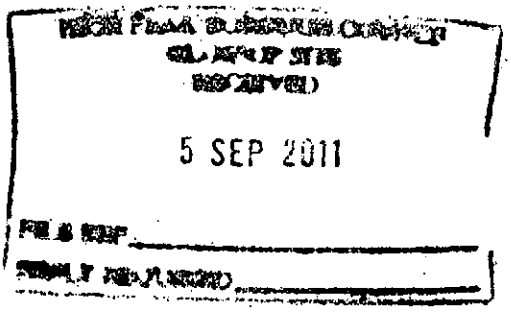
HPK/2011/0492

RSK GROUP PLC

GEO-ENVIRONMENTAL SITE INVESTIGATION REPORT

YORK STREET, GLOSSOP



REFERENCE: 16367-R1 (01)

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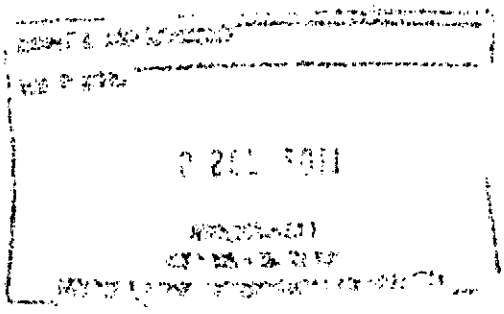

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GEO-ENVIRONMENTAL SITE INVESTIGATION REPORT
YORK STREET, GLOSSOP

REPORT NO : 16367-R1 (01)

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This report is not to be used for contractual or engineering purposes unless the above is signed where indicated by the author, the project manager and the technical reviewer of the report, and the report is designated "FINAL".

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

EXECUTIVE SUMMARY

It is proposed to redevelop a site off York Street, Glossop with low-rise residential properties. RSK STATS Geoconsult Limited (RSK) was commissioned by PE Jones (Contractors) Limited to carry out a geo-environmental site investigation.

A Preliminary Risk Assessment (PRA) has been carried out based on a site walkover and review of published data, including historical maps and an environmental database.

Available geological maps indicate the site to be underlain directly by Boulder Clay, which is in turn underlain by the Millstone Grit Group. The solid geology is classed as a Minor / Secondary A aquifer by the Environment Agency. There is a westward flowing brook along the southern boundary of the site (understood to be dry). The brook is a tributary of the southward flowing Shelf Brook, located approximately 300m to the west of the site.

The site was undeveloped until the 1950s, when a bus depot was constructed. A number of tanks (presumably fuel supply tanks) have been present across the site.

The PRA undertaken by RSK has identified a number of potential pollutant linkages associated with the site. These include: ground gas migration from a number of sources into excavations or buildings; and ingestion, inhalation or dermal contact with potentially contaminated soils / leachate from on- and off-site sources. It was therefore deemed necessary to carry out an intrusive investigation to confirm ground conditions prior to redevelopment.

The site investigation comprised the drilling of nine probeholes across the site. During the investigation, soil and groundwater samples were recovered and submitted to the laboratory for a range of testing. In situ geotechnical testing was also undertaken during the investigation. A monitoring well was installed in five of the probeholes to enable future monitoring of ground gas and groundwater.

Across most of the site made ground was encountered to depths of less than 0.50m. Deeper made ground (up to 2.50m) was encountered at two locations. The made ground was underlain by natural clay soils, with some sand horizons.

The investigation has indicated the presence of elevated concentrations of PAH and hydrocarbons when compared against generic assessment criteria (GAC) for human health. It is recommended that further investigation be carried out in the vicinity of the PAH and hydrocarbon hotspots to delineate the extent of the impact. It is considered at this stage an allowance for the excavation and removal off site of unsuitable materials should be made. This is likely to include the removal of hydrocarbon impacted materials in vicinity of the former fuel supply tanks, vehicle washing area and associated drainage.

Marginally elevated concentrations of heavy metals and benzo-a-pyrene were also encountered, within the general fill materials across the site. Based on the results of the soils analyses, it is

considered over areas of made ground, provision of a capping layer be provided. A cover thickness of 350mm should be adopted in gardens and areas of open space.

The results of the gas monitoring indicate elevated steady state concentrations of methane (up to 12.6 per cent by volume) and carbon dioxide (up to 11.3 per cent by volume) associated with depleted oxygen concentrations. Gas flow rates were generally recorded to be low. Based on a comparison of the results with the NHBC 'Traffic Light' system, it is considered the site be characterised as 'Amber 1', where gas ingress preventative measures are required within the proposed residential properties.

Mitigation measures are proposed during construction works in regard to depleted oxygen concentrations. Continual monitoring for oxygen concentrations and no man entry into excavations unless suitable conditions are proven by gas monitoring should be adopted.

The findings of the chemical analyses indicate that alternative pipeline construction material may be required (e.g. protectaline) for water supply pipes, given the elevated hydrocarbon concentrations over specific areas of the site. Advice should be sought from the utility provider for the site.

The findings of the geotechnical assessment indicated that a Design Sulphate Class of DS-1 may be adopted for the site, and that an Aggressive Chemical Environment for Concrete classification of AC-1 may be assumed for design purposes. The proposed extensions may generally be supported on deep strip or trench fill foundations, although piled foundations may be required in some areas. All foundations should be taken down through any made ground and placed on the underlying firm clay. Foundations may be designed to an allowable net bearing pressure of 100kN/m^2. The clay was found to be of high volume change potential. Road pavements should be designed on a CBR value of 2% to 5%.

1. INTRODUCTION

RSK STATS Geoconsult Limited (RSK) was commissioned by PE Jones (Contractors) Limited (Jones) to carry out a geo-environmental site investigation of the land at York Street, Glossop. This assessment was carried out with the understanding that the site is to be redeveloped with low-rise residential properties.

1.1 Objectives

The objectives of this assessment are as follows:

- To provide preliminary information regarding the site history, geology and environmental setting from which potential risks to end-users and the environment can be assessed; and
- To obtain information pertaining to ground conditions to assist in the design of foundations and infrastructure.

1.2 Scope

The scope of the investigation and layout of this report has been designed in accordance with CLR11[(1)] and PPS23[(2)] and guidance issued by the Environment Agency in July 2005 for land contamination reports[(3)]. A summary of relevant legislation and government policies applicable to land development is provided in Appendix A.

The risk management process comprises up to three stages of risk assessment: preliminary, generic quantitative and detailed quantitative (PRA, GQRA and DQRA). The basis for the risk assessment is a conceptual model that is produced as part of the PRA and is updated throughout the risk management process.

The scope of works for the environmental assessment includes:

- A PRA involving the review of geological, hydrogeological and hydrological information, a commercially available database, historical plans and a site walkover. This information is used to construct an outline conceptual model and consider any possible pollutant linkages (where a receptor may be connected to a source by a viable pathway) that may be present and design intrusive investigation if required;
- Where required, evaluation of possible pollutant linkages by intrusive investigation and laboratory analysis. This information is used to refine the conceptual model;
- GQRA to assess possible pollutant linkages identified in the PRA and enable the outline conceptual model to be refined; and
- Provide recommendations for further works, DQRA and remedial actions of ground and groundwater (if deemed applicable).

The scope of works for the geotechnical assessment includes:

- Review of published geological data including a commercially available database with information pertaining to ground stability;
- Review of utility location information and site walkover;
- Coal mining search/solution features search/cavities search;
- Intrusive investigation and laboratory analysis to enable soil parameters for geotechnical purposes to be ascertained; and
- Interpretation of ground conditions and geotechnical data to provide recommendations with respect to soakaway design, foundation, floor slabs and infrastructure design.

1.3 Limitations

The comments given in this report and the opinions expressed are based on the ground conditions encountered during the site work and on the results of tests made in the field and in the laboratory. However, there may be conditions pertaining to the site that have not been disclosed by the investigation and therefore could not be taken into account. In particular, it should be noted that there may be areas of made ground not detected due to the limited nature of the investigation or the thickness and quality of made ground across the site may be variable. In addition, groundwater and ground gas levels may vary from those reported due to seasonal, or other, effects.

This report is subject to RSK's service constraints given in Appendix B.

1.4 Previous Work

It is not known if any previous investigations have been completed on the site. None have been made available to RSK to review.

2. SITE DETAILS

The site location, description and future development are discussed below.

2.1 Site Location

The site is situated on York Street, Glossop and is located at National Grid reference SK 041 942. The site is located on the northern outskirts of the town, in a predominantly residential area. A site location plan is presented as Figure 1.

2.2 Site Description

The site occupies approximately 0.58ha and currently comprises a disused bus depot (Stagecoach) with offices and a vehicle maintenance area surrounded by areas of

hardstanding and some grassed areas particularly in the west of the site. The site is at an elevation of approximately 160m above Ordnance Datum (AOD) and is sensibly level. A site plan is presented as Figure 2. Further information on the site description is provided in Section 3.6, Site Walkover.

2.3 Future Development

It is proposed to redevelop the site with 28 low-rise residential properties.

2.4 Licences and Permissions

It is understood that no discharge consents or permits currently apply to the site.

3. PRELIMINARY RISK ASSESSMENT

The following section describes the findings of a review of information for the site provided within a commercially available database (Envirocheck report[4]) and a site walkover. The information, together with that presented in Section 2, has been used to identify potential contaminant sources and sensitive receptors, from which an outline conceptual model has been developed. A copy of the Envirocheck report is provided in Appendix C.

3.1 Geology

Published geological records indicate the site to be underlain by drift deposits consisting of Devensian Till (Boulder Clay). This is in turn underlain by solid geology of the Millstone Grit Group of Namurian age (mudstones, siltstones and sandstones).

A north-south trending fault is present immediately off-site to the east.

The National Radiological Protection Board information contained within the Envirocheck report indicates that the property is not within a radon affected area, as less than 1% of homes are above the action level. Radon protection measures are therefore not considered necessary for the site.

3.2 Hydrogeology

The Groundwater Vulnerability Map contained within the Envirocheck report[4] shows the underlying geology to be classified as a minor aquifer, defined as fractured or potentially fractured rocks, which do not have a high primary permeability, or other formations of variable permeability including unconsolidated deposits. These aquifers will seldom produce large quantities of water for abstraction, but are important for both local supplies and in supplying base flow to rivers. However, due to the implementation of

new aquifer designations on 1 April 2010 by the Environment Agency, the bedrock beneath the site is now classified as a Secondary A aquifer, defined as having permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. The superficial geology does not have an aquifer classification.

3.2.1 Groundwater Abstractions

The Environment Agency has defined source protection zones (SPZ) for nearly 2,000 groundwater sources used for public drinking water supply. The SPZ provides an indication of the potential risk of pollution. Three zones (Inner, Outer and Total Catchment) are usually defined. Information on the Environment Agency website[5] indicates the site is not situated within a groundwater SPZ, and there are no SPZs in the immediate vicinity.

Groundwater abstractions identified within a 2km radius of the site are summarised in Table 1.

Table 1: Groundwater Abstractions

Reference	Comment	Distance and Orientation from Site
2569010008	Sunlight services, issued on 18 October 1996. Abstraction through a borehole located on the premises. Abstraction for industrial / commercial / public services.	~560m to the west.
2569010048	Modus Gregory Limited, issued on 18 August 2004 for industrial / commercial / public services: general coding.	~1365m to the west.
2569010018	Mrs J Bradley issued on 7 February 1966 for abstraction at a spring-fed collection tank at Hoecraft Farm, Glossop for general agricultural use.	~1425m to the south.
2569010022	N Greenhalgh, issued on 7 February 1966 for abstraction at a spring-fed collection tank at Lane ends Farm, Glossop for general agricultural use.	~1450m to the south.
2569010027	N Sharples, issued on 7 February 1966. Abstraction from Spring fed collection tanks at Bettenhill Farm for general agricultural use.	~1665m to the northwest.

Reference	Comment	Distance and Orientation from Site
2569010036	Plater Chemicals Limited, issued on 2 January 2009. Abstraction from a borehole at High Street West, Glossop, for Chemicals: process water.	~1750m to the west.
2569010017	Mr Wilman, issued on 8 February 1966. Abstraction from spring-fed well at Little Padfield Farm, Hadfield, Hyde. Abstraction for general agricultural use.	~1980m to the northwest.

3.2.2 Soil Leaching Potential

The soils beneath the site are classified as having low leaching potential. These are soils where pollutants are unlikely to penetrate the soil layer either as a result of largely horizontal water movement or because the soil has the ability to attenuate diffuse pollutants. Lateral flow in these soils may contribute to groundwater recharge elsewhere in the catchment. The soils generally have high clay content.

3.3 Hydrology

There is a westward flowing brook along the southern boundary of the site. The brook is a tributary of the southward flowing Shelf Brook, located approximately 300m to the west of the site.

3.3.1 Surface Water Abstractions

Surface water abstractions identified within a 2km radius of the site are detailed in Table 2.

Table 2: Surface Water Abstractions

Reference	Comment	Distance and Orientation from Site
2569010005	E and R Polymers Limited, issued 22nd November 2001. Located at the reservoir, fed by Shelf Brook. Abstraction for Industrial/ commercial/ public services: general cooling	~320m to the southwest.
2569010014	Flexible Steel Lacing Company Limited, issued 1st January 2001. Abstraction at Blackshaw Clough on premises, for Industrial/commercial/ public services: process water.	~725m to the north.

Reference	Comment	Distance and Orientation from Site
2569010045	Glossop Golf Club. Abstraction from Hurst Brook at Chapel-en-le-Frith, issued 1 January 1988. Abstraction for irrigation.	~1050m to the east.
2569010032	Zurich Assurance Limited, issued 7 January 2008. Abstraction from Glossop Brook for Industrial/ commercial/ public services: general cooling	~1350m to the west.
2569010033 2569010048	Modus Gregory Limited, Glossop Brook issued 18 August 2004. Abstraction for Industrial/ commercial/ public services: general cooling	~1365m to the west.
2569010030	Chartdell Utilities Limited, issued 18 October 1991. Abstraction from Glossop Brook and Gamesley Brook, Glossop. Abstraction for Industrial/commercial/ public services: process water	~1650m to the west.

3.3.2 Flooding

Information contained within Envirocheck report[4] indicates the site is not situated within a Zone 2 or Zone 3 flood risk zone.

3.4 Sensitive Land Uses

A review of available information indicates a number of sensitive land uses in vicinity of the site. These include: an area of adopted greenbelt located approximately 180m to the northeast of the site; an Environmentally Sensitive area approximately 560m (details unknown) to the northeast and the Peak District National Park approximately 740m to the east. A comprehensive evaluation of ecological receptors is outside the scope of this report.

3.5 Site History Review

A review of the site history has been carried out through the study of Ordnance Survey maps dating from the late 1800s and information from the regulatory authorities and trade directories. The review is designed to identify potential historic sources of contamination that may have impacted soil or groundwater quality beneath the site and to identify any potentially contaminative land uses in the area.

3.5.1 Historic Maps

A review of the historical maps for the site from between 1882 and 2010 was undertaken using the extracts provided within the Envirocheck report[4]. Selected maps are reproduced as Figures 3 to 8. These are not to scale, although all the evaluations in this report have been made from the scaled plans.

3.5.1.1 History of the site

The 1882 map (Figure 3) indicates the site to be occupied by undeveloped agricultural land. The 1898 map (Figure 4) and 1923 map (Figure 5) show little change to the land use.

By 1954 (Figure 6) a rectangular building had been constructed in the southern area of the site and by 1968 (Figure 7) this was indicated as a bus depot with a tank present near the eastern boundary. The 1985 map (Figure 8) indicates the tank to have been removed and a further tank is shown on the eastern side of the building. The site has remained largely unchanged to the present day (last date of mapping, 2010).

3.5.1.2 History of the Surrounding Area

The 1882 map (Figure 3) indicates residential properties off-site, along the western boundary of the site. Further residential properties are present approximately 100m to the south of the site. The site is surrounded to the east and north by agricultural land. There are two quarries approximately 250m and 500m to the north of the site and a further five quarries located between 250m and 500m to the southwest. There is also a number of mills within 1km of the site; a cotton mill and a flourmill approximately 250m to the south and southwest, respectively, and two cotton mills approximately 500m to the east and northeast. There is a gas works approximately 500m to the southwest and a railway that terminates approximately 650m to the southwest of the site.

By 1898 (Figure 4) more residential properties have been constructed up to the southern boundary of the site. The quarry to the north no longer appears on the maps and the cotton mill to the south is now disused.

The 1923 map (Figure 5) shows that all the quarries to the southwest are now disused and some of them have been built upon. The gas works no longer appears and the cotton mill to the southeast is now disused. Many of the other quarries within 1km of the site are also now indicated as disused. A tank is now shown approximately 500m to the north northeast of the site; however its content is not indicated.

By 1954 (Figure 6) the mill pond approximately 500m to the south of the site has been infilled. By 1985 (Figure 8) there has been a lot of urban development around the site.

There are four works approximately 250m to the southwest of the site, one of which is still in operation by 2010.

3.5.2 Aerial Photographs

Aerial photographs were not reviewed for this site.

3.5.3 Database and Regulatory Information

3.5.3.1 Pollution incidents to controlled waters

There have been two recorded pollution incidents to controlled waters within 250m of the site: a Category 2 (significant) incident approximately 15m to the west of the site involving the release of mud/clay/soil into Shelf Brook, and a Category 3 (minor) incident approximately 180m to the southwest of the site involving the release of unknown waste.

3.5.3.2 Substantiated Pollution Incident Register

There have been three substantiated pollution incidents registered within 1km of the site. The closest was in 2004 approximately 400m to the north of the site and registered as a Category 2 (significant) impact on air quality. There was another approximately 470m to the southwest that was registered as a Category 2 impact on land and a Category 3 (minor) impact on air and water. The furthest was approximately 700m to the southeast of the site, classed as Category 2 land impact, Category 3 water impact and category 4 (no impact) air impact.

3.5.3.3 Waste

There are no current registered landfill sites within a 1km radius of the site. There is one historic landfill site approximately 220m to the south of the site, which accepted domestic waste.

3.5.3.4 Discharge consents

One discharge consent is held within 250m of the site. This is approximately 220m to the southwest of the site and is for public sewage and storm sewage overflow into Shelf Brook (a tributary of Glossop Brook). There are no discharge consents between 250m and 500m of the site, and three between 500m and 100m, all of which are for sewage, either storm overflow or final effluent.

3.5.3.5 Integrated Pollution Prevention Control

There are no integrated pollution controls within 250m.

3.5.4 Contemporary Trade Directories

There are five relevant contemporary trade directories within 500m of the site. These include a carpet, curtain and upholstery cleaners (17m to the northwest), a car dealers (77m to the south), Fluorochem Limited (452m to the north) and Ocean Chemicals (also 452m to the north).

3.5.5 Anecdotal Information

A Stagecoach employee informed RSK that the brook adjacent to the site has been dry for a number of years. RSK was also informed about an asbestos survey that had been conducted within the last few years.

The external oil tanks are understood to have always been in their current location; however the bund is apparently a later addition and was not originally present when the tanks were installed. The tanks are described further in Section 3.6.

3.5.6 Summary of Historic Potentially Contaminative Land Uses

The review of the site history indicates the following potentially contaminative land uses on or close to the site:

- On-site tanks;
- Four former quarries (possibly infilled) within 500m of the site;
- Four disused mills within 500m of the site;
- Gas works approximately 500m from the site; and
- Historic landfill site approximately 220m from the site.

3.6 Site Walkover

A site inspection was carried on 24 June 2010. The findings are summarised below and are supported by the site walkover photographs presented in Appendix D.

- To the west the surrounding area is dominated by residential properties, while to the east it is largely dominated by agricultural land;
- A dry water course is present along the southern boundary of the site;
- The present land use is dominated by a non-operational bus depot, with a large depot for vehicle storage and maintenance and office space and external hardstanding. There are minor areas of surface concrete disrepair inside the building located near a drain gully in the north;
- The ground slopes gently to the south;
- In the north western area of the site is a grassed embankment of approximately 1m in height;

- There are two large oil tanks located outside to the east of the building, in a bunded area, one containing oil and the other containing fuel. Both are now believed to be empty;
- An electric generator is present inside the building;
- Drains are present in the north of the building, understood to be for the collection of runoff from vehicle washing. The drains contained a thick black sludge;
- An oil room is present in the north of the building, containing five oil tanks of approximately 1500 litres (engine oil, diff oil, gear box oil, sump oil and waste oil). These were direct filled via outside taps but emptied via indoor taps;
- A vehicle maintenance pit is located in the extended area to the north of the building. The drain from the pit appeared to be blocked as it contained water residue;
- Building wall panels was marked as containing asbestos;
- The drains to the north of the site contained a mixture of organic debris and litter, and the water within the drains had a possible hydrocarbon sheen;
- Vegetation consisted predominantly of overgrown grass with a large oak tree on the southwest corner and a large silver birch tree to the north; and
- Japanese Knotweed was observed in a small area located along the western site boundary.

3.6.1 Other

Japanese Knotweed is a non-native, highly invasive species and spreads via rhizomes (underground 'stems') rather than seeds in the UK. It is found in a range of habitats across the UK including roadsides, riverbanks and derelict land.

Japanese Knotweed was identified on site, as indicated on Figure 9. There is a number of methods by which Japanese Knotweed can be treated/eradicated, all of which are detailed in the Environment Agency's 'The Knotweed Code of Practice'. A competent Knotweed contractor should be employed to manage and perform the works in line with this guidance.

3.7 Summary of Potential Contaminant Sources

3.7.1 Onsite

- Possible localised hydrocarbon contamination associated with redundant above ground storage tanks located within the workshop and in the bunded area outside;
- Hydrocarbon contamination from drainage water from vehicle maintenance and wash areas; and
- Asbestos containing materials (ACMs) within the depot buildings.

3.7.2 Offsite

- A number of nearby active trade entries including a cleaners, a car dealership, and two chemical firms;
- The historical landfill site approximately 220m to the south of the site;
- Possible backfill material in former quarries surrounding the site; and
- Contamination from former cotton and flour mills located close to the site.

3.8 Sensitive Receptors

There are a number of sensitive receptors that may be affected by the potential contamination hazards identified above. These may include:

- Brook located along southern boundary, dry during site walkover;
- Shelf Brook, approximately 300m to the west of the site;
- Shallow (perched) water in any made ground materials or superficial deposits;
- Deeper groundwater in the Secondary A aquifer;
- Site operatives during redevelopment works;
- Future site occupants and buildings on site;
- Plant uptake;
- Neighbouring residents and surrounding areas; and
- Building infrastructure and services, including plastic utilities.

3.9 Summary of Plausible Pathways

The routes by which potential contamination could plausibly come into contact with the receptors are:

- Surface water run-off and/or infiltration;
- Groundwater migration in any permeable soils and existing/proposed service runs;
- Direct human ingestion, dust inhalation and/or dermal contact;
- Vapour migration from volatile compounds;
- Ground gas migration in permeable soils or existing/proposed service runs; and
- Plant uptake of contaminated soils.

3.10 Outline Conceptual Model

The information presented in Sections 2 and 3, above, has been used to compile an outline conceptual model. The identified potential contaminants and receptors have been considered, together with any possible pathways that may link them. The resulting pollutant linkages are considered in Table 3. The risk classification has been estimated in accordance with information in Appendix E.

Table 3: Risk Estimation for Potential Pollutant Linkages in Outline Conceptual Model

Potential Source	Potential Receptor	Possible Pathway	Likelihood	Severity	Risk
Organic and inorganic contamination associated with fill materials and/or fuels that may have been used on the site	Brook adjacent to southern boundary of site (currently dry)	Surface water run-off, infiltration, groundwater migration	Low likelihood	Medium	**Moderate/low**. Fill materials may be contaminated and in direct contact with perched water/surface water. Anecdotal information indicates brook has been dry for several years and therefore not a receptor.
	Shelf Brook (300m west)	Groundwater migration	Unlikely	Medium	**Low.** The low permeability superficial deposits beneath the site/region and distance from site will reduce the likelihood of the pathway being realised. Shelf Brook 300m from site.
	Perched water in made ground or superficial deposits	Vertical and horizontal migration of perched water and groundwater	Likely	Mild	**Moderate/Low.** Fill materials may be contaminated and in direct contact with perched water.
	Groundwater (minor / secondary A aquifer)		Low likelihood	Medium	**Moderate/Low**. Any contamination that may reach the minor aquifer could pose a significant risk to groundwater. Low permeable superficial deposits will reduce the likelihood of pathway being realised.
	Site operatives	Vapour and dust inhalation, human ingestion, and dermal contact	Low likelihood	Medium	**Moderate/low.** Although contact with soil is likely during the redevelopment works, risks can be mitigated during the development process using appropriate personal protective equipment (PPE).
	Future site occupants	Vapour and dust inhalation, human ingestion, dermal contact and plant uptake	Low likelihood / likely	Medium/ severe	**Moderate**. Contact with soil by future occupants is likely given that gardens are proposed.
	Plant uptake (phytotoxic effects)	Plant uptake from contaminated soil	Low likelihood	Minor	**Very low.** Plants may come into contact with contaminants within the soil which may be detrimental to plant growth.
	Neighbouring residents	Dust inhalation	Low likelihood	Mild	**Low.** Dust may be created that could be contaminated.
	Plastic utilities	Permeation	Likely	Mild	**Moderate/Low.** There may be some organic soil contamination on site, which could have a detrimental effect on plastic utilities.
Hazardous ground gases/vapours associated with on and off site made ground, including off-site landfill site and backfilled quarries	Site operatives	Vapour ground gas migration in permeable soils	Likely	Severe	**High**. Workers may enter excavations. Formal working practices and appropriate PPE will minimise risk.
	Future site occupants and buildings				**High**. Although unproven, there is a potential risk of asphyxiation in confined spaces or explosion if there is a build up of methane.
	Neighbouring residents and buildings		Low likelihood	Severe	**Moderate.** Build up of methane may lead to explosion in buildings, low permeable soils will minimise risk.

Potential Source	Potential Receptor	Possible Pathway	Likelihood	Severity	Risk
ACMs	Site operatives	Inhalation of asbestos fibres	Low likelihood	Severe	**Moderate.** The potential risks to human health associated with the presence of asbestos are severe, though the risks can be mitigated during the development process by using appropriate PPE.
	Future site occupants and neighbouring residents		Unlikely	Severe	**Moderate/low.** The potential risks to human health associated with the presence of asbestos are severe, though the risks can be mitigated.

The initial Conceptual Model has identified the following possible pollutant linkages with a severity of Moderate of higher:

- Surface water run-off/groundwater migration of contaminated water to brook adjacent to site boundary;
- Leaching of soil contaminants to perched water and groundwater in minor/secondary A aquifer;
- Inhalation/ingestion of/dermal contact with potentially contaminated soil and dust by site operatives and future occupants;
- Ingestion of contaminated plants by future residents;
- Permeation of soil/water contaminants of plastic water supply pipes;
- Inhalation of potentially hazardous ground gases/vapours by site operatives, future site occupants and neighbouring residents;
- Build up of explosive concentrations of migrating gases into buildings (on- and off-site); and
- Inhalation of asbestos containing material dust by site operatives, future occupants and neighbouring residents.

3.11 Preliminary Risk Assessment Conclusions and Recommendations

The review of information and the construction of the outline conceptual model highlight potential pollutant linkages. It will, therefore, be necessary to undertake an intrusive investigation of the site, which will provide further information on actual contaminants present and viable pathways to sensitive receptors.

4. ENVIRONMENTAL SITE INVESTIGATION

RSK carried out intrusive investigation work on 9 July 2010 and subsequent gas and groundwater monitoring between 16 July and 6 September 2010 to further investigate the potential pollutant linkages identified in the outline conceptual model.

4.1 : Scope of Works

The site investigation comprised the following scope of works:

- Drilling of nine probeholes to a maximum depth of 6m below ground level (bgl);
- Installation of six monitoring wells;
- Recovery of soil samples for laboratory chemical and geotechnical analysis;
- Recovery of groundwater samples for laboratory chemical analysis; and
- Undertaking six ground gas monitoring visits.

Upon completion, each exploratory hole was backfilled either with arisings or with a monitoring installation (consisting of pea gravel, bentonite and groundwater/gas monitoring pipework). The installations were finished with a lockable cover to maintain the integrity of the exploratory hole.

The investigation locations were chosen to target areas of potential concern and to provide a spread of data across the site.

4.1.1 Health and Safety Considerations

Utility plans were obtained from United Utilities, National Grid and Stagecoach, A CAT and Genny were also used on site to clear each location for services before drilling. Hand dug inspection pits were then excavated to 1.2m to ensure that no services were present.

4.1.2 Investigation Locations

The location of the intrusive investigations are shown in Figure 9. The rationale for these locations is given in Table 4.

Table 4: Exploratory Hole Location Rationale

Exploratory Hole Number	Location and Rationale	Rationale for Installation
PH1	Location close to external oil tanks to assess any impact.	Hydrocarbon odour noted.
PH2	Near inlets to internal oil tanks, to assess whether any oil spills have resulted in contamination.	Not installed.
PH3	Up-gradient of site, to assess if any off site contamination is entering the site.	To determine potential groundwater contamination and ground gases migrating on to site.

Exploratory Hole Number	Location and Rationale	Rationale for Installation
PH4	Close to blocked drain containing liquid sheen, to assess whether drain has impacted surrounding soils.	Strong hydrocarbon odour noted.
PH5	Inside building in old vehicle wash-off area, near broken concrete. To assess if run-off from vehicle wash-off area has impacted underlying soils.	Strong hydrocarbon odour noted and black residue on soil.
PH6	Inside building, down gradient of PH5, to assess if any potential contamination has migrated down-slope.	Not installed.
PH7	Down-gradiant of site, to assess if any potential contamination is migrating off-site.	Assess potential contamination and ground gases migrating off-site.
PH8	Close to former tank.	Not Installed.
PH9	To assess ground conditions in the banked area.	Assess potential ground gas and contamination in raised area.

The depths of the exploratory holes, descriptions of strata encountered, comments on groundwater conditions, samples obtained and installation details are included on the exploratory probehole records presented in Appendix F.

4.1.3 Soil Sampling

At least one sample of soil was recovered from each stratum. Where visual or olfactory evidence of contamination was observed, samples were obtained above, below and in the area of contamination. Selected samples were placed in polythene bags and the headspace screened with a PID. Samples were collected and stored in accordance with the RSK quality procedures to maintain sample integrity and preservation and to minimise the chance of cross-contamination. Samples were transferred from site to the office in chilled cool boxes. On return to the office samples were placed in refrigerators prior to dispatch to the laboratory in chilled cool boxes. Sixteen samples were taken and are recorded, together with their depths and PID screening results, on the exploratory probehole logs presented in Appendix F. The samples were transported to the laboratory in chilled cool boxes. Laboratory Chain of Custody Forms can be provided if required.

Samples were selected and scheduled for a range of organic and inorganic chemical analyses in order to classify the near-surface ground conditions with regard to contamination.

4.1.4 Groundwater Monitoring and Levelling

Depths to groundwater were recorded using an electronic dip meter during the six monitoring rounds.

The results of groundwater monitoring are presented in Appendix G.

4.1.5 Groundwater Sampling

The groundwater monitoring wells were purged prior to sampling. Sampling was undertaken using a disposable bailer dedicated to each monitoring location to avoid the risk of cross-contamination of samples.

The groundwater samples were collected in a variety of containers appropriate to the anticipated testing suite required (generally 1l amber glass jars and VOC vials). The containers were filled to capacity, where possible, and placed in a cool box to minimise volatilisation. Samples were transported to the testing laboratory in a cool box under Chain of Custody documentation directly to the testing laboratory.

4.1.6 Ground Gas Monitoring

Ground gas monitoring has been carried out over six monitoring rounds, as considered the minimum for residential housing, in line with the NHBC report[6]. This included periods of low and falling atmospheric pressures and during rainfall.

An infrared gas meter was used to measure concentrations of carbon dioxide (CO_2), methane (CH_4) and oxygen (O_2) in percentage by volume, whilst hydrogen sulphide (H_2S) and carbon monoxide (CO) were recorded in parts per million. Initial and steady state concentrations were recorded. A separate flow meter was used to measure borehole flow rate in litres per hour (l/hr). In addition, during the first monitoring round, all wells were screened with a photo-ionisation detector to establish the presence or otherwise or any interferences and cross-sensitivity of other hydrocarbons with the infrared gas meter.

In addition, the atmospheric pressure before and during monitoring, together with the weather conditions, was recorded.

All gas monitoring results together with the temporal conditions, are contained within Appendix G, and discussed in Section 4.2.3.

4.2 Ground Conditions

The results of the on-site observations are detailed below.

4.2.1 Soil Stratigraphy

The probehole records are presented in Appendix F and include the soil samples taken, results of PID readings, visual or olfactory evidence of contamination and details of monitoring well installations or reinstatement. The ground conditions described are based on the probeholes drilled by RSK.

Ground conditions across the site encountered concrete hardstanding or grassed areas generally along the western boundary of the site, over natural clay soils and sand.

Made ground was present to shallow depths across most of the site, (generally between 0.20m and 0.30m of concrete underlain by between 0.10m and 0.30m of made ground). Deeper made ground was present in the vicinity of the former vehicle maintenance pit (2.5m in PH6) and consisted of sand and some gravelly clay. A concrete obstruction (slab) was proved at 2.50m bgl within probehole PH6 located within the existing building considered to be the former infilled maintenance inspection pit. Slightly deeper made ground was also noted in a strip of raised land to the northwest of the site (1.70m in PH9). Here it consisted of gravelly sandy clay with occasional brick and limestone cobbles.

The made ground was underlain at most locations by a sandy subsoil and beneath this by slightly sandy clay and gravelly sand. Probehole PH1 encountered a yellow grey gravelly sand, described as possible weathered sandstone, below 5.70m.

The probeholes were generally unstable during drilling of the sandy horizons, though remained stable throughout the clay.

4.2.2 Groundwater regime

Due to casing of the holes it was not possible to ascertain groundwater levels during drilling.

During the monitoring visits, groundwater was present in a number of the installations. The results of the groundwater monitoring are presented in Appendix G.

4.2.3 Ground Gas Regime

The results of the ground gas monitoring (including initial and steady state concentrations) presented in Appendix G are also summarised in Table 5 below, where calculated gas screening values (GSVs) are provided. GSVs are the product of gas

concentration and gas flow from a borehole and therefore provide an indication of the flow of the particular gas in question out of the ground.

Table 5: Summary of Ground Gas Monitoring Data

Date	Methane		Carbon Dioxide		Oxygen		Flow Rate l/hr		GSV CO_2 and Methane	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Monitoring round 1 16 July 2010	<0.1	23.1	<0.1	13.2	1.3	20.5	<0.1	0.4	<0.001	0.026
Monitoring round 2 23 July 2010	<0.1	9.5	<0.1	10.4	5.4	20.5	<0.1	0.1	<0.001	<0.001
Monitoring round 3 5 August 2010	0.1	11.4	<0.1	8.7	0.1	18.3	<0.1	0.1	<0.001	0.009
Monitoring round 4 19 August 2010	0.3	10.7	0.3	11.3	<0.1	20.1	<0.1	0.1	<0.001	0.010
Monitoring round 5 27 August 2010	0.4	12.6	0.5	13.6	0.1	19.9	<0.1	0.7	<0.001	0.092
Monitoring round 6 6 September 2010	0.4	11.2	0.6	10.8	19.9	0.5	<0.1	0.5	<0.001	0.021

Date	Atmospheric pressure during the preceding three days prior to the monitoring round			Temporal conditions during the monitoring round		
	3	2	1	Atmospheric Pressure	Rainfall	Other
Monitoring round 1 16 July 2010	1030	1015	1005	995	Light, constant	Slightly breezy, overcast
Monitoring round 2 23 July 2010	1009	1004	1013	1021	Dry	100% Could Cover
Monitoring round 3 5 August 2010	1018	1014	1006	1012	Light drizzle	100% Cloud Cover
Monitoring round 4 19 August 2010	1018	1009	1009	1009	Dry	50% could cover, sunny
Monitoring round 5 27 August 2010	1005	1012	1008	1012	Dry	Sunny sparse cloud
Monitoring round 6 6 September 2010	1022	1021	1018	1007	Dry	Sunny

The gas monitoring data collected indicate that there may be a risk posed to site operatives and end-users of the site in relation to carbon dioxide, methane and depleted oxygen concentrations encountered across the site.

4.3 Analytical Strategy and Methodology

A total of 14 soil and 2 groundwater samples were tested for the analytes listed in Tables 6 and 7 below. The analytical schedule was based on the previous and current uses of the site identified in Section 3 and the ground conditions encountered. The results of PID screening analysis were also used to assist in scheduling the laboratory analyses. All analysis was undertaken by UKAS and MCERTS certified laboratories. The details of the laboratory certification are included on the certificates in Appendices H and I.

Table 6: Scheduled Analysis – Soil

Exploratory Hole No. & Sample Depth (m bgl)	Analyte	Rationale
PH1 @ 0.3-0.4	Metals, pH and sulphate (BRE), speciated PAH, speciated TPH	Located near bunded oil tanks, had hydrocarbon odour.
PH1 @ 0.6-0.7	Speciated TPH	Located near bunded oil tanks, had hydrocarbon odour.
PH1 @ 1.1-1.2	pH and sulphate (BRE), speciated TPH	Located near bunded oil tanks, no hydrocarbon odour. To determine whether hydrocarbons had leached into natural clay.
PH1 @ 3.1-3.2	pH and sulphate (BRE)	At potential foundation depth.
PH3 @ 1.3-1.4	pH and sulphate (BRE)	At potential foundation depth.
PH4 @ 0.9-1.1	Metals, pH and sulphate, speciated PAH, speciated TPH	Located near old blocked drain on the outside of the building with oil sheen, had hydrocarbon odour.
PH4 @ 1.8-2.0	pH and sulphate (BRE), Speciated TPH	Located near old blocked drain with oil sheen, had hydrocarbon odour.
PH5 @ 0.2-0.5	Speciated TPH	Located near vehicle washing area near a blocked drain, had very strong hydrocarbon odour.
PH5 @ 1.2-1.4	Metals, pH and sulphate (BRE), speciated PAH, speciated TPH	Located near vehicle washing area near a blocked drain, had slight hydrocarbon odour.
PH5 @ 2.1-2.3	pH and sulphate (BRE), speciated TPH	Located near vehicle washing area near a blocked drain, no hydrocarbon odour. To determine whether hydrocarbons had leached into natural clay.
PH6 @ 1.9-2.1	Metals, pH and sulphate, speciated PAH, speciated TPH	Made ground.

Exploratory Hole No. & Sample Depth (m bgl)	Analyte	Rationale
PH7 @ 5.0-6.0	Metals, pH and sulphate, speciated PAH, speciated TPH	To determine whether contaminants are migrating to the aquifer.
PH8 @ 0.6-0.8	pH and sulphate (BRE), speciated TPH	Area of former tank.
PH9 @ 0.9-1.1	Metals, pH	Made ground.

Table 7: Scheduled Analysis – Groundwater

Exploratory Hole No.	Analyte	Rationale
PH5	Metals, pH and sulphate, speciated PAH, speciated TPH	To determine whether groundwater is contaminated.
PH7	Metals, pH and sulphate, speciated PAH, speciated TPH	To determine whether groundwater is contaminated.

4.4 Chemical Conditions

Full analytical certificates for soil and groundwater samples are provided in Appendices H and I, respectively. The results are discussed in the GQRA, Section 5.

5. GENERIC QUANTITATIVE RISK ASSESSMENT

In line with CLR11[(1)], there are two stages of quantitative risk assessment: generic and detailed. The GQRA comprises the comparison of soil, groundwater and ground gas results with generic assessment criteria (GAC) that is appropriate to the linkage being assessed. The GAC used in this assessment are included in Appendix J for human health (together with details of their derivation) and in Appendix K for the assessment of phytotoxic effects, risks to plastic utilities and to controlled waters.

The site investigation work and subsequent monitoring indicate that there are relevant pollutant linkages at the site, which require further consideration.

5.1 Relevant Linkages for Assessment

The linkages for assessment are presented in Table 8.

Table 8: Linkages for Generic Quantitative Risk Assessment

Relevant Pollutant Linkage	GAC
Direct contact pathways to site operatives and future residents	Human health GAC for a proposed residential end use with private gardens since proposed end use includes residential gardens.

Relevant Pollutant Linkage	GAC
Leaching and dissolved phase migration to minor/secondary A aquifer and nearby surface water features	GAC recorded in Table 3 of Appendix K for minor aquifers.
Concentrations of methane and carbon dioxide in ground gas entering and accumulating in: • Depressions and excavations during any site works and development that could affect site workers; and • Enclosed spaces or small rooms in new buildings, which could affect future residents. In the case of methane, this could create a potentially explosive atmosphere, whilst death by asphyxiation could result from carbon dioxide.	Gas screening values (GSV) have been calculated using maximum methane and carbon dioxide concentrations with maximum flow rates recorded at the site. The GSV have been compared with the generic Traffic Lights, as presented within the NHBC ground gases guide[4].
Plant uptake	GAC presented in Appendix K for phytotoxic determinants
Permeation of plastic utilities	GAC presented in Appendix K for water supply pipes

5.2 Methodology and Results

The methodology and results of the generic quantitative risk assessment are presented for each relevant pollutant linkage in turn.

5.2.1 Leaching and Migration of Dissolved Phase Contaminants to Minor/Secondary A Aquifer and Surface Water Bodies

Two groundwater samples have been obtained as part of this investigation. The GAC used to assess this linkage are presented in Appendix K and comprise the minor aquifers/surface water courses. These are considered the most appropriate GAC owing to the site's location on a minor aquifer. The results indicate elevated hydrocarbons within the water sample recovered from probehole PH5, which was located near the vehicle washing area. Probehole PH5 encountered a strong hydrocarbon odour within the shallow granular soils during the drilling works. It is likely further delineation of this area will be required, which may result in some limited remedial works. The results indicate that a relevant pollutant linkage may exist.

5.2.2 Direct Contact and Vapour Inhalation by Site Operatives and Future Occupants

The laboratory data (Appendix H) have been compared directly to the GAC presented in Appendix J. The results are summarised in Tables 9, 10 and 11.

Table 9: Summary of Soil Test Results - Metals

Contaminant	GAC mg/kg	Range of Results in mg/kg (No. tested)	Pass/Fail Max. Value Test	Comments
Arsenic	32	<1 – 22 (6)	Pass	
Cadmium	10	<0.5 (6)	Pass	
Chromium	3,000	3 – 31 (6)	Pass	
Copper	2,300	3 – 120 (6)	Pass	
Lead	450	6 – 586 (6)	Fail	PH1 @ 0.30-0.40: 586mg/kg
Mercury	0.17	<0.17 – 0.39 (6)	Fail	PH1 @ 0.30-0.40: 0.23mg/kg PH9 @ 0.90-1.10: 0.39mg/kg
Nickel	130	6 – 43 (6)	Pass	
Selenium	350	<1 – 1 (6)	Pass	
Zinc	3,800	21 – 120 (6)	Pass	

Table 10: Summary of Soil Test Results – PAH

Contaminant	GAC mg/kg	Range of Results in mg/kg (No. tested)	Pass/Fail Max. Value Test	Comments
Naphthalene	1.5	<0.01 – 16.9 (5)	Fail	PH4 @ 0.90-1.10: 7.58mg/kg PH5 @ 1.20-1.40: 13.9mg/kg
Acenaphthylene	170	<0.01 – 1.27 (5)	Pass	
Acenaphthene	210	<0.01 – 1.99 (5)	Pass	
Fluorene	160	<0.01 – 14.7 (5)	Pass	
Phenanthrene	92	0.02 – 14.2 (5)	Pass	
Anthracene	2,300	<0.01 – 1.27 (5)	Pass	
Fluoranthene	260	<0.01 – 3.52 (5)	Pass	
Pyrene	560	<0.01 – 2.76 (5)	Pass	
Benz(a)anthracene	3.1	<0.01 – 0.62 (5)	Pass	
Chrysene	6.0	0.02 – 1.49 (5)	Pass	
Benzo(b)fluoranthene	5.6	<0.01 – 0.5 (5)	Pass	
Benzo(k)fluoranthene	8.5	<0.01 – 0.68 (5)	Pass	
Benzo(a)pyrene	0.83	<0.01 – 0.85 (5)	Fail	PH6 @ 1.90-2.10: 0.85mg/kg
Indeno(123cd)pyrene	3.2	<0.01 – 0.25 (5)	Pass	
Dibenzo(ah)anthracene	0.76	<0.01 – 0.03 (5)	Pass	
Benzo(ghi)perylene	44	<0.01 – 0.61 (5)	Pass	

Table 11: Summary of Soil Test Results – Petroleum Hydrocarbons

Contaminant	GAC mg/kg	Range of Results in mg/kg (No. tested)	Pass/Fail Max. Value Test	Comments
Benzene	0.079	<0.01 (12)	Pass	
Toluene	120	<0.01 (12)	Pass	

Contaminant	GAC mg/kg	Range of Results in mg/kg (No. tested)	Pass/Fail Max. Value Test	Comments
Ethylbenzene	65	<0.01 (12)	Pass	
Xylene O	87	<0.01 – 2.01 (12)	Pass	
MTBE	1.8	<0.01 (12)	Pass	
Aliphatic C_5–C_6	30	<0.01 – 0.17 (12)	Pass	
Aliphatic C_6–C_8	73	<0.01 – 0.47 (12)	Pass	
Aliphatic C_8–C_{10}	19	<0.01 – 24.6 (12)	Fail	PH5 @ 1.20-1.40: 24.6mg/kg
Aliphatic C_{10}–C_{12}	93	<0.1 – 1,200 (12)	Fail	PH4 @ 0.20-0.40: 1,200mg/kg PH4 @ 0.90-1.10: 530mg/kg PH5 @ 1.20-1.40: 696mg/kg
Aliphatic C_{12}–C_{16}	744	<0.1 – 4,530 (12)	Fail	PH4 @ 0.20-0.40: 4,530mg/kg PH4 @ 0.90-1.10: 1,860mg/kg PH5 @ 1.20-1.40: 2,320mg/kg
Aliphatic C_{16}–C_{21}	45,100	<0.1 – 6,630 (12)	Pass	
Aliphatic C_{21}–C_{35}	45,100	<0.1 – 3,900 (12)	Pass	
Aromatic C_8–C_9	130	<0.01 – 3.31 (12)	Pass	
Aromatic C_9–C_{10}	27	<0.01 - 31.1 (12)	Fail	PH5 @ 1.20-1.40: 31.1mg/kg
Aromatic C_{10}–C_{12}	69	<0.1 – 168 (12)	Fail	PH4 @ 0.20-0.40: 78.9mg PH4 @ 0.90-1.10: 156mg/kg PH5 @ 1.20-1.40: 168kg
Aromatic C_{12}–C_{16}	140	<0.1 – 1,060 (12)	Fail	PH4 @ 0.20-0.40: 598mg/kg PH4 @ 0.90-1.10: 905mg/kg PH5 @ 1.20-1.40: 1,060mg/kg
Aromatic C_{16}–C_{21}	250	<0.1 – 1,300 (12)	Fail	PH4 @ 0.20-0.40: 1,200mg/kg PH4 @ 0.90-1.10: 1,070mg/kg PH5 @ 1.20-1.40: 1,300mg/kg
Aromatic C_{21}–C_{35}	890	<0.10 – 517 (12)	Pass	

The GAC values for lead, mercury, naphthalene, benzo-a-pyrene and a number of hydrocarbon bands were exceeded in at least one soil sample.

With regard to the lead and mercury exceedances, these are considered only very marginal. The concentrations are not considered likely to pose a risk to construction workers or neighbouring residents. The minimal risk to future site residents should be mitigated by placement of an inert growing medium (topsoil) of at least 350mm in garden areas.

The elevated naphthalene and petroleum hydrocarbon concentrations were recorded in probeholes PH4 and PH5, in the vicinity of the interceptor pit, vehicle wash area, drain and refilling taps for the new indoor fuel tank. In many cases the concentrations are significantly elevated and pose a risk to human health.

The elevated benzo-a-pyrene concentrations in probehole PH6 is considered so marginal that it should not represent a risk to human health, assuming that an inert growing medium is placed in garden areas.

5.2.3 Uptake of Contaminants by Vegetation, Potentially Inhibiting Plant Growth

The results have been compared with the GAC presented in Appendix K for this linkage and indicate concentrations of all determinants to be below the respective GAC values. A relevant pollutant linkage is therefore unlikely to exist associated with phytotoxic effects.

5.2.4 Permeation of Plastic Utilities

The results of the soil analyses have been compared with the GAC presented in Appendix K for water supply pipes and indicate elevated arsenic concentrations at two locations (PH1 at 0.30m-0.40m: 22mg/kg, and PH9 at 0.90m-1.00m: 21mg/kg, compared with the GAC of 10mg/kg). This arsenic GAC for water supply pipes is based on old guidance for human health (e.g. construction workers), rather than the potential for permeation of plastic pipes. As neither samples exceeds the current arsenic GAC for human health of 32mg/kg, see Appendix J this linkage can be discounted (as discussed in Section 5.2.2 above).

The results also indicate elevated petroleum hydrocarbon concentrations in probeholes PH4 and PH5 when compared against the petroleum hydrocarbon GAC for water supply pipes, which relates to permeation of plastic pipes. A potential linkage therefore exists in relation to permeation of plastic supply pipes in this area if this material remains on site. Advice should be sought from the utility provider in terms of any requirements for supply pipe materials.

5.2.5 Ground Gas

In order to assess the significance of ground gases at the site, measured concentrations and flow rates have been used to derive GSVs, as discussed in section 4.2.3 above. For the purposes of this assessment it has been assumed that the dwellings will have a ventilated sub-floor void. As such, the GSVs and total gas concentrations recorded have been compared with the generic Traffic Lights, as presented within the NHBC ground gases guide[6].

The GSV for both methane and carbon dioxide is calculated by multiplying the maximum borehole flow rate by the maximum gas concentration. This calculation is automatically generated in the NHBC GSV worksheet presented in Appendix L, which also indicates the level of gas protection measures required, if any.

The results of the gas monitoring generally indicate elevated (steady state) methane concentrations, up to a maximum of 12.6 per cent by volume and carbon dioxide up to a maximum of 11.3 per cent by volume. Elevated methane and carbon dioxide concentrations were generally proved in probeholes PH1, PH4 and PH5, associated with depleted oxygen concentrations.

Gas flow rates recorded were generally negligible, less than 0.5 l/hr. Probeholes PH3, PH7 and PH9 recorded low concentrations of methane and carbon dioxide.

The tabulation of gas monitoring results presented as Appendix L assesses each monitoring result in terms of the NHBC Traffic Lights classification. A comparison of the total methane and carbon dioxide gas results would characterise the site as "Amber 2". On one occasion an initial methane concentration of over 20 per cent by volume was measured which is a 'Red' characterisation. All of the calculated GSVs are <0.16 l/hr for methane and <0.78 l/hr for carbon dioxide which are the threshold values for 'Green' characterisation where gas ingress precautions are not considered to be necessary.

Based on all the information, it would be prudent at this stage to characterise the site as "Amber1"[6].

5.2.6 Asbestos Containing Materials

Based on the findings of the site walkover, building materials on site were identified to contain asbestos. Consideration will need to be given for the safe removal of all asbestos containing materials by specialised contractors prior to demolition.

5.3 Refined Conceptual Site Model

Following intrusive investigations, subsequent monitoring and the GQRA it is now possible to refine the outline conceptual site model, as detailed in Section 3.10, given our better understanding of the site.

The identified potential contaminants and receptors have been reconsidered and are presented in Table 12 below.

Table 12: Risk Estimation for Refined Conceptual Model

Potential Source	Potential Receptor	Possible Pathway	Likelihood	Severity	Risk
Organic and inorganic contamination associated with fill materials and/or fuels that may have been used on the site	Brook adjacent to southern boundary of site (currently dry)	Surface water run-off, infiltration, groundwater migration	Unlikely	Mild	**Very low**. Natural soils encountered adjacent to the brook in the southern area of the site (PH7), associated with negligible concentrations of contaminants tested.
	Shelf Brook (300m west)	Groundwater migration	Unlikely	Medium	**Low.** The low permeability superficial deposits beneath the site/region and distance from site will reduce the likelihood of the pathway being realised. Shelf Brook 300m from site.
	Perched water in made ground or superficial deposits	Vertical and horizontal migration of perched water and groundwater	Likely	Mild	**Moderate/Low**. Elevated hydrocarbons identified in shallow water samples recovered from site, considered to be localised and contained within the fill materials located adjacent to the former fuel storage tanks and vehicle washing area including drainage system.
	Groundwater (minor / secondary A aquifer)		Low likelihood	Medium	**Moderate/Low**. Any contamination that may reach the minor aquifer could pose a significant risk to groundwater. Low permeable superficial deposits will reduce the likelihood of pathway being realised.
	Site operatives	Vapour and dust inhalation, human ingestion, and dermal contact	Low likelihood	Medium	**Moderate/low.** Although contact with soil is likely during the redevelopment works, risks can be mitigated during the development process using appropriate personal protective equipment (PPE).
	Future site occupants	Vapour and dust inhalation, human ingestion, and dermal contact and plant uptake	Low likelihood / likely	Medium/ severe	**Moderate**. Contact with soil by future occupants is likely given that gardens are proposed.
	Plant uptake (phytotoxic effects)	Plant uptake from contaminated soil	Low likelihood	Minor	**Very low.** Plants may come into contact with contaminants within the soil which may be detrimental to plant growth.
	Neighbouring residents	Groundwater and leachate migration in permeable soils	Unlikely	Medium	**Low.** The site is underlain by low permeable superficial deposits, thereby reducing the likelihood of migration of any contaminants off-site.
		Dust inhalation	Low likelihood	Mild	**Low.** Dust may be created that could be contaminated.

Potential Source	Potential Receptor	Possible Pathway	Likelihood	Severity	Risk
	Plastic utilities	Permeation	Likely	Mild	**Moderate/low.** Some hydrocarbon impacted soils/groundwater which could permeate plastic utility pipes.
Hazardous ground gases associated with on and off site made ground, including off-site landfill site and backfilled quarries	Site operatives	Vapours/gas migration in permeable soils	Likely	Severe	**High.** Workers may enter excavations. Formal working practices and appropriate PPE will minimise risk.
	Future site occupants and buildings				**Moderate/low.** Elevated concentrations of methane and carbon dioxide associated with fill materials on site.
	Neighbouring residents and buildings		Unlikely	Severe	**Moderate/low.** Low concentrations of hazardous gases identified in three monitoring wells installed across the site, indicating gas migration to be low.
ACMs	Site operatives	Inhalation of asbestos fibres	Low likelihood	Severe	**Moderate.** The potential risks to human health associated with the presence of asbestos are severe, though the risks can be mitigated during the development process by using appropriate PPE.
	Future site occupants and neighbouring residents		Unlikely	Severe	**Moderate/low.** The potential risks to human health associated with the presence of asbestos are severe, though the risks can be mitigated.

The refined conceptual model identifies the following pollutant linkages:

- Leaching of soil contaminants to perched water and groundwater in minor/secondary A aquifer;
- Inhalation/ingestion of/dermal contact with potentially contaminated soil and dust by site operatives and future occupants;
- Ingestion of contaminated plants by future residents;
- Permeation of plastic water supply pipes;
- Inhalation of potentially hazardous ground gases/vapours by site operatives and future site occupants;
- Inhalation of oxygen-depleted air by site operatives;
- Build-up of explosive concentrations of migrating gases into future buildings (on site); and
- Inhalation of ACMs by site operatives, future site occupants and neighbouring residents.

6. GEOTECHNICAL SITE ASSESSMENT

It is proposed to construct low-rise residential units. The aim of the geotechnical investigation is to ascertain ground conditions at the site and provide some data regarding the soil parameters to enable the design of foundations, floor slabs and infrastructure to be carried out. This aim was achieved by:

- Drilling of nine probeholes to a maximum depth of 6.00m bgl;
- Completion of in-situ standard penetration tests (SPTs); and
- Recovery of soil samples for inspection and laboratory geotechnical analysis.

6.1 Methodology

Information from the probeholes was used for the geotechnical assessment. Details of the intrusive investigation and the ground conditions encountered are provided in Sections 4.1 and 4.2. The methodology for the geotechnical intrusive investigation is presented below.

6.1.1 In-situ Testing

SPTs were carried out to assess the relative density of the strata. The values of penetration resistance (N-values) are given in the probehole records (Appendix F).

6.1.2 Laboratory Analysis

The geotechnical testing has generally been carried out in accordance with the methods given in BS 1377[7].

pH and water soluble sulphate analysis was carried out on eight soil samples for the assessment of the potential for chemical attack on buried concrete based on current BRE guidance[8]. The results of the pH and sulphate analysis are included in the contamination analysis certificates in Appendix H.

The natural moisture contents and liquid and plastic limits of one sample of the cohesive soil were determined. The results are presented in Appendix M.

6.1.3 Assessment of Mining

The site is understood to lie within an area unaffected by mining.

6.2 Chemical Attack on Buried Concrete

This assessment of the potential for chemical attack on buried concrete is based on current BRE guidance[8]. The desk study and site walkover indicate that, for the

purposes of this assessment of the aggressive chemical environment, the site should be considered as a brownfield development that has not been subject to previous industrial development and does not contain pyrite. A suite of chemical analyses appropriate to this site classification was carried on soil samples.

The maximum water-soluble sulphate content (using the BRE method) in soil of 0.07g/l has been taken as the characteristic value. As this value is below the limiting value of 3.0g/l, consideration of magnesium is not required. Based on Table 2 in the BRE guidance, result one for Design Sulphate Class for the site is DS-1.

The assessment of groundwater was not carried out. The second result two has therefore not been determined.

Although for the purposes of this assessment the site has been classified as brownfield, the pH is nowhere less than the limiting value of 5.5. The third assessment of design sulphate class specific to brownfield sites is therefore not required.

From consideration of result one, a Design Sulphate Class of DS-1 may be adopted for the site. It has been assumed that groundwater conditions are mobile. From consideration of the characteristic pH value, an Aggressive Chemical Environment for Concrete classification of AC-1 may be assumed for design purposes.

6.3 Foundation Design

Based on inspection of the soils encountered in the probeholes as well as the results of the in-situ testing and the anticipated structural loads for the proposed two-storey buildings, it is considered that the majority of the housing may be supported on strip or trench fill foundations taken down through any made ground and soft soils and placed on the underlying firm or stiff clay or medium dense sands. Such foundations may be designed to an allowable net bearing pressure of 100kN/m^2. All formations should be inspected and if any pockets of soft or firm clay are found these should be excavated and the foundations locally deepened.

The results of the laboratory test, given in Appendix M, indicate the clay to be of high volume change potential, although is based on one result only. Based upon the results of the moisture content determinations and the corresponding liquid and plastic limit value, it is considered that at the time of the investigation the clay soils were not desiccated. NHBC standards 2008 Chapter 4.2 Table 17[9] should be used as a guide where any high water demand trees are, or have been, present.

The presence of high water demand trees such as willows/poplars in soils of high volume change potential may lead to foundation depths in excess of 2.5m being required, and consequently piled foundations may prove to be more economic.

Details on designing to accommodate heave are dependent upon the volume change potential of the soil (determined from the modified plasticity index) and are set out for each foundation type in NHBC Standards Chapter 4.2. This also provides guidance on the types of suspended floor that are acceptable where there is potential for precautionary measures.

Consideration will need to be given where clay soils are found below a depth of 1.5m and sand deposits are present at more shallow depth. In the vicinity of any trees, the underlying clay may dictate foundation depths. Particular reference should be made to Clause D6(f) of the NHBC Standards, Chapter 4.2 and it may therefore be necessary to excavate additional pits to establish the depth of the sand/clay boundary should any of the proposed houses in this area of the site be close to trees.

The existing buildings will have to be demolished. However, based on the findings of the site walkover, building materials on site were identified to contain asbestos and consideration will need to be given for the safe removal of all asbestos containing materials by specialised contractors prior to demolition. Following removal of all the asbestos, it is likely most of the building materials and surface hardstanding would then be suitable for crushing and re-use on site.

Where new houses overlap the footprints of any existing buildings, it will be necessary to break out any existing foundations where intersected by the excavations for the new, and place these on the underlying undisturbed material. This is likely to result in slightly deeper foundations locally. There may also be other areas of deeper structures and service runs, which will require breaking out and foundations may be deepened locally. Footings for a single unit should preferably be founded entirely on either the clay or the sand. Therefore, in areas where the soil interface is encountered, it will be necessary to locally deepen foundations for individual units. Alternatively, if foundations span both soil types, it will be necessary to provide nominal reinforcement in both the top and bottom of the footings to 2m either side of the interface.

Suspended floor slabs will be required where the new buildings overlap the footprints of the existing buildings, as specified in the NHBC Standards Chapter 5.2, Suspended Ground Floors: 2001[10].

Over the southern area of the building, deeper fill is present. Probehole PH6 proved made ground to 2.50m bgl where upon a concrete obstruction (possible slab) was encountered. This area of the site is considered to be the infilled former inspection pit. Once a housing layout has been finalised, further investigation should be carried out to determine the extent and suitability of the infilled materials. Over this area and the area of the existing inspection pit located in the north of the site, a number of options for foundations exist. Following the breaking out and removal of the concrete bases / slabs and removal of the fill materials within the former inspection pit, foundation options will include: the provision of clean inert engineered fill and the adoption of shallow reinforced

slab foundations; or the provision of loosely placed clean inert granular fill subjected to vibro-imported with the adoption of reinforced strip footings. An alternative foundation solution is the adoption of piles and ground beam type foundations. A range of pile types may be suitable and specialist contractors should be considered as to the applicability of their systems.

Should a piled foundation solution be adopted, pile design parameters can be obtained from the probehole records and the geotechnical laboratory results presented in Appendices F and M, respectively. Advice should be sought from specialist contractors as to the size and number of piles considered necessary to support the working loads. If a piled solution is adopted, they should be designed to accommodate the uplift forces on the upper portion of their shafts together with the upward forces imposed on the underside of the groundbeams. Advice in relation to pile type foundations should be obtained from NHBC Chapter 4.5[11].

6.4 Infrastructure

6.4.1 Road Construction

Given the nature of the drift deposits beneath the site, it is anticipated that road pavements should be designed on a CBR value of 2% to 5%. Any soft or loose material at formation level should be removed and replaced with well-compacted granular material. All formations should be compacted to make good any disturbance caused by excavation. It is recommended that the formation not be exposed for any period of time during inclement weather.

6.4.2 Soakaway Design

Below the made ground the natural soils at this site were found to generally comprise sandy clay of low permeability. In these conditions, it is considered that soakaway drainage would not be feasible.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Environmental

The relevant pollutant linkages that require further action based on the available information are:

- Leaching of soil contaminants to perched water and groundwater in minor/secondary A aquifer;
- Inhalation/ingestion of/dermal contact with potentially contaminated soil and dust by site operatives and future occupants;

- Ingestion of contaminated plants by future residents;
- Permeation of plastic water supply pipes;
- Inhalation of potentially hazardous ground gases/vapours by site operatives and future site occupants;
- Inhalation of oxygen-depleted air by site operatives;
- Build-up of explosive concentrations of migrating gases into future buildings (on site); and
- Inhalation of ACMs by site operatives, future site occupants and neighbouring residents.

The results of the gas monitoring completed indicate concentrations of elevated methane and carbon dioxide associated with low oxygen concentrations. Comparison of these results and the calculated GSVs indicate 'Amber2' characterisation for the site in accordance with the NHBC "Traffic Lights" classification.

Depleted oxygen concentrations pose a potentially severe risk to construction workers by asphyxiation in areas of limited access (such as service or foundation trenches). It will therefore be necessary to continually monitor excavations for oxygen concentrations and a policy of no man-entry into excavations should be adopted unless suitable conditions are proven by gas monitoring.

Polyethylene water-supply pipelines may not be suitable over areas of the site owing to elevated petroleum hydrocarbon concentrations. To mitigate risks associated with permeation of plastic water supply pipes, alternative pipeline construction material may be required (e.g. protectaline) if these materials remain on site. The local water utility provider should be contacted to confirm their requirements.

Elevated PAH and petroleum hydrocarbon concentrations were recorded within the made ground in probeholes PH4 and PH5. It is recommended that further intrusive investigation be carried out in this area to delineate the extent of the impact. It is considered likely these materials to be unsuitable and will require excavation and removal off site for disposal, together with any impacted perched groundwater.

It is recommended, based on the marginal concentrations of contaminants indicated within the fill materials, that provision for the placement of an inert capping layer be made over areas of made ground in proposed gardens and areas of open space. At this stage an allowance of 350mm inert cover be made. However, these recommendations will need to be agreed with the regulators responsible for the site.

Asbestos was present in the building structure. As such, the demolition of the existing building will need to be carried out by a specialist contractor.

Japanese Knotweed was identified during the site walkover and should be removed off site or treated by a competent Knotweed contractor, see Section 3.6.1.

7.2 Geotechnical

The results of the pH and sulphate analysis indicate that a Design Sulphate Class of DS-1 may be adopted for the site, and that an Aggressive Chemical Environment for Concrete classification of AC-1 may be assumed for design purposes.

It is considered likely that a piled foundation solution will need to be adopted for some areas. Elsewhere it is likely that deep strip and trench fill foundations will be suitable. All foundations should be taken down through any made ground and placed on the underlying firm clay. Foundations may be designed to an allowable net bearing pressure of 100kN/m^2.

It is anticipated that road pavements should be designed on a CBR value of 2% to 5%. Any loose material at formation level should be removed and replaced with well-compacted granular material.

8. REFERENCES

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