both to a depth of 30m, were sunk by Hydracrat Limited across the site between 28th and 29th January 2020.	Appendix 12
Rationale	To confirm mining assessment from previous work carried out by others and to allow standpipes to be installed into the underlying bedrock.	
Chemical contamination testing	**Ninety four soil samples** from the trial pits and **two surface and twenty eight groundwater samples** were analysed by I2 Analytical at our instruction. The soil testing programme comprised the following chemical parameters; **asbestos (presence and type), pH, total sulphate, water soluble sulphate, sulphides, phenols, total cyanide, Total Petroleum Hydrocarbons (TPH), Polyaromatic Hydrocarbons (PAH), arsenic, mercury, selenium, lead, total chromium, hexavalent chromium, cadmium, copper, nickel, zinc, water soluble boron and percentage soil organic matter (SOM)**. All samples were tested for **leachability** where appropriate. In addition, a random selection of samples was scheduled for **asbestos (presence and type)** and **a suite of commonly encountered pesticides** to determine whether these contaminants were present at the site. The ground and surface water testing programme comprised the following chemical parameters – **arsenic, mercury, selenium, copper, nickel, zinc, lead, chromium (total), hexavalent chromium, cadmium, calcium, iron, magnesium, manganese, boron, sulphate, chloride, sulphide, cyanide, phenols, BOD, ammoniacal nitrogen, phosphate, speciated PAH** and **TPH (GC)**. Samples were tested on site for **pH, conductivity, dissolved oxygen** and **temperature**.	Appendix 13
Rationale	To determine concentrations of potential chemical contaminants in the soils, surface water and groundwater underlying the site.	
Gas and water monitoring	Gas and water monitoring at standpipes installed in twenty six of the soils boreholes and the two rotary boreholes was carried out. Levels of methane, carbon dioxide, oxygen, nitrogen, carbon monoxide, hydrogen sulphide and atmospheric pressure were recorded. Flow rates were also recorded. Following the collection of the gas data the depth to any water present within the	Appendix 14

Work Item	Description	Appendix
	standpipes installed in the boreholes was measured using a dipmeter.	
Rationale	To determine the groundwater and ground gas regimes at the site	
On site testing of ground and surface waters	Ground and surface water samples were tested on site for the following key parameters: **temperature, dissolved oxygen level, pH** and **conductivity**. **Rising head tests** were also undertaken following purging of the boreholes. Recovered groundwater samples were tested for a wide range of potential contaminants as discussed in the following sections.	Appendix 14
Rationale	To determine concentrations of potential chemical contaminants in the surface water and groundwater underlying the site.	

Targeted Investigation Point	Target	Specific Contamination Analysis
Trial Pit SP1 to SP11	Stockpiles on site	General suite plus asbestos.
Borehole S322	Landfill adjacent to eastern site boundary	For gas monitoring purposes.

5.2 Contamination Assessment Sampling Protocols

JPB's sampling protocol is discussed in detail in Appendix 8. Site specific sampling details are discussed below.

Soil Sampling

In the investigations, locations were targeted at known historical features such as the farm steading, but were also spread across the site to achieve appropriate site coverage. For main investigations BS10175 indicates that "typical" densities can vary between 10m and 25m centres. However, given the predominantly greenfield nature of the vast majority of the site throughout its history, JPB consider that investigations at between 25m and 50m centres is more appropriate. This was confirmed by trial pits which showed that soils at the site predominantly comprised natural deposits, with localised made ground associated with the former steading.

For this site, with an area of 31.49ha, this is equivalent to between 125 and 503 investigation locations. During the works a total of 130 investigation locations (96 trial pits, and 34 boreholes) and 94 samples had been undertaken, which falls in the lower end of the above requirements for a main investigation for a site of this size. This does not include the previous works carried out at the site.

Groundwater and Surface Water Sampling

Attempts were made to recover water samples from all of the boreholes except boreholes S323 which were dry. During this exercise only minor water was present in S302, S318, S320, S322, S324, S326, S327, S329, and S331 which did not recharge on purging, therefore, there was insufficient in volume to allow representative samples to be collected from these boreholes. Following purging representative samples were recovered from S301, S303, S304, S305, S306, S307, S308, S309, S312, S314, S315, S316, S319, S321, S325, S328, and S330.

Surface waters were also recovered from the small drain at the north eastern site boundary water both upstream and downstream of the site.

PART FOUR – GEOTECHNICAL

6.0 SITE GEOLOGY

6.1 General

The general geological conditions beneath the site were assessed from the available information including a review of geological maps and boreholes. This provided an indication of the general thickness of the superficial cover.

The recent investigations appear to confirm the anticipated geological conditions with generally topsoil, and very occasional made ground overlying glacial deposits. A summary of ground conditions is shown on JPB Drawing TG276-22/R/F/07.

6.2 Made Ground

General site

Made ground was encountered in trial pits TP320, TP323, TP324 TP328, TP338, TP345, TP355, TP362, TP365, TP366, TP368, and in the previous investigation by D R Murray TP222, TP248, TP249, and TP250.

In the majority of cases, this is believed to be reworked natural material, as there is little evidence of anthropogenic materials apart from occasional ceramic fragments noted within the soil.

Within trial pit TP320 a sandy gravelly clayey topsoil with bin bags, plastic, netting, cloth, and decaying vegetation was noted from ground level to 0.6m

Within trial pits TP222, TP248, TP249 and TP250 of the previous investigation a layer of ash and cinders intermixed with silty sand, with porcelain and glass fragments was recorded. This was recorded from depths between 0.1m to 0.2m to depths between 0.3m to 1.3m and was between 0.2m to 1.1m in thickness

Stockpiles

The stockpiles that were present across the site were also investigated, with shallow pits (SP1 to SP11) being excavated into these. The material within the stockpiles were recorded as a silty, sandy, gravelly clay with cobbles, and also recorded ceramics, plastic, occasional brick fragments, and rootlets. This appears to be reworked natural deposits with some construction materials present.

6.3 Natural Deposits

The site is covered by a layer of topsoil which varies in thickness from 0.1m to 0.8m, though parts of the site where earthworks have been undertaken have had the topsoil removed.

This is generally underlain by a firm to stiff consistency, occasionally noted as soft or very soft consistency, medium to high strength, occasionally noted as low strength, sandy, gravelly clay with varying amounts of cobbles and boulders.

Within many of the trial pits and boreholes a silty, clayey, gravelly sand, or silty, sandy, cobbly gravel was also noted, often interbedded within the clay deposits above. This was recorded from depths between 0.2m to 2.6m to depths between 0.35m to 3.0m and was between 0.15m to 1.3m in thickness.

Within trial pits TP312, TP312A, TP312C, TP312D, and TP321 a soft consistency, low strength, sandy, gravelly peaty clay was recorded. Decaying vegetation was also noted in trial pit TP321. This was recorded from depths between 1.30m to 2.50m to depths between 1.80m to 3.1m and was between 0.2m to 0.7m in thickness.

Trial pits TP312, TP312A, TP312C, TP312D, TP117 from the previous investigations, also recorded a clayey silty amorphous peat. This was recorded from depths between 0.10m to 2.4m to depths between 0.35m to 2.5m, and was between 0.1m to 0.3m in thickness.

It should be noted that peat may extend beyond the locations shown on site.

In the previous investigation, trial pit TP225 and borehole BH17 also recorded a sandy silty from depths between 0.2m to 1.2m to depths between 0.9m to 2.35m and was between 0.7m to 1.15m in thickness.

6.4 Solid Geology

In the eastern area of the site, several of the trial pits and boreholes from both the current and previous investigation encountered potential rockhead at depths between 0.7m to 2.35m. Within the central area of the site this was recorded at depths between 1.8m to 3.8m, while in the western area of the site, two trial pits encountered possible bedrock at depths between 1.5m to 1.7m.

The rotary drilling carried out in the current investigation encountered rockhead at between 13.0m and 15.2m. The strata were recorded as a sequence of sandstone and mudstones with no coals or limestones encountered. These strata were proven up to a maximum of 30m depth which is consistent with the anticipated Carboniferous strata.

6.5 Groundwater

Water was recorded in the trial pits and boreholes as follows. The remainder were recorded as dry.

Trial Pit/Borehole	Depth (m)	Comment
TP305	-	Pit noted as wet
TP307	-	Pit noted as wet
TP311	-	Pit noted as wet
TP314	2.4	Pit noted as terminated due to flooding water at base.
TP321	3.3	Slight seepage noted at base.
TP326	2.3	Rapid ingress of water flooding pit. Pit terminated due to flooding
TP329	1.65	Slight seepage
TP332	0.7	Slight seepage
TP339	2.6	Water ingress. Trial pit terminated due to flooding
TP369	-	Slight seepage noted within pit
TP377	0.25	Moderate ingress
TP378	0.3	Slight ingress
TP382	-	Pit noted as wet
TP386	0.8	Water seepage
S316	0.4	-
S326	1.7	-

The standpipes installed during the investigation were subsequently monitored and the results are summarised in the following table.

BH	Surface level (mAOD)	Response Zone	Response Materials	Water level (mAOD)					
				17-18/02/20	02/03/20	23/03/20	06/04/20	20/04/20	13-15/05/20
R1	101.9	15m to 20m	Bedrock	Dry	-	81.97	81.69	81.69	81.03
R2	102.3	13m to 18m	Bedrock	Dry	82.3	Dry	Dry	Dry	Dry
S301	96.1	1m to 3.5m	Glacial till	95.73	95.79	95.26	95.39	95.12	95.11
S302	97.1	1m to 4m	Glacial till	95.26	96.66	96.58	96.66	96.34	96.41
S303	103.4	1m to 4m	Glacial till	-	103.12	101.99	-	101.79	101.75
S304	96.6	1m to 5m	Glacial till	96.03	96.19	95.72	-	95.51	95.57
S305	99.6	1m to 5m	Glacial till	99.15	99.39	98.29	99.01	98.99	98.96
S306	99.6	1m to 5m	Glacial till	99.13	99.16	98.29	98.52	98.22	98.16
S307	93.9	0.5m to 3.5m	Glacial till	93.72	93.68	92.91	92.91	92.72	92.79
S308	90.2	1m to 2.4m	Glacial till/Bedrock	89.64	89.8	89.42	89.39	89.29	89.19
S309	90.9	1m to 1.5m	Glacial till/Bedrock	Dry	90.68	90.5	90.35	90.35	90.29
S312	82.5	1m to 5m	Glacial till	81.82	-	82.15	82.03	82.04	81.91
S314	85.8	1m to 2.8m	Glacial till	85	84.76	84.59	84.54	84.14	84.62
S315	84.6	1m to 2.4m	Glacial till	84.6	84.5	84.52	84.31	83.85	84.19
S316	89	1m to 2.9m	Glacial till	88.78	89	-	88.43	-	88.33
S318	87.2			85.4	86.73	86.44	85.99	86.21	86.02
S319	88.3	1m to 4.6m	Glacial till	87.97	86.37	87.05	86.98	86.32	87.11
S320	86.8	0.5m to 1.3m	Glacial till	86.27	85.73	85.66	85.67	Dry	85.7
S321	36.5	1m to 1.9m	Glacial till	35.81	36.28	35.16	34.85	Dry	34.79
S322	88.5	1m to 3m	Glacial till	88.27	88.38	88.13	87.56	87.16	87.42

BH	Surface level (mAOD)	Response Zone	Response Materials	Water level (mAOD)					
				17-18/02/20	02/03/20	23/03/20	06/04/20	20/04/20	13-15/05/20
S323	95.75	1m to 2.6mm	Glacial till	Dry	95.25	95.32	94.69	94.76	94.64
S324	95.9	1m to 2.5m	Glacial till	91.63	94.7	95.35	95.12	95.31	95.22
S325	92.5	1m to 3.8m	Glacial till/Bedrock	91.57	92.31	92.09	91.8	91.73	91.61
S326	94	1m to 2.5m	Glacial till/Sand	93.81	93.71	93.41	93.2	92.98	93.09
S327	92.4	1m to 3.9m	Glacial till	92.28	92.18	91.72	91.61	91.39	91.52
S328	94.6	1m to 5m	Glacial till	Dry	94.46	94.42	93.57	93.62	93.48
S329	97.6	1m to 4.4m	Glacial till	Dry	97.38	97.16	96.39	96.75	96.44
S330	100.2	1m to 5m	Glacial till	99.97	99.48	99.71	99.56	99.71	99.59
S331	99	1m to 5m	Glacial till	97.7	98.81	98.62	98.62	-	98.59
S332	99.7	1m to 5m	Glacial till	-	-	-	99.01	99.02	98.88

Calculated hydraulic conductivity for the boreholes were calculated as follows.

Borehole	Borehole Rising Head Permeability Value (m/s) (First monitoring round)	Borehole Rising Head Permeability Value (m/s) (second monitoring round)	Additional Remarks
S301	4.86×10^{-8}	1.58×10^{-6}	-
S302	4.35×10^{-8}	3.69×10^{-8}	-
S303	-	1.31×10^{-8}	Instant recharge (first visit)
S304	1.45×10^{-8}	9.87×10^{-9}	-
S305	1.97×10^{-8}	1.48×10^{-7}	-
S306	-	5.02×10^{-8}	Did Not recharge (first visit)
S307	3.60×10^{-8}	7.65×10^{-9}	-
S308	2.90×10^{-6}	1.08×10^{-6}	-
S309	1.28×10^{-5}	1.28×10^{-7}	-
S312	2.23×10^{-8}	-	(unable to monitor on second visit)
S314	1.87×10^{-7}	5.25×10^{-7}	-
S315	1.43×10^{-7}	1.30×10^{-6}	-
S316	6.76×10^{-8}	1.80×10^{-8}	-
S318	3.23×10^{-8}	2.41×10^{-8}	-
S319	7.63×10^{-8}	-	-
S320	1.83×10^{-8}	-	Did not recharge (second visit)
S321	1.15×10^{-6}	1.32×10^{-7}	-
S322	2.34×10^{-8}	7.87×10^{-7}	-
S323	-	5.43×10^{-8}	Dry (first visit)
S324	8.34×10^{-8}	4.67×10^{-9}	-
S325	4.65×10^{-8}	6.93×10^{-9}	-
S326	1.92×10^{-7}	5.52×10^{-7}	-
S327	1.12×10^{-7}	2.96×10^{-8}	-
S328	2.36×10^{-8}	7.61×10^{-9}	-
S329	5.89×10^{-9}	1.30×10^{-9}	-
S330	1.53×10^{-8}	2.30×10^{-9}	-
S331	1.66×10^{-8}	9.20×10^{-9}	-

Bear, J. (1972). Dynamics of Fluids in Porous Media suggest the following characteristics of an aquifer based on permeability.

K (cm/s)*	10^{2}	10^{1}	10	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}
Relative Permeability	Pervious				Semi-Pervious				Impervious				
Aquifer	Good					Poor				None			

***Note measurement in cm/s not m/s.**

Based on this the deposits are classed are generally classed as an impervious poor aquifer, though a few would be classed as a semi-pervious and poor aquifer. This is what would be anticipated for a glacial till with limited granular deposits.

The results do not indicate the presence of a clearly defined water table at the site. Some limited ingress of water has been recorded within the standpipes which may be as a result of the surface water ponding on the site at the time of the investigation. Site results indicate that there was generally limited or no recharge of groundwater following purging.

7.0 ENGINEERING CHARACTERISTICS OF THE SUPERFICIAL MATERIALS

7.1 General

The results of the in situ and laboratory geotechnical testing of the samples recovered during the recent investigations are included in Appendix 11. The soil parameters from the in situ and laboratory testing of samples are summarised in the following table.

7.2 Natural Superficial Deposits

Cohesive

Material Type	Glacial till
Natural Moisture Content (%)	11.2-21.9
Plastic Limit (%)	12-18
Liquid Limit (%)	24-34
Plasticity Index (%)	10-16
Soil type based on plasticity chart	Clay of low plasticity
Soil descriptions from PSD	Silty, sandy, gravelly, clay
Range of consistency	Generally firm to very stiff, occasionally soft and very soft
Soil Density (Mg/m^3)	1.97-2.32
Hand Vane tests results	20-143kPa
Undrained triaxial test results **c =** **Φ =**	 7-130kPa 2-17°
Average Shear Strength	16-263kPa
Undrained Shear Strength Classification	Very low to Very high strength
Standard Penetration Test (SPT) N values	15-27
Mass Shear Strength (c) based on SPT value using Stroud Correlation	96-189kPa
Undrained Shear Strength Classification	High to very high strength
One-dimensional consolidation testing **m_v =**	 0.021-0.333m^2/MN (*)
Compressibility	Very low to high compressibility
Modulus of volume compressibility (m_v) based on SPT value (Stroud)	0.052-0.104m^2/MN
Compressibility	Low to medium compressibility
California Bearing Ratio (CBR) value (%)	0.2-1.9

(*) - The m_v values recorded for overconsolidated soils such as glacial till can often be out by a factor of up to 2. As such it is anticipated that these soils have a low to medium compressibility. This is confirmed by using the correlation proposed by Stroud using the SPT N value and plasticity index.

Granular

Material Type	Glacial till
Standard Penetration Test (SPT) N values	5
State of Compaction	Loose

8.0 FOUNDATION DESIGN CONSIDERATIONS

8.1 General

Based upon the engineering properties of the soils as discussed in previous sections of this report, we would offer the following comments regarding suitable founding horizons. The wall loadings for the proposed development are unknown at present but are assumed to be in the range of 50kN/m to 75kN/m for the houses. A summary of ground conditions is shown on JPB Drawing TG276-22/R/F/07.

8.3 Natural Deposits

The investigation has indicated the presence of very low and low strength alluvial clays, which commonly contain peaty inclusions, and peat horizons. These deposits are not considered to be suitable as a foundation horizon and as such the foundation loading should be transferred to the deeper glacial deposits with a medium to high strength. It is recommended that the peat deposits are removed from site.

Strip foundations

In some places within the site, granular glacial deposits lie at shallow depths. Where this material lies within foundation depth then a conservative design would be to assume an N value at foundation level at shallow depth of around 5. From this, the allowable bearing capacity for 0.6m, 0.8m and 1.0m wide strip foundations placed at 600mm depth or 300mm into the natural, whichever is shallower, with all settlement within acceptable limits less than 25mm are summarised below in the following table.

Width (m)	Allowable Bearing Capacity (kN/m^2)	Equivalent Line Loading (kN/m run of foundation)
0.6	60	36
0.8	55	44
1.0	50	50

The cohesive glacial till deposits lie at shallow depths across parts of the site. Where this material lies within foundation depth then a conservative design would be to assume a shear strength at foundation level at shallow depth of around 45kN/m^2. From this, the allowable bearing capacity for 0.6m, 0.8m and 1.0m wide strip foundations placed at 600mm depth or, where made ground is present at 600mm depth, 300mm into the natural, whichever is shallower, with all settlement within acceptable limits less than 25mm are summarised below in the following table.

Width (m)	Allowable Bearing Capacity (kN/m^2)	Equivalent Line Loading (kN/m run of foundation)
0.6	100	60
0.8	97	77
1.0	94	94

8.4 Rock Strata

Borehole information from both this and the previous phases of site investigation indicates weathered rockhead was encountered at around 0.7m to 3.8m in parts of the site, and with the two rotary boreholes encountering bedrock between 13.0m to 15.2m in the western site area. This would be the suggested founding horizon if the materials noted above cannot support the proposed foundations, and they are within shallow depth. A presumed bearing capacity for the rock would be at least 250kN/m^2.

8.5 General Comments

pH values and sulphate levels were recorded above laboratory reporting limits therefore an assessment was carried out in accordance with BRE Special Digest 1. The ground conditions indicate design sulphate class DS-1 and ACEC class AC-1s. **Therefore, concrete specifications should be such as to be protective of buildings exposed to these conditions.**

During site works, should any localised softening of the soils be encountered then these materials should be removed and replaced with well compacted hardcore. In addition, it is imperative that the foundation excavations are kept dry to ensure the integrity of the glacial till deposits as this material is very sensitive to wetting. All excavations should be examined to ensure that the material is consistent with that used in the assessment.

The foundations may span material varying between granular to cohesive in nature and therefore the possibility of differential settlement should be taken into account during the design work.

Groundwater was encountered during the investigation at depths of around 0.4m. As such this could be encountered during any excavations during the site development works. Therefore, during the design of any excavations at the site due consideration should be given to the control of surface water and possible ground inflow and sidewall stability, with all necessary precautions being taken to ensure safe working conditions. This should be carried out in accordance with Health & Safety and CDM Guidance.

Shallow rock was encountered at parts of the site and this may be encountered during any excavations during the development such as the construction of sewers.

8.6 Compaction Characteristics and Foundations on Upfill

Compaction testing has been undertaken, and we are currently awaiting the results of these. These will be discussed in the final report.

9.0 ROAD CONSTRUCTION

The investigation has indicated that the site is underlain by natural soil deposits generally comprising glacial till then in parts of the site shallow rock. In parts of the site, lower strength alluvial deposits, comprising peaty clays and peat were also noted.

Where the peat and peaty clays were recorded these will require to be removed and replaced with acceptable material. Any material beneath the road will require to be placed in accordance with the Specification of Highway Works Series 600 and appropriate testing carried out to confirm the acceptability of the material.

Prior to the construction of any adoptable roads CBR testing would be required at 25m centres along the route of these in order to ascertain the requirements for a capping layer. It should be noted, however, that any road built on areas of made ground or any upfilled areas would require a full capping layer.

Selective CBR test were carried out at random locations and these indicated CBR values in the range of 0.2% to 1.9%.

The recorded CBR values were below 2.5% and therefore the material is a soft sub-grade as per Interim Advice Note 73/06 Revision 1 (2009) Design Guidance for Road Pavement Foundations (Draft Hd25) then the measures outlined in that document should be undertaken to address these issues. The guidance is as follows

The minimum permitted Design CBR is 2.5% CBR. Where a subgrade has a lower CBR it is considered unsuitable support for a pavement foundation. It must therefore be permanently improved using one of the options given in the following paragraphs.

The material at the surface can be removed and replaced by a more suitable material. If the depth of relatively soft material is small, it can be replaced in its entirety, although it may only be necessary to replace the top layer. The thickness removed will typically be between 0.5 and 1.0m.

Although the new material may be of better quality, the new Design CBR should be assumed to be equivalent to 2.5%, in order to allow for effects of any softer underlying material and the potential reduction in the strength of the replacement material to its long-term CBR value.

If the soil is cohesive, a lime (or similar) treatment may be appropriate, subject to soil suitability being demonstrated. Details of various soil treatments are given in HA44 (DRAB 4.1.1). The new Design CBR should again be assumed to be equivalent to 2.5% unless agreed otherwise under Departure from Standard approval. HA 74 (DMRB 4.1.6) contains further advice on stabilisation.

The investigation has confirmed that there is no constraint to any adoptable roads on the site due to shallow abandoned mineworkings.

Site Operatives During Construction of the Development

While no specific unusual risks have been identified, any development works should be carried out in accordance with the Construction Industry Research and Information Association (CIRIA) Report 132 entitled “A Guide for Safe Working on Contaminated Sites 1996”.

There are no requirements for gas remedial works in the road although adequate health and safety provisions should be made with regard to monitoring gas levels within any trenches formed on site.

Roads Maintenance Workers in the Completed Development

While there no specific unusual risks have been identified, any works should be carried out in accordance with the Construction Industry Research and Information Association (CIRIA) Report 132 entitled “A Guide for Safe Working on Contaminated Sites 1996”.

General

As with any construction or maintenance activity, risks to workers should be managed by appropriate health and safety risk assessments/COSHH undertaken in the normal manner by the employer prior to works being undertaken as required by health and safety legislation.

PART FIVE – CHEMICAL CONTAMINATION AND GAS EMISSIONS ASSESSMENT

10.0 STAGE 2 GENERIC QUANTITATIVE RISK ASSESSMENT - CHEMICAL CONTAMINATION

10.1 Introduction

The Stage 2 generic quantitative assessment of risk to human health, property, ecology, surface water and ground water considers the potential for exposure based on comparison of the results to conservative generic criteria. JPB's risk assessment methodology is discussed in detail in Appendix 8 and is summarised in the flow chart presented in that appendix.

In terms of human health, the guideline concentration appropriate to the proposed end use of the site is used in the interpretation of the results. The site is proposed for development as houses with gardens, therefore, the most relevant criteria, those for a residential with plant uptake development have been adopted. At Stage 2 all soil contaminant concentrations are compared with GACs. If necessary, at Stage 3 representative soil contaminant concentrations are calculated and used for comparison with assessment criteria.

10.2 Risk Assessment

The following tables summarise the results of the Stage 2 assessment. For C4SLs, S4ULs and EIC/AGS/CL:AIRE values derived using 1% soil organic matter have been adopted where available. JPB derived GAC have been derived conservatively assuming site soils have 1% soil organic matter.

Human Health - Chemical Contamination

Parameter	Concentration range (mg/kg)	Concentration range exceeding JPB GAC (mg/kg)	GAC Residential with plant uptake (mg/kg)	Source of GAC	No. and location of exceedences
Arsenic	1.5-13	None	37	C4SL	None
Boron	<0.2-1.7	None	290	S4UL	None
Cadmium	<0.2-0.6	None	22	C4SL	None
Chromium (III)	14-58	None	910	S4UL	None
Hexavalent Chromium (Chromium (VI))	Below Detectable Limits	None	21	C4SL	None
Copper	7.8-190	None	2400	S4UL	None
Lead	12-290	210-290	200	C4SL	Twelve TP332 at 0.2 TP334 at 0.15 TP338 at 0.1 TP344 at 0.2 TP366 at 0.2 TP393 at 0.3 TP396 at 0.2 SP1 at 0.2 SP7 at 0.2 SP9 at 0.2 SP10 at 0.2 SP11 at 0.2
Mercury (Inorganic mercury)	<0.3-1.6	None	40	S4UL	None
Nickel	9.5-44	None	130	S4UL	None
Selenium	<1.0-2.7	None	250	S4UL	None
Zinc	24-270	None	3700	S4UL	None
Cyanides	<1-2	None	24.5	JPB GAC	None
Toluene	Below Detectable Limits	None	130	S4UL	None
Ethylbenzene	Below Detectable Limits	None	47	S4UL	None
Benzene	Below Detectable Limits	None	0.87	C4SL	None
o - xylene	Below Detectable Limits	None	60	S4UL	None
m - xylene	Below Detectable Limits	None	59	S4UL	None

Parameter	Concentration range (mg/kg)	Concentration range exceeding JPB GAC (mg/kg)	GAC Residential with plant uptake (mg/kg)	Source of GAC	No. and location of exceedences
p – xylene	Below Detectable Limits	None	56	S4UL	None
Phenols	<1.0-1.2	None	120	S4UL	None
Aliphatic TPH EC_5 –EC_6	Below Detectable Limits	None	42	S4UL	None
Aliphatic TPH >EC_6 –EC_8	Below Detectable Limits	None	100	S4UL	None
Aliphatic TPH >EC_8 –EC_{10}	Below Detectable Limits	None	27	S4UL	None
Aliphatic TPH >EC_{10} –EC_{12}	<1.0-9.3	None	130	S4UL	None
Aliphatic TPH >EC_{12} –EC_{16}	<2.0-21	None	1100	S4UL	None
Aliphatic TPH >EC_{16} –EC_{35}	<8.0-182	None	65000	S4UL	None
Aromatic TPH >EC_5 –EC_7	Below Detectable Limits	None	70	S4UL	None
Aromatic TPH >EC_7 –EC_8	Below Detectable Limits	None	130	S4UL	None
Aromatic TPH >EC_8–EC_{10}	Below Detectable Limits	None	34	S4UL	None
Aromatic TPH >EC_{10} –EC_{12}	<1.0-1.9	None	74	S4UL	None
Aromatic TPH >EC_{12} –EC_{16}	<2.0-9.2	None	140	S4UL	None
Aromatic TPH >EC_{16} –EC_{21}	<10-28	None	260	S4UL	None
Aromatic TPH >EC_{21} –EC_{35}	<10-120	None	1100	S4UL	None
Naphthalene	<0.05-0.46	None	2.3	S4UL	None
Acenaphthylene	Below Detectable Limits	None	170	S4UL	None
Acenaphthene	<0.05-0.79	None	210	S4UL	None
Fluorene	<0.05-0.51	None	170	S4UL	None
Phenanthrene	<0.05-4.7	None	95	S4UL	None
Anthracene	<0.05-1.0	None	2400	S4UL	None
Fluoranthene	<0.05-5.5	None	280	S4UL	None
Pyrene	<0.05-5.2	None	620	S4UL	None
Benz(a)anthracene	*	*	*	*	*
Chrysene	*	*	*	*	*
Benzo(b)fluoranthene	*	*	*	*	*
Benzo(k)fluoranthene	*	*	*	*	*
Benzo(a)pyrene	<0.05-2.4	None	5.0	C4SL	None
Indeno (1,2,3-CD) pyrene	*	*	*	*	*
Dibenzo(a,h)anthracene	*	*	*	*	*
Benzo(g,h,i)perylene	*	*	*	*	*

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** Parameter assessed using the benzo(a)pyrene surrogate marker approach.*
PAH ratios have not been calculated as all samples had low or no appreciable PAH contents.

Human Health - Asbestos

Ninety four soil samples were scheduled for laboratory testing for the presence of asbestos. **Chrysotile (white asbestos)** fibres were detected to be present in the soil sample from SP7 at 0.2m. This asbestos was in the form of loose fibres. Asbestos was not identified within the ninety three other samples scheduled for analysis. The sample found to have asbestos present was additionally scheduled for quantification of asbestos, the asbestos contents of the positive sample (SP7 at 0.2m) was <0.001% by weight.

Phytotoxicity – Soils

Parameter	Concentration range (mg/kg)	Concentrations exceeding GAC (mg/kg)	GAC (mg/kg)	Source of GAC	No. and location of exceedences
Copper	7.8-190	120-190	pH dependent	MAFF Guidance	Four TP332 at 0.20 TP334 at 0.15 TP393 at 0.30 SP7 at 0.20
Zinc	24-270	240-270	pH dependent	MAFF Guidance	Three TP332 at 0.20 TP334 at 0.15 SP7 at 0.20
Nickel	9.5-44	None	pH dependent	MAFF Guidance	None
Cadmium	<0.2-0.6	None	3	MAFF Guidance	None
Lead	120-290	None	300	MAFF Guidance	None
Mercury	<0.3-1.6	1.1-1.6	1	MAFF Guidance	TP307 at 0.20 TP316 at 0.20 TP362 at 0.20 SP10 at 0.20
Chromium	14-58	None	400	MAFF Guidance	None
Selenium	<1.0-2.7	None	3	MAFF Guidance	None
Arsenic	1.5-13	None	50	MAFF Guidance	None

Buildings and Services

Buildings and Services – Soils Effect on Concrete

Parameter	Concentration Range	SSAC BRESD1/BRE PBMCL
pH	5.1-8.3	<5 or >8
Total Sulphate	100-2100mg/kg	Not Applicable
Water soluble sulphate	5.1-96mg/L	Not Applicable

Water Environment

1. Groundwater Resource Receptors

A review of the potential water environment receptors at the site was undertaken in the light of the information gained during site investigations.

The site has been shown to be underlain by topsoil, with limited made ground, in turn underlain by very low permeability glacial till which is not a water body. Water monitoring at standpipes has confirmed that groundwater is either absent or intermittently present in low volumes with very slow recharge. The underlying rock is afforded protection by the thick, very low permeability glacial till overlying it. On the basis of this information groundwater resource receptors are considered to be absent from the site and no further assessment of groundwater quality at the site is required.

Leachates

Parameter	Concentration Range (µg/L unless stated otherwise)	Groundwater Receptors		Surface Water receptors	
		RPV/DWS (source) (µg/L unless stated otherwise)	No. and location of exceedences	EQS/MRL (Source) (µg/L unless stated otherwise)	No. and location of exceedences
Arsenic	Below detectable limits	10	None	50	None
Cadmium	Below detectable limits	5	None	Hardness dependant	None
Chromium	1.2	50	None	4.7	None
Copper	21	2000	None	33.17 (m-BAT tool)	None

Parameter	Concentration Range (µg/L unless stated otherwise)	Groundwater Receptors		Surface Water receptors	
		RPV/DWS (source) (µg/L unless stated otherwise)	No. and location of exceedences	EQS/MRL (Source) (µg/L unless stated otherwise)	No. and location of exceedences
Lead	9.0	10	None	1.2	TP316
Mercury	Below detectable limits	1 (MRL)	None	0.07	None
Nickel	2.3	20	None	22.25 (m-BAT tool)	None
Selenium	Below detectable limits	10	None	10	None
Zinc	13	5000 (*)	None	37.14 (m-BAT tool)	None
Cyanide	Below detectable limits	50	None	1 (free cyanide)	None
Sulphate	2.4mg/L	250mg/L	None	400mg/L	None
Sulphide	Below detectable limits	MRL	None	MRL	None
Phenol	1.7	0.5 (*)	TP316	7.7	None

* - indicates a parameter where no maximum concentration is given in the Water Supply (Water Quality) Scotland Regulations 2001 and as such the value from the Water Supply (Water Quality) Scotland Regulations 1990 has been used.

Groundwater

Parameter	Concentration Range (µg/L unless stated otherwise)	Groundwater Receptors		Surface Water receptors	
		RPV/DWS (source) (µg/L unless stated otherwise)	No. and location of exceedences	EQS/MRL (Source) (µg/L unless stated otherwise)	No. and location of exceedences
Arsenic	<0.15-5.40	10	None	50	None
Cadmium	<0.02-0.08	5	None	Hardness dependant	None
Chromium	<0.2-17	50	None	4.7	None
Hexavalent Chromium	<5	MRL	None	3.4	None
Copper	<0.5-69	2000	None	33.17 (m-BAT tool)	Four S319, S328 (wk1 & wk2), S322
Lead	<0.2-2.8	10	None	1.2	Four S309, S321, S328, S322
Mercury	<0.05-0.06	1 (MRL)	None	0.07	None
Nickel	1.0-27	20	One S308	22.25 (m-BAT tool)	One S308
Selenium	<0.6-7.5	10	None	10	None
Zinc	<0.5-35	5000 (1)	None	37.14 (m-BAT tool)	None
Cyanides	Below detectable limits	50	None	1 (free cyanide)	None
Sulphate	4.65-92.2mg/L	250mg/L	None	400mg/L	None
Chloride	6.4-88mg/L	250mg/L	None	250mg/L	None
Sulphide	Below detectable limits	MRL	None	MRL	None
Phenol	<1-6.8	0.5 (1)	Twelve	7.7	None
Iron	<4-26000	200	S308 (wk1 & wk2), S316, S326, S320, S315 (wk1 & wk2), S322	1000	S308 (wk1 & wk2), S316, S314, S315 (wk1 & wk2), S322
Calcium	16-230mg/L	250mg/L (1)	None	MRL	Twenty eight
Magnesium	0.01-27	50mg/L (1)	None	MRL	Twenty eight
Manganese	0.39-1900	50	Twenty three	283.96 (m-BAT tool)	Nineteen

Parameter	Concentration Range (µg/L unless stated otherwise)	Groundwater Receptors		Surface Water receptors	
		RPV/DWS (source) (µg/L unless stated otherwise)	No. and location of exceedences	EQS/MRL (Source) (µg/L unless stated otherwise)	No. and location of exceedences
Boron	<10-66	1000	None	2000	None
BOD_5	<1.0-69				
Ammoniacal Nitrogen	<0.015-1.7	0.5mgNH_4/L	S308 (wk1 & wk2), BS315, S321, S328, S322,	0.3mg total NH_4-N/L	S308 (wk1 & wk2), S312, S319, S315, S321, S328, S322,
Phosphate (as P)	30-130	2200	None	100	S321
Benzene	Below detectable limits	1	None	10	None
Toluene	Below detectable limits	700	None	74	None
Ethylbenzene	Below detectable limits	300	None	20	None
Xylenes	<1.0-5.4	500	None	30	None
Aliphatic TPH EC_5 –EC_6	Below detectable limits	15,000 (2)	None	10 (MRL)	None
Aliphatic TPH >EC_6 –EC_8	Below detectable limits	15,000 (2)	None	10 (MRL)	None
Aliphatic TPH >EC_8 –EC_{10}	Below detectable limits	300 (2)	None	10 (MRL)	None
Aliphatic TPH >EC_{10} –EC_{12}	Below detectable limits	300 (2)	None	10 (MRL)	None
Aliphatic TPH >EC_{12} –EC_{16}	Below detectable limits	300 (2)	None	10 (MRL)	None
Aromatic TPH >EC_8–EC_{10}	<1.0-8.9	300 (2)	None	10 (MRL)	None
Aromatic TPH >EC_{10} –EC_{12}	Below detectable limits	100 (2)	None	10 (MRL)	None
Aromatic TPH >EC_{12} –EC_{16}	Below detectable limits	100 (2)	None	10 (MRL)	None
Aromatic TPH >EC_{16} –EC_{21}	Below detectable limits	90 (2)	None	10 (MRL)	None
Aromatic TPH >EC_{21} –EC_{35}	Below detectable limits	90 (2)	None	10 (MRL)	None
Total TPH	<1.0-8.9	90 (3)	None	10 (MRL)	None
PAH (sum of 4)(4)	Below detectable limits	0.1	None	N/A	N/A
Anthracene	Below detectable limits	N/A	N/A	0.1	None
Benzo(a)pyrene	Below detectable limits	0.01	None	0.01	None
Fluoranthene	Below detectable limits	N/A	N/A	0.1	None
Naphthalene	Below detectable limits	N/A	N/A	2	None

1 - indicates a parameter where no maximum concentration is given in the Water Supply (Water Quality) Scotland Regulations 2001 and as such the value from the Water Supply (Water Quality) Scotland Regulations 1990 has been used.

2 - indicates a parameter where no maximum concentration is given in the Water Supply (Water Quality) Scotland Regulations 2001 and as such the value from the World Health Organisation document WHO/SDE/WSH/05.08/123 (2005): Water Petroleum Products in Drinking Water has been used.

3 - value assumed worst case from document used above (2).

4 - PAH (sum of 4) is the sum of the concentrations of; Benzo(b)fluoranthene; Benzo(k)fluoranthene; Benzo(ghi)perylene and Indeno(123cd)pyrene.

Surface Water

Parameter	Concentration Range (µg/L unless stated otherwise)	Surface Water receptors	
		EQS/MRL (Source) (µg/L unless stated otherwise)	No. and location of exceedences
Arsenic	0.40-0.83	50	None

Parameter	Concentration Range (µg/L unless stated otherwise)	Surface Water receptors	
		EQS/MRL (Source) (µg/L unless stated otherwise)	No. and location of exceedences
Cadmium	0.05-0.06	Hardness dependant	None
Chromium	1.0-1.1	4.7	None
Hexavalent Chromium	Below detectable limits	3.4	None
Copper	5.2-7.7	33.17 (m-BAT tool)	None
Lead	0.22-0.54	1.2	None
Mercury	Below detectable limits	0.07	None
Nickel	2.5-2.9	22.25 (m-BAT tool)	None
Selenium	Below detectable limits	10	None
Zinc	7.5-16	37.14 (m-BAT tool)	None
Cyanides	Below detectable limits	1 (free cyanide)	None
Sulphate	3.81-15.8mg/L	400mg/L	None
Chloride	14-18mg/L	250mg/L	None
Sulphide	Below detectable limits	MRL	None
Phenol	Below detectable limits	7.7	None
Iron	220-540	1000	None
Calcium	8.5-19	MRL	Two
Magnesium	2.6-3.4	MRL	Two
Manganese	18-56	283.96 (m-BAT tool)	None
Boron	Below detectable limits	2000	None
BOD_5	2.7-3.8		
Ammoniacal Nitrogen	<0.015-0.39	0.3mg Total NH_4.N/L	One SW1 Down
Phosphate (as P)	Below detectable limits	100	None
TPH	Below detectable limits	10 (MRL)	None
Benzene	Below detectable limits	10	None
Toluene	Below detectable limits	74	None
Ethylbenzene	Below detectable limits	20	None
Xylenes	Below detectable limits	30	None
Anthracene	Below detectable limits	0.1	None
Benzo(a)pyrene	Below detectable limits	0.01	None
Fluoranthene	Below detectable limits	0.1	None
Naphthalene	Below detectable limits	2	None

Other Parameters

The remaining parameters tested for recorded concentrations below the relevant Stage 2 Risk Assessment generic criteria and, therefore, no Stage 3 assessment was required for these substances for the development considered.

10.3 Summary

Human Health & Phytotoxicity

A range of toxic and phytotoxic soil contaminants were encountered at the site. Asbestos was also recorded within one sample on site. Where recorded concentrations exceeded Stage 2 criteria these parameters are considered further in the Stage 3 assessment.

Water Environment

Lead and phenol leachate concentrations in soil leachates and nickel, iron, manganese, copper, lead, calcium, magnesium, manganese, phenol, phosphate, hexavalent chromium, and ammoniacal nitrogen concentrations in the groundwater were found to exceed Stage 2 criteria. Within the surface waters calcium, magnesium, and ammoniacal nitrogen concentrations were found to exceed Stage 2 criteria. Manganese, lead, magnesium, iron, nickel, copper, calcium, phosphate and ammoniacal nitrogen are likely to be present due to natural processes including mineralisation and microbial action. At the levels recorded these are not considered to be a significant risk to the superficial groundwater receptor.

While one exceedance of hexavalent chromium has been recorded within the groundwater, due to the site history this is not an anticipated contaminant. Confirmation of this result was sought with the lab who noted that this result may be caused by interference. A further sample of groundwater was obtained and tested from this borehole which noted a result that was below detectable limits for hexavalent chromium. As such it is considered that the initial result was due to interference as noted by the lab, and that hexavalent chromium contamination is not present on the site.
The phenol concentrations recorded are considered to be minor exceedances of the GAC, and it is also considered that there is not a groundwater receptor present due to the presence of glacial till across the site. As such this is not considered to be a significant risk. Therefore, it is concluded that **no remedial measures are required to protect water environment receptors.**

Buildings and Services

pH values and sulphate concentrations indicated that the ground conditions fall within design sulphate class DS-1 and ACEC class AC-1s as defined in BRE Special Digest 1.

The requirements for water supply pipes are outlined in the Water Supply Pipes section of this report.

11.0 STAGE 3 DETAILED QUANTITATIVE RISK ASSESSMENT – HUMANS, PLANTS, BUILDINGS & SERVICES

11.1 Introduction

JPB's Stage 3 assessment focuses on chemicals detected in soil, leachates and water samples at concentrations in excess of the Stage 2 criteria. This process assesses whether the potential risks posed are real risks using JPB's quantitative risk assessment methodology. In this section the focus is on the assessment of risk to the human and plant receptors identified using the initial conceptual site model (ICSM). Comments relating to buildings and services receptors from sulphate/concrete specification and hydrocarbons are included in the Remedial Recommendations Section of this report.

Risk item from Stage 2		Receptor from ICSM
Human health		R1 – Children and adult receptors R2 – Workers and trespassers. R3 - Adjacent land users.
Plant Receptors		R4 – Plant growth.
Buildings & services	Chemical conditions	R5 – Buildings and associated infrastructure
	Combustion	
	Slag unsoundness	

11.2 Human Health

In order to determine whether concentrations of contaminants recorded were of concern in the context of the proposed development, a wide range of pollutant linkages were examined in order to determine whether intact linkages existed or could occur as a consequence of development.

The Stage 2 assessment compares all soil contaminant results with GACs, at Stage 3 a Representative Contaminant Concentration (RCC) is derived for each contaminant whose concentration exceeds its GAC or for which there is no GAC and concentrations exceed the laboratory's MRL. As the lead GAC is not based on CLEA modelling, as discussed in JPB's methodology, the GAC of 200mg/kg lead has been conservatively adopted as the SSAC in this case.

RCCs are compared with Site Specific Assessment Criteria (SSAC) derived using CLEA 1.071 as described in, JPB's methodology exceedence of which confirms that a risk to human health is posed by a contaminant's soil concentrations. RCCs have been calculated in accordance with JPB's methodology and consist of either the maximum concentration recorded or a 95% Upper Confidence Limit (UCL95).

CLEA Model

The output spreadsheets for the CLEA modelling and statistical analysis are presented in Appendix 15 and the RCCs and SSACs are summarised below.

Parameter	RCC (UCL_{95} or Max value) (mg/kg)	Type	Human Health assessment		Outliers present
			SSAC Residential with plant uptake (mg/kg)	SSAC exceeded (Yes/No)	
Lead	107.3	Chebyshev UCL	200	No	None
Log Lead	64.86	Chebyshev UCL	200	No	None

NA -Not Applicable

None of the contaminant UCL95 exceeded SSAC concentrations, therefore, contaminant concentrations at the site do not pose a risk to human health and no remedial measures are required.

As the lead model on which the GAC is based is a geometric model, the data was log transformed before statistical analysis was performed. As recent guidance warns that log transformations can mask some statistically important differences, the data was analysed using both raw and log transformed data sets. This indicates that neither the lead nor the log transformed lead RCC exceed the SSAC. It should be noted that no outlier was detected in either data set. The assessment has therefore looked at the RCCs calculated for both lead and log transformed lead. Therefore, based on the above modelling information, it is considered that lead **does not represent a human health risk and therefore no remedial measures are required.**

11.3 Plant Receptors

Based on the results of the Stage 2 assessment, it is noted that the exceedances recorded are marginal to low exceedances of the GAC. Also it should be noted that the site has been used as active agricultural land, with healthy

plant growth. As such, given the nature of the exceedances and the history of the site, is considered that there is **no phytotoxic constraint at the site and no remedial actions are required**.

12.0 WATER SUPPLY PIPES

The following assessment has been undertaken in accordance with Scottish Water guidance and UK Water Industry Research (UKWIR) guidance document, "Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites", UKWIR report reference 10/WM/03/21, 2010. Investigations at the site have confirmed the following conditions.

- The site currently comprises agricultural land.
- Historical OS maps indicate that the site has been greenfield from the earliest available OS map until the present day.
- No industrial, commercial or residential land uses are shown on OS maps and the land has been unoccupied.
- Soils encountered during previous and recent investigations comprised topsoil or occasional reworked natural soils overlying glacial till deposits. In addition, alluvial deposits were identified close to the water courses on the site.
- No evidence of contamination or made ground soils was encountered other than reworked natural soils.

The site has been greenfield throughout its history and according to researches and a site walkover visit no toxic chemicals are stored in the areas of the site under consideration and there is no evidence available that they have been stored on site in the past. Current Scottish Water Guidance - Water Pipe Draft Guidance Version 3.1, indicates that provided desk study information is sufficient, an intrusive investigation including chemical testing will not be required on sites where contaminants are not present such as greenfield sites.

There is, therefore, no restriction on the type of pipe materials which can be used for water supply pipes at the site, other than those imposed by the relevant current Standards and Codes of Practice. On the basis of the above assessment we, therefore, **recommend that Polyethylene (PE) plastic pipes are suitable for use as water supply pipes at the site.**

It should be noted that the water company may require that a PID survey of the route of water supply pipes is undertaken, extending to 15m either side of the pipe route, in order to confirm that no unexpected chemical contamination is present. Alternatively, this requirement can be satisfied by upgrading pipe materials to PE-Al-PE barrier pipe, which would be protective of water supplies.

While TPH products were recorded within several trial pits across the site, further examination of the chromatograms indicate that these are likely to be plant based hydrocarbons rather than any form of fuel product. Also the majority of these were found at shallow depth, in soil which any water pipes are unlikely to come into contact with.

As such it is considered that no contaminant concentrations were identified which are considered to permeate water pipes or impact on their integrity. Therefore, no restriction is made on the type of water pipes which can be used on the site. Scottish Water supply pipe assessment documents are presented in Appendix 16.

Backfill Materials

We would recommend that clean backfill is used around the pipes as this will both protect the pipes from contaminants in the surrounding soil and also reduce the risk of contamination to personnel making any repairs to the pipes in the future.

Health and safety

Scottish Water indicated that consideration should be given to the health and safety of any workers working during installation and on the pipe in the future.

Health and Safety Risk Assessments and COSHH Assessments should be carried out by the designated engineer or manager. As contamination is known to be present on the site, appropriate PPE and safety equipment, as determined by the Risk and COSHH assessments should be made available. This may include but is not limited to;

- Dust: Dust protection measures including dust suppression and where required respiratory protection (such as dust masks) must be used.
- Gas Testing: The use of suitable air quality monitoring equipment is advised at all times. Carbon Dioxide, Hydrocarbons, Methane and Sulphide should be considered as part of any test suite.
- Skin Protection: Skin barriers including suitable gloves, clothing and footwear must be worn at all times.

Site personnel should maintain vigilance to detect any unpleasant odours, strangely coloured made ground, made ground other than generally observed during this investigation, fibrous materials or chemical residues in order that they can be assessed by suitably qualified personnel.

The risk to personnel from contaminated soil during the repair of the water pipes in the future should be low as the use of clean backfill around the pipes has been recommended.

Potential contamination to the proposed mains services should a burst occur

Scottish Water indicated that consideration should be given to potential contamination to the proposed mains services should a burst occur.

As detailed above, we have recommended that the water pipes are placed in clean backfill is used around the pipes. It is considered that this will provide protection the water main from surrounding contaminated soils should a burst occur.

13.0 GAS EMISSIONS

13.1 General

Due to the presence of made ground at the site, gas monitoring was undertaken at standpipes installed in twenty nine of the recent boreholes; S301 to S309, S312, S314 to S316, S318 to S331, and R1 and R2, and the results are included in Appendix 14.

The assessment of ground gas as a potential constraint to development has been the subject of a great deal of research and published guidance. Ground gas can be a concern for several reasons; flammable gases may cause an explosion, accumulation of gases within poorly ventilated areas may lead to asphyxia or toxic gases may cause harm to those exposed to them. Some physical properties of ground gases are tabulated below.

Gas	Explosive Range	Density at 20ºC	Toxicity (% by volume in air)*
Methane	5-15% by volume	0.72 kg/m^3	30 (low)
Carbon dioxide	N/A	1.98kg/m^3	0.5 (high)
Carbon monoxide	12.5-74.2% by volume	1.25kg/m^3	0.02 (high)
Hydrogen sulphide	4.2-46% by volume	1.54kg/m^3	0.001 (high)

* short term occupational exposure limits. The long term occupational exposure limit for carbon monoxide is 30ppm and for hydrogen sulphide is 5ppm.

Radon

Radon is a naturally occurring radioactive gas that is formed from the decay of uranium and radium present in some types of rocks. It can migrate through cracks and fissures into the soil and by this route into buildings. Radon can accumulate inside structures over the long term posing a risk to health. Long term exposure increases the risk of developing lung cancer, in a building with high levels of radon, long-term exposure can increase the risk to the point where preventative action is necessary.

Gas Emissions Sources

The desk based information and initial CSM identified the following potential gas generation sources at the site;

- Made ground – low generation potential source.
- Adjacent landfill – moderate to very high generation potential source

13.2 Analysis of Results

Gas measurements recorded at borehole standpipes are summarised in the table below.

Summary of Gas Monitoring Results

Borehole	Response zone	Response Strata	Number of monitoring occasions	Methane (% by volume)		Carbon dioxide (% by volume)		Oxygen (% by volume)		Carbon monoxide (ppm)		Hydrogen sulphide (ppm)		Peak Flow Rate (l/hr)	Steady State Flow Rate (l/hr)	Groundwater Depths (m)	
				Min	Max	Min	Max	Min	Max	Min	Max	Min	Max			Min	Max
R1	15m to 20m	Bedrock	6	<0.1	0.6	0.1	2.7	0.1	21.9	<1	1	<1	<1	7.6	7.6	19.93	Dry
R2	13m to 18m	Bedrock	6	<0.1	0.6	0.1	2.4	0.1	21.9	<1	2	<1	<1	7.7	7.7	Dry	Dry
S301	1m to 3.5m	Glacial till	4	<0.1	0.1	0.1	1.6	20.1	21.8	<1	1	<1	<1	3.7	3.7	0.31	0.99
S302	1m to 4m	Glacial till	6	<0.1	0.1	0.1	0.8	20.1	22.5	<1	5	<1	<1	0.2	0.2	0.44	1.84
S303	1m to 4m	Glacial till	6	<0.1	<0.1	0.1	1.3	21.0	21.9	<1	1	<1	<1	0.2	0.2	0.28	1.65
S304	1m to 5m	Glacial till	6	<0.1	0.1	0.1	0.2	20.9	22.3	<1	<1	<1	<1	0.1	0.1	0.0	1.09
S305	1m to 5m	Glacial till	6	<0.1	0.1	0.1	0.2	20.6	21.9	<1	<1	<1	<1	0.1	0.1	0.21	1.31
S306	1m to 5m	Glacial till	6	<0.1	0.1	0.1	1.5	20.1	21.9	<1	1	<1	<1	0.3	0.1	0.44	1.44
S307	0.5m to 3.5m	Glacial till	6	<0.1	0.1	0.1	0.4	20.9	21.9	<1	<1	<1	<1	0.1	0.1	0.18	1.18
S308	1m to 2.4m	Glacial till/Bedrock	6	<0.1	0.1	0.1	1.4	20.5	21.9	<1	1	<1	<1	0.4	0.2	0.4	1.01
S309	1m to 1.5m	Glacial till/Bedrock	6	<0.1	0.1	0.1	1.3	20.9	22.0	<1	<1	<1	<1	0.2	0.2	0.22	0.61
S312	1m to 5m	Glacial till	5	<0.1	<0.1	0.1	0.8	20.6	22.0	<1	<1	<1	<1	0.1	0.1	0.35	0.68
S314	1m to 2.8m	Glacial till	6	<0.1	0.1	0.1	7.6	14.4	21.9	<1	1	<1	<1	0.4	0.4	0.8	1.66
S315	1m to 2.4m	Glacial till	6	<0.1	0.1	0.1	3.0	18.1	202.0	<1	<1	<1	11	1.3	1.3	0.0	0.75
S316	1m to 2.9m	Glacial till	4	<0.1	<0.1	0.1	2.8	19.1	21.7	<1	<1	<1	<1	0.3	0.2	0.0	0.67
S318			6	<0.1	0.2	0.1	1.4	14.3	21.8	<1	<1	<1	<1	2.5	2.3	0.47	1.8
S319	1m to 4.6m	Glacial till	6	<0.1	0.1	0.1	0.6	17.3	21.8	<1	23	<1	<1	15.4	15.4	0.33	1.98
S320	0.5m to 1.3m	Glacial till	6	<0.1	0.1	0.1	1.0	19.7	22.0	<1	<1	<1	<1	0.3	0.2	0.57	Dry
S321	1m to 1.9m	Glacial till	6	<0.1	0.1	0.1	3.9	18.5	22.1	<1	<1	<1	<1	2.1	2.1	0.22	Dry
S322	1m to 3m	Glacial till	6	<0.1	0.1	0.1	0.4	20.2	22.0	<1	<1	<1	<1	0.1	<0.1	0.12	1.34
S323	1m to 2.6mm	Glacial till	6	<0.1	0.1	0.1	4.2	14.5	22.0	<1	<1	<1	<1	6.1	6.1	0.43	Dry
S324	1m to 2.5m	Glacial till	6	<0.1	<0.1	0.1	1.3	16.1	22.1	<1	2	<1	<1	0.1	0.1	0.55	1.2
S325	1m to 3.8m	Glacial till/Bedrock	6	<0.1	0.1	0.1	0.6	20.0	22.1	<1	<1	<1	<1	0.2	0.2	0.19	0.93
S326	1m to 2.5m	Glacial till/Sand	6	<0.1	0.1	0.1	0.5	20.6	22.1	<1	<1	<1	<1	<0.1	<0.1	0.19	1.09
S327	1m to 3.9m	Glacial till	6	<0.1	0.1	0.1	0.2	21.0	22.2	<1	1	<1	<1	0.2	0.2	0.12	1.01
S328	1m to 5m	Glacial till	6	<0.1	0.1	0.1	0.2	20.5	22.2	<1	<1	<1	<1	0.1	0.1	0.14	1.12
S329	1m to 4.4m	Glacial till	6	<0.1	<0.1	0.1	1.2	20.4	22.1	<1	1	<1	<1	0.3	0.3	0.22	1.32
S330	1m to 5m	Glacial till	6	<0.1	<0.1	0.1	0.4	20.5	22.0	<1	<1	<1	<1	0.3	0.2	0.23	0.72
S331	1m to 5m	Glacial till	5	<0.1	<0.1	0.1	2.3	19.1	21.9	<1	7	<1	<1	1.1	1.0	0.19	1.3
S332	1m to 5m	Glacial till	3	<0.1	<0.1	0.1	0.1	21.6	22.0	<1	<1	<1	<1	<0.1	<0.1	0.68	0.82

13.3 Risk Assessment and Conclusions

Tier 1 ground gas risk assessment

JPB use the following generic screening levels to determine whether a potential risk exists: methane <1% by volume in boreholes and carbon dioxide <5% by volume in boreholes, providing borehole flow rates do not exceed 7 L/h and 1.4 L/h respectively. As these screening concentrations are exceeded by gas levels recorded at the site a more detailed Tier 2 assessment is required.

Tier 2 ground gas risk assessment

During the gas monitoring atmospheric pressure varied from 973mb to 1014mb with 2 sets of readings undertaken when values were below 1000mb. The monitoring indicated low concentrations of ground gas (methane up to 0.6% by volume and carbon dioxide up to 3.4% by volume).

While high flow rates were noted within some of the soils boreholes, it is considered that these are not representative of the site, and were caused by flooding within the boreholes. As such due to this low headspace the highest flow rates were recorded in these boreholes (up to 15.4l/h in S319). These flows are considered to be unreliable as a measure of gas generation in the ground as they are likely to be due the piston effect caused by small movements in the water level. Across the majority of the site the flow levels are generally low, ranging between 0.1l/h to 0.4l/h, and it is considered that this is more representative for the situation within the soils. However gas flows in the rotary standpipes where water levels were lower were noted to have flow levels of up to 7.7l/h. As such these have been adopted for use as the flow rate.

BS8485 requires that the "worst case" scenario is checked as a precursor to any more detailed assessment. Therefore maximum recorded gas and flow levels and Characteristic Situation evaluations based on the modified Wilson and Card approach outlined in CIRIA C665 are summarised in the table below. In these calculations we have used the term Hazardous Gas Flow Rate as used in BS8485 this is also known as Gas Screening Value in CIRIA C665.

Gas	Maximum gas concentration (% by volume)	Maximum borehole flow rate (L/h)	Hazardous Gas Flow Rate (L/h)	Site Characteristic Situation
Carbon dioxide	7.6	7.7	0.5852	2
Methane	0.6	7.7	0.0462	1

Based on the recorded methane levels the site was found to be a Characteristic Situation 1 site, while on the basis of the carbon dioxide levels the site was found to be a Characteristic Situation 2 site. It is therefore considered that overall the site is a Characteristic Situation 2 site and there is **a source, intact pollutant linkages are present and therefore remedial works are required**.

However it should be noted that the Characteristic Situation 2 is only caused due to the high flow levels found within the two rotary boreholes, and due to elevated carbon dioxide levels recorded in borehole S314 during weeks 4, 5, and 6. As such it is considered that this could be zoned by having a 50m zone surrounding each borehole in which remedial measures would be required as shown on JPB Drawing TG276-22/R/F/06, whereas in the remaining areas of the site, remedial measures would not be required.

While borehole S314 has recorded elevated carbon dioxide, with further data the recommended remedial measures may be able to be removed. As such it is recommended that further gas monitoring is carried out at the site, and this may allow the remedial measures around this borehole to be reassessed to a Characteristic Situation 1.

Risks Posed By Carbon Monoxide

Elevated carbon monoxide was recorded at S319 on two occasions, the highest concentration recorded at other boreholes was 7ppm by volume, a concentration below toxic levels. The carbon monoxide concentration recorded at S319 at the other monitoring rounds before the elevated reading were all low (maximum 11ppm by volume), and both these readings and the high reading then dropped off to lower levels which remained steady. The concentrations recorded are considerably below carbon monoxide's lower explosive limit of 12% by volume and levels at which carbon monoxide would be considered to be toxic by inhalation. Therefore, the levels of carbon monoxide recorded at BHA4 are **not considered to represent a source of gas emissions and no remedial measures are required.**

Radon

Risks posed by radon have been assessed in accordance with current authoritative guidance as detailed in JPB's risk assessment methodology presented in Appendix 8.

The Radon Risk Map (Appendix 1) indicates that and area in the north western portion of the site is within an area requiring radon protection and that, therefore, additional protective measures are required for buildings. The report indicates that the estimated probability of the property being above the Action Level for radon is 5-10%, classifying the site as requiring **full radon protection measures** as defined in the building regulations.

14.0 RECOMMENDATIONS FOR CHEMICAL CONTAMINATION AND GAS

14.1 Validated Conceptual Site Model & Requirement for Remedial Measures

A reassessment of the initial conceptual site model in the light of information gained from both the site investigations and risk assessments has been undertaken and a resultant validated conceptual site model compiled. As the potential sources identified in the initial CSM table have now been either identified to be present or absent the source terms and pollutant linkages are re-assessed below.

SPR item	SPR item present based on site investigations (Yes/No)	Comment
Sources		
S1 – Contamination from former land use - Human Health	No	Risk assessment found no significant risks to human health. No remedial measures are required.
S1 – Contamination from former land use - Phytotoxic	No	Risk assessment found no phytotoxic risk at the site. No remedial measures are required.
S1 – Contamination from former land use - Water Pipes	No	No contaminant concentrations were identified which are considered to permeate water pipes or impact on their integrity. Therefore, no restriction is made on the type of water pipes which can be used on the site.
S1 – Contamination from former land use - Concrete Specification	No	pH values and sulphate concentrations indicated that the ground conditions fall within design sulphate class DS-1 and ACEC class AC-1s as defined in BRE Special Digest 1. Therefore, concrete specifications should be such as to protect building elements in contact with these conditions.
S2– Contamination from adjacent land	No	No evidence was encountered of contamination migration onto site from adjacent land. No remedial measures are required.
S3 – Ground gas	**Yes**	Elevated ground gas emissions recorded in the investigation. The site is also within a radon affected area. Remedial measures required.
S4 – Leachable/mobile contaminants	No	Water environment assessment indicated no significant risks posed to water environment receptors. No remedial measures required.

Significant Pollution Linkage			SPL item present based on SI & risk assessment (Yes/No)	Comment
Source	**Pathway**	**Receptor**		
		Human receptors		
S3 – Ground gas	P9 – Migration of gas	R1 – Children & adults	Yes	Elevated ground gas emissions recorded in the investigation. Also site affected by radon. Remedial measures required

14.2 Selection of Remedial Actions

The reassessment of the conceptual site model has confirmed the need for remedial actions to sever identified pollutant linkages. Based on the type and level of contaminants at the site, the following remedial actions have been evaluated in order to select the most appropriate remedial actions to address the identified pollutant linkages.

Contamination Linkage	Options Considered	Comments	Considered Further (Y/N)
Ground gas Emissions	Removal of all made ground at site for disposal to landfill (Source removal).	Impractical in terms of the levels of the proposed development and cost for disposal of waste from site.	N
	Removal of all gas source at site for disposal to landfill (Source removal).	Source is naturally occurring radon or deep mine gas. Source removal is not technically feasible	N
	Break pollutant linkage by incorporation of a barrier system (Sever pathway).	Pollutant linkage can be broken using a gas barrier system.	**Y**

14.3 Land Remediation Relief

Based on the presence of historical contamination there is the possibility of claiming for Land Remediation Relief from Her Majesties Customs and Excise. It is understood that a valid claim results in additional relief equal to 50% of the qualifying land remediation expenditure as described in HMRC documents "CIRD60015 - Remediation of contaminated land: entitlement: summary" and "CIRD60145 - Remediation of contaminated land: definition: qualifying land remediation expenditure". Full details are given on the HMRC website at http://www.hmrc.gov.uk/manuals/cirdmanual/CIRD60015.htm.

14.4 Reuse of On-site Materials

SEPA's "Land remediation and waste management guidelines" set out SEPA's approach to regulating the remediation of contaminated sites under the waste regulatory regime.

In general, if materials are to avoid becoming waste, they must be suitable to be reused within an existing site boundary without resulting in an unacceptable risk of harm to human health or pollution of the environment.

To be suitable for reuse materials must also meet the six conditions outlined in the above guidance;

1. The use is a necessary part of the planned works.
2. The material is suitable for that use.
3. The material does not require any processing or treatment before it is reused.
4. No more than the quantity necessary is used.
5. The use of the material is not a mere possibility but a certainty.
6. The use of the soil will not result in pollution of the environment or harm to human health.

Materials which require treatment (such as bioremediation) to make them suitable for use may potentially be reused on site, however, the treatment will require to be licensed or permitted under waste legislation.

It should be noted that the above guidance indicates that SEPA does not consider asbestos to be a suitable material for backfilling or other construction purposes. "Bulk" asbestos must not be backfilled or otherwise reused in site works.

14.5 Disposal of Waste Materials to Landfill

Waste soil or made ground materials which cannot be accommodated at the site or and is not suitable for reuse at another site should be removed to an appropriately licensed landfill site or "soil hospital" facility. Such material should be disposed of in accordance with the current waste regulations following pre-notification to SEPA.

It should be noted that due to the implementation of the Landfill Directive it is likely that any material being disposed of from the site will require some form of pre-treatment. This may include minimisation or stabilisation.

Waste Classification and Waste Acceptance Criteria Testing

All waste material disposed of to landfill from the site will require to undergo testing in order to characterise the waste properties of the material and to determine an appropriate disposal route. This process will require the assessment of general chemical test results to characterise any hazardous properties the waste may have. Depending on the circumstances, the process may also include assessment of Waste Acceptance Criteria (WAC) testing in order to aid the selection of appropriate disposal route. These tests are a legal obligation and no material will be able to be accepted at a landfill unless the results of the tests are available. The time taken for this testing should be factored into any programme for the site.

14.6 Chemical Contamination

General site

No elevated contaminants in relation to human health, plant growth or the water environment were recorded within the samples from the general site area, and, therefore, no remedial measures are required.

Stockpiles

Asbestos was recorded at one investigation locations, within one of the stockpiles on site. The sample was recorded from SP07, which is located in one of the smaller stockpiles in the south western area of the site. As such it is recommended that this stockpile be segregated and that further testing be carried out to determine if it is prevalent within the stockpile as a whole.

Asbestos Risks

Asbestos was also recorded at the site. This was in the form of loose fibres and was recorded in the sample from SP7 at 0.2m. The asbestos contents of this sample was <0.001% by weight. As noted above it is recommended that this stockpile be segregated, and further testing be undertaken to determine if it is prevalent throughout this material.

14.7 Asbestos

General

During the investigations, asbestos fibres were identified to be present in SP7 at 0.2m at the site. It is recommended that further testing be undertaken to determine whether this is prevalent throughout this stockpile.

In order to protect site operatives, site occupiers and the general public the requirements of Control of Asbestos Regulations 2012 and Asbestos Codes of Practice should be followed by site staff at all times. The following specific regulations will be of relevance:

Control of Asbestos Regulations 2012 Regulation 6:

"an employer shall not carry out work which is liable to expose his employees to asbestos unless he has -

(a) made a suitable and sufficient assessment of the risk created by that exposure to the health of those employees and of the steps that need to be taken to meet the requirements of these Regulations;
(b) recorded the significant findings of that risk assessment as soon as is practicable after the risk assessment is made; and
(c) implemented the steps referred to in sub-paragraph (a)."

Control of Asbestos Regulations 2012 Regulation 16 which states that every employer shall,

"prevent or, where this is not reasonably practicable, reduce to the lowest level reasonably practicable the spread of asbestos from any place where work under his control is carried out".

Remedial Actions

In addition, the following measures are recommended to protect site receptors and future maintenance workers at the site.

Should any visible fragments of asbestos containing materials be encountered at the site within the stockpile material this should be hand-picked to remove it. Hand-picking from the surface of the site should be carried out by suitably qualified personnel wearing appropriate PPE/RPE. Any asbestos cement fragments or pieces should be double-bagged and stored for removal. The contractor must ensure that a lockable skip is established and maintained on-site throughout the works for storage of hand-picked asbestos waste which must be double bagged and labelled accordingly. This skip should be removed under controlled conditions to a suitably licensed landfill site.

Should any of this material require to be removed from site it should be excavated and removed by a licensed asbestos removal contractor under controlled conditions to a suitably licensed landfill site. These works should be carried out by an Asbestos Removal Contractor licensed in accordance with the Control of Asbestos Regulations 2012 Regulation 8 and associated Asbestos Codes of Practice.

All asbestos product materials removed from site may be considered to be "special waste" under the Special Waste Regulations 1996 and should be disposed of to an appropriately licensed landfill in accordance with the Duty of Care requirements of the Environmental Protection Act 1990 and the Environment Act 1995.

However, based on the findings to date it is apparent that the quantities of asbestos fibres recorded to be present in the soil to date are unlikely to constitute 0.1% by weight of the materials, the threshold for special waste. Consequently, we are of the opinion that the soil made ground material is unlikely to be classified as "special waste" in terms of asbestos but rather as non-hazardous waste, which should not attract the premium cost for disposal.

14.8 Site Personnel

The generation of dust during site works may expose site operatives or the occupiers of adjacent properties to health risks and should be managed by the provision of appropriate PPE and adoption of appropriate site practices as described in CIRIA document 132 "A guide for safe working on contaminated sites".

No elevated contaminants were recorded and the risks from exposure to any contaminated materials are considered to be low. Normal Health and Safety precautions should be implemented during the works. Site personnel should maintain vigilance to detect any unpleasant odours, strangely coloured made ground, made ground other than generally observed during this investigation, fibrous materials or chemical residues in order that they can be assessed by suitably qualified personnel.

It should be noted that care should be taken during the site development works to ensure that no spillage of fuel or other liquids or detrimental material occur on site. This is due to the fact that any spilled material has a high probability of contaminating the ground and surface waters. As such all works should be carried out in accordance with the requirements of the Scottish Environment Protection Agency as set out in Pollution Prevention Guidelines PPG5: "Works in, near or liable to affect watercourses" and PPG6: "Working at construction and demolition sites" and other relevant documents.

14.9 Buildings and Services

pH values and sulphate concentrations indicated that the ground conditions fall within design sulphate class DS-1 and ACEC class AC-1 as defined in BRE Special Digest 1. Therefore, concrete specifications should be such as to protect building elements in contact with these conditions.

No contaminant concentrations were identified which are considered to permeate water pipes or impact on their integrity. Therefore, no restriction is made on the type of water pipes which can be used on the site.

14.10 Gas and Vapour Emissions

Radon

The Radon Risk Map (Appendix 17) indicates that an area of the north western portion of the site is within an area requiring radon protection and that, therefore, additional protective measures are required for buildings. The report indicates that the estimated probability of the property being above the Action Level for radon is 5-10%, classifying the site as requiring **full radon protection measures** as defined in the building regulations. The approximate site area requiring radon protection measures is indicated on JPB Drawing No TG276-22/R/F/05.

On the basis of the above classification, the following radon protective measures are recommended in accordance with the guidance contained in Section 5.2 of BRE publication BR211 – "Radon: guidance on protective measures for new buildings".

- Installation of a continuous radon-proof membrane between the dwelling and the soil.
- The radon-proof membrane must be a minimum of 1200 gauge polyethylene. A gas barrier specified below for ground gas protection will also act as the radon barrier.
- Appropriate attention must be given to the design and installation of the membrane including sealing joints, bonding the membrane to the cavity tray replacing the normal damp-proof course, and sealing around entry and exit points for mains services.
- For suspended concrete ground floors the solum void shall be adequately ventilated and air shall not be drawn from the void into the dwelling for any purpose.

The radon-proof membrane need not be in addition to a damp-proofing membrane, a single membrane should be sufficient provided it is designed to meet the requirements for damp proofing and those described above for radon.

The design requirements detailed above for protection against risks posed by ground gases and is considered sufficient to provide protection from radon gas, and, therefore, no additional measures are required.

Detailed protection measures are described in BRE publication BR211 to which the reader is referred.

Ground Gases

Based on the gas levels encountered, a 50m area of the site surrounding some of the boreholes has been classified as a Characteristic Situation 2 site and therefore the following remedial measures are required in order to satisfy the local authority. It is advised that discussions should be held with the Local Authority to confirm that these remedial works will meet their requirements.

Remedial measures will be installed in all **habitable** buildings including **integral** garages and conservatories in order to protect the development from elevated ground gas emissions and the risk of organic vapour intrusion into buildings, including the incorporation of a suitable gas and organic vapour resistant membrane and passive venting of the building solums, underslab voids/upfill and wall cavities. Where non habitable buildings, such as detached garages are constructed, no gas membrane will be installed. The approximate extent of the area requiring remedial measures is indicated on JPB Drawing No TG276-22/R/F/06.

Site Classification (CIRIA C665)	Characteristic Situation 2 site. Type A buildings, private housing.
Remedial Measures Required	Yes
Required Gas Protection Score (from BS8485)	**3.5**
In order to achieve this level of protection the following remedial measures are required	

The following is a brief summary of the types of remedial measures that are required at the site. The relevant tables, and related footnotes are given in BS8485 (2015), CIRIA (C665) and NHBC Report No. 10627-R01(04) and **the reader should refer to these for full details of the requirements**.

Item	Specification	Score	Comments
a) Venting/dilution			
Passive sub floor ventilation (venting layer can be a clear void or formed using no-fines gravel with gas drains, geocomposite or polystyrene void former blanket).	Good performance	1.5	Performance criteria for methane and carbon dioxide are shown in Figure B.6 and Figure B.7, respectively. The selected score should be assigned taking into account the recommendations in Annex B. Passive ventilation should be designed to meet at least "good performance", see Annex B.
b) Barriers - Floor slabs			
Cast in situ monolithic reinforced concrete suspended floor slab with limited service penetrations that are cast into slab.		1 or 1.5*	*It is good practice to install ventilation in all foundation systems to effect pressure relief as a minimum.* *Breaches in floor slabs such as joints have to be effectively sealed against gas ingress in order to maintain these performances.* **To achieve a score of 1.5 the raft or suspended slab should be well reinforced to control cracking and have minimal penetrations cast in.*
c) Barriers-Membranes			
Proprietary ground gas resistant membrane *meeting all of the criteria* below, installed to reasonable levels of workmanship in line with current good practice under independent inspection. • *sufficiently impervious, both in the sheet material and in the sealing of sheets and sealing around sheet penetrations, to prevent any significant passage of methane and/or carbon dioxide through the membrane; a membrane with a methane gas transmission rate <40.0 ml/day/m2/atm (average) for sheets and joints (tested in accordance with BS ISO 15105-1: 2007 manometric method) is regarded as sufficiently impervious.* • *sufficiently strong [B]) to withstand the installation process and following trades until covered (e.g. penetration from steel fibres in fibre reinforced concrete, penetration of reinforcement ties, tearing*		2	*The performance of membranes is heavily dependent on the quality and design of the installation, resistance to damage after installation and the integrity of joints.* *[B]) For example, reinforced LDPE (virgin polymer) membranes having a minimum mass per unit area of 370 g/m^2 and not significantly less than 0.4 mm thickness between the reinforcement scrim (tested in accordance with*

Item	Specification	Score	Comments
due to working above it, dropping tools, etc); and to withstand in-service stresses (e.g. settlement if placed below a floor slab); *• sufficiently strong to withstand the installation process and following trades until covered (e.g. penetration from steel fibres in fibre reinforced concrete, penetration of reinforcement ties, tearing due to working above it, dropping tools, etc);* *• capable, after installation, of providing a complete barrier to the entry of the relevant gas; and* *• verified in accordance with CIRIA C735***			*Procedure D (2 mm diameter tip) of BS EN ISO 9863-1:2016) installed above floor slabs are considered sufficiently strong to meet the performance criteria (see also C.3). Thicker and more robust membranes or an additional membrane protection layer should be installed directly beneath cast-in-situ floor slabs.*
Total		4.5	

*** JPB gas protection measures verification procedures will take due cognisance of the guidance give in CIRIA C735 where applicable.*

All of the above protection elements must meet the appropriate individual quality requirements given in BS8485 (2015) and its Annexes.

In the construction of the above remedial measures the following should be adhered to.

- Where the solum is to be vented by pipework these need to be at 2m centres and bedded in a 200mm minimum thickness layer of minimum 20mm gravel (no fines). In all cases the granular blanket must be at least 100mm greater than the diameter of the gas drain/vent pipe. The ventilation pipes need to extend beyond the length of the building and must be connected to a vent which must extend above ground level.

- All ground slabs and concrete should be well constructed.

- A suitably sealed gas impermeable membrane is required which must extend to all external brickwork with the use of suitably sealed top hats at service entries. Where a membrane is not supplied as prewelded, all joints must be sealed in accordance with the manufacturer's instructions using appropriate tapes and/or jointing products. In addition, the membrane detail should include appropriate preformed upstand and downstand corner cloaks to ensure a suitable seal at corners.

14.11 Invasive Plant Survey

An invasive plant survey was carried out during the works prior to commencement of the investigation. The report is included in Appendix 3. The report's main findings are summarised below.

- No Japanese Knotweed, Giant Hogweed or Himalayan Balsam plants were identified during the walkover.

Not noted within the report was the presence of a fenced off area was noted in the western area of the site, with signs noting that Japanese knotweed was present and currently undergoing treatment within this area.

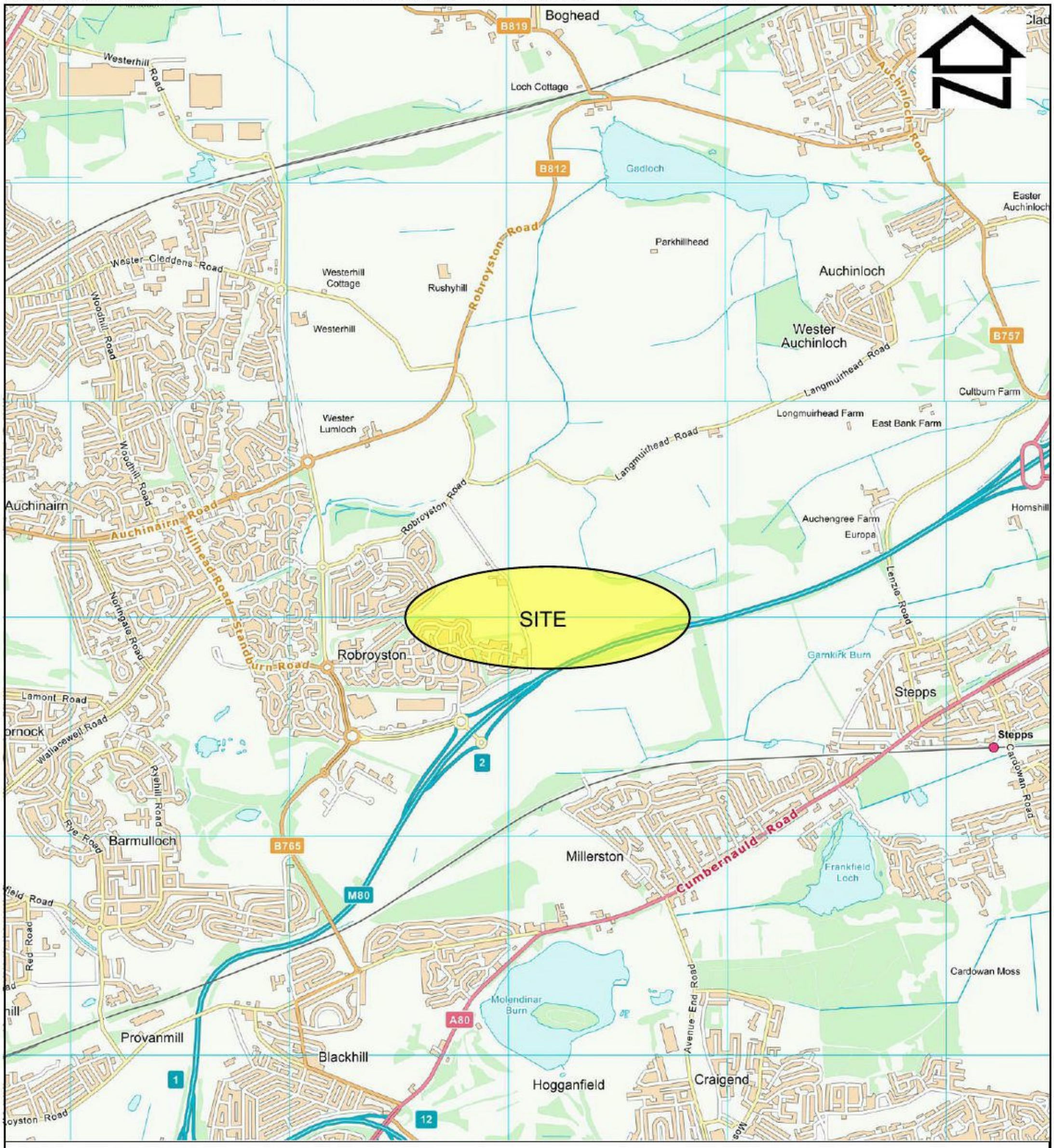
14.12 Site Verification

If Local Authority/NHBC certification is to be sought for the proposed development then the following remedial works, which can be supervised by JPB, are likely to require verification:

Constraint	Action
Remedial Strategy	Produce Remedial Strategy based on the findings of the site investigation in accordance with CLR11 and obtain approval from the Local Authority.
Ground Gas Emissions	Ground gas impermeable membrane in building solum. Passive venting of building solums, underslab voids/upfill and wall cavities.
Gas Monitoring Standpipes	As part of the development all boreholes must be decommissioned in accordance with SEPA guidance "*Decommissioning Redundant Boreholes and Wells*".
Verification Statement	Produce verification statement in accordance with CLR11 and obtain approval from the Local Authority.

APPENDICES

Appendix 1 Drawings



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CLIENT

BARRATT HOMES WEST SCOTLAND

PROJECT TITLE

ROBROYSTON NORTH, ROBROYSTON

DRAWING TITLE

SITE LOCATION PLAN

JOHNSON POOLE & BLOOMER CONSULTANTS
GEO-ENVIRONMENTAL & MINERALS
CELEBRATING 175 YEARS 1844 - 2019

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SUPERFICIAL DEPOSITS

ARTIFICIALLY MODIFIED GROUND

Made Ground — Areas where the ground is known to have been deposited by man; spoil heaps, road and rail embankments

Worked Ground and Made Ground — Wholly or partially back-filled quarries and pits

Within urban areas, much of the surface may have been disturbed by human activity, but not all areas of artificial made, worked, infilled and landscaped ground have been shown.

QUATERNARY DEPOSITS

HOLOCENE — FLANDRIAN

Peat

Alluvium — Clay, silt, sand and gravel

Lacustrine Deposits — Mainly clay and silty clay

PLEISTOCENE — LATE DEVENSIAN

Raised Marine Intertidal to Subtidal Deposits — Mainly laminated clay

Raised Marine Beach Deposits — Mainly sand and gravel

Glaciofluvial Deposits, undifferentiated — Mainly sand and gravel

Till — Diamicton, grey to brown and red-brown, massive, silty, sandy clay with boulders and pebbles

The Quaternary Deposits listed above are not necessarily shown in order of superposition

Uncoloured areas are where the nature or subdivision of the substrate to the artificial deposits or water is unknown or uncertain

BEDROCK

Bedrock at or near surface, or beneath artificial deposits

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EXTRACT FROM THE BRITISH GEOLOGICAL SURVEY MAP NS66NW

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