

PHASE IIA ENVIRONMENTAL
ASSESSMENT

PENNYCROFT WAY
UTTOXETER

EAST STAFFORDSHIRE
BOROUGH COUNCIL

NOVEMBER 2013



IVY HOUSE
environmental

DRAFT

SUMMARY TABLE: PHASE IIA ENVIRONMENTAL ASSESSMENT		
SITE:	Pennycroft Way, Uttoxeter	
CLIENT:	East Staffordshire Borough Council	
DATE:	November 2013	
HUMAN HEALTH:	PAH & TPH contaminated site with hotspots of cyanide, arsenic and lead. Asbestos fibres and fragments present in made ground.	Cap required for all units, RMS required for gas holder waste, fill and ash in south eastern section.
CONTROLLED WATERS:	Groundwater contaminated with sulphate, PAH, TPH, phenols, VOC and SVOC.	Remediation required to reduce risk to controlled waters.
GAS RISK:	Low levels of carbon dioxide. No vapour risk	Additional gas assessment required post remediation.
CONSTRUCTION PHASE:	RMS to consider waste characterisation of made ground and likely disposal costs during groundworks phase. Remediation may be required to reduce hazardous properties of contaminated made ground to non-hazardous or inert.	
COMMENTS:	Post demolition assessment of existing buildings footprint recommended. RMS to be produced with input from specialist contractors and regulators.	

Authorised:		Richard Sutton MRICS <i>Director</i>
Date:	21 st November 2013	
Revision:	1.0	



IVY HOUSE

environmental

Scotland Farm, Ockbrook, Derby, DE72 3RX
rps@ivyhousenv.co.uk • www.ivyhousenv.co.uk • 01332 820 488

CONTENTS

1.0	INTRODUCTION	1
2.0	PHASE II REVIEW	2
3.0	PHASE I CONCEPTUAL MODEL	5
4.0	PHASE IIA FIELDWORK.....	7
5.0	GROUND CONDITIONS	10
6.0	CONTAMINATION ASSESSMENT	13
7.0	PHASE IIA CONCEPTUAL SITE MODEL	17
8.0	RISK MANAGEMENT & REMEDIATION.....	19
9.0	RECOMMENDATIONS	21
10.0	CONCLUSIONS	21

APPENDICES

Appendix A	Site Location and Layout Plans
Appendix B	Exploratory Hole Location Plan – 2010 Investigation
Appendix C	ESBC Correspondence
Appendix D	Exploratory Hole Location Plan & Logs
Appendix E	Soil Chemical Analysis Results
Appendix F	Groundwater Chemical Analysis Results
Appendix G	Vapour Analysis Results
Appendix H	Gas & Groundwater Monitoring Results
Appendix I	Generic Assessment Criteria & Statistical Analysis Sheets

1.0 INTRODUCTION

1.1 PREAMBLE

This Phase II Environmental Assessment has been produced for East Staffordshire Borough Council (ESBC) to provide a secondary Phase II (Phase IIA) assessment of the site area referred to as *Area B, Pennycroft Way* and an investigation of an additional parcel of land to the west of Area B (skip yard).

Area B was initially investigated in 2010 by BWB Consulting (ref. P2010/01134); this report aims to fill in data gaps in the 2010 report, provide an assessment of the Skip Yard and comply with recommendations and comments made by the client.

The site is the subject of a feasibility study for residential development.

1.2 SITE LOCATION

The site is located approximately 500m to the north of Uttoxeter town centre. The National Grid Reference (NGR) for the approximate centre of the site is SK 091 340. The site location and the site layout are illustrated in Appendix A.

1.3 PROJECT BRIEF

The brief for the Phase IIA Environmental Assessment incorporates:

1. A review and assessment of the site history, with reference to potentially contaminative uses and previous site investigation reports.
2. A review of regulatory authority correspondence relating to previous site investigations.
3. A site inspection.
4. Develop a strategy for a Phase IIA Environmental Assessment of the site.
5. Develop the Phase IIA conceptual model.
6. Undertake a Detailed Quantitative Risk Assessment as required.
7. Draft a remediation Method Statement.

Items 1-5 are reported in this document. Items 6 and 7 will form a separate report to be issued after consultation with ESBC, the Environment Agency and specialist remediation contractors.

1.4 REFERENCES

- *Phase 1 Geo-Environmental Assessment Report. The Dove Way (Areas A & B) Uttoxeter.* BWB Consulting. Ref. NTE285/01/V1. July 2010.
- *Phase 2 Geo-Environmental Assessment Report. The Dove Way (Areas A & B) Uttoxeter.* BWB Consulting. Ref. NTE285/01/V1. August 2010.
- CLR 11: Model Procedures for the Management of Land Contamination (EA/Defra. Sept 2004).

2.0 PHASE II REVIEW

2.1 HISTORICAL REVIEW

The site area has been in industrial use since the 1800's, with a gas works occupying the whole area up until the 1960's. Two gas holders were located in the western section of the site, with a third located on land to the north-west. A railway line ran through the eastern section of the site up until the 1980's, when the cutting was infilled.

Since the 1960's the site has been used as a depot, with commercial units and a refuse tip (recycling centre) also on site.

2.2 SITE DESCRIPTION

The northern section of the site is occupied by the local authority recycling centre, which receives household wastes such as paper, white goods, rubble, wood, oil, batteries and clothing.

The western site area (Skip Yard) is currently used as a skip/waste depot by ESBC and houses a small block of lock up units, old office/admin buildings and stores along the south-western boundary and an area for skip/bin cleaning and storage.

Along the central southern boundary, a single storey commercial unit is currently occupied by a printers and a vehicle servicing garage. The majority of the central area is rough tarmac hardstanding, with a toilet block located in the centre of the site.

The eastern section of the site comprises scrubland which has been subject to tipping, as evidenced by an overgrown centrally located mound. The west to east flowing Wharf Brook flows along a concrete culvert through the centre of the site, the banks of which are populated by mature trees and shrubs.

2.3 SITE INVESTIGATION REPORTS

The BWB reports assessed two parcels of land, the area southern parcel (Area B) which this report focuses on, and a parcel to the north-east of Area B (Area A). An adjoining strip of land was also subject to assessment by BWB.

Area B was subject to the advancing of seven window sample boreholes to between 2.0 and 3.0mbgl; three cable percussion boreholes to between 5.3 and 9.0mbgl and three trial pits to 2.7 - 3.5mbgl. The BWB exploratory hole location plan is presented in Appendix B.

2.3.1 Ground Conditions

In summary, ground conditions across Area B were reported as follows:

MADE GROUND: Sandy gravelly clay and clayey gravelly sand with gravel of coal, brick, quartzite and sandstone to a maximum depth of 2.7mbgl in the northern (Tip) section.

Slag and clinker gravel in general across the southern section to a maximum depth of 2.9mbgl.

Localised very soft blue clay (Blue Billy) in TP137.

ALLUVIUM: Present along the bank of the Wharf Brook at 0.5 – 3.0mbgl.

FLUVIOGLACIAL: Medium dense sand and gravel with gravel of quartzite from 1.7 – 7.2mbgl.

MERCIA MUDSTONE: Weak red-brown mudstone from 1.5 – 9.0mbgl.

Contamination observations included a solvent odour and potential Blue Billy in trial pit TP137 (0.3 – 2.69mbgl) and a slight hydrocarbon odour in borehole WS4 at 0.5 – 1.5mbgl.

2.3.2 Contamination Assessment – Human Health

Chemical analysis of soil samples taken from made ground and natural strata across the site by BWB reported the following:

- Cyanide: 22,000mg/kg @2.0mbgl in TP137; 194mg/kg @1.0 – 1.5mbgl in WS4.
- TPH: 3710mg/kg @0.1 – 0.09mbgl in WS3; 2640mg/kg @0.1 – 0.5mbgl in WS4 3090mg/kg @0.3 – 1.0mbgl in WS5; 3090mg/kg @0.3 – 1.0mbgl in WS6; 162mg/kg @0.5mbgl in TP136; 267mg/kg @1.0mbgl in TP136; 8970mg/kg @2.0m in TP137.
- PAH: 114mg/kg @1 – 1.5mbgl in WS4; 190mg/kg @0.3 – 1.0mbgl in WS5; 830mg/kg @0.3 – 1.0mbgl in WS6; 221mg/kg @0.5mbgl in TP136; 134mg/kg @1.0mbgl in TP136; 1030mg/kg @2.0mbgl in TP137.
- Arsenic: 50.8mg/kg @2.0mbgl in TP137.

2.3.3 Contamination Assessment – Controlled Waters

Groundwater samples taken from the cable percussion boreholes and surface water sampled from the Wharf Brook were analysed by BWB. A summary of the analytical results is provided below:

- Elevated cyanide 0.957 – 1.63mg/l), EPH (823 – 1880µg/l) & PAH (63.5 – 82.8µg/l) in samples from BH8 and BH9.
- Elevated PAH, lead and zinc in surface water samples at up, mid and downgradient locations.

2.3.4 Contamination Assessment – Ground Gas

Maximum gas concentrations from the three cable percussion boreholes are summarised below:

- Carbon Dioxide: 3.1% v/v
- Methane: 0.1% v/v
- Flow: 0.4/hr

No soil vapour monitoring was undertaken by BWB.

2.4 ESBC COMMENTS

A review by the ESBC Contaminated Land Officer, dated April 2013, is contained in Appendix C. The scope of this assessment is based on the review, which is summarised below:

- **Sample density....**the current sampling points do not adequately characterise the site in terms of ground contamination. Considerable levels of contamination affect this site, and the extent of such areas or plumes (in the near-surface soils and at depth) have not been sufficiently delineated, leaving a lack of confidence in the data.
- **Proposed mitigation....** measures have been proposed, which involve the use of a soil capping layer and a hard to dig layer in garden and landscaped areas. The use of capping layers is not appropriate where gross contamination exists...remedial works as a whole are not well-defined.
- **Groundwater contamination....**groundwater contamination appears to be migrating from the site to the east, and may also represent a risk to the surface waters (Wharf Brook)....report recommends a DQRA.....such a report has not been submitted for consideration.

- **Requirements:** A Remediation Method Statement...has not been submitted....such a statement cannot be effectively produced and relied upon unless the information gaps detailed above are addressed first.

3.0 PHASE IIA SCOPE OF WORKS

In consideration of the site history, the development proposal, the 2010 site investigation data and the ESBC comments, Ivy House Environmental compiled a scope of works to ensure the Phase IIA works targeted specific contaminant sources and pathways, whilst providing sufficient coverage of the Skip Yard and expanding the data set.

The scope of works also considers the likely requirement for remediation to protect human health and controlled waters, the potential for hazardous waste to be produced during construction activities and the likely implications for budgets and construction programmes.

3.1 SCOPE OF WORKS

The scope of works for the Phase IIA investigation includes the following:

- Combination of trial pits and window sample boreholes across the site. Located according to site access, current usage and reinstatement requirements.
- Trial pits/trenches to delineate the footprint of the historical gas holders.
- Excavator the preferred method but WS boreholes to be used where surface disruption has to be kept to a minimum.
- Up to 20No trial pits and 14No WS boreholes (5-8 monitoring installations)
- Chemical analysis – up to 20No soils/made ground, 10No groundwater, 5No soil leachate for specified suites (metals, hydrocarbons, SVOC, VOC, phenols, asbestos fibres).
- Minimum of 3No gas & groundwater monitoring visits.
- Vapour sampling from 4No boreholes using BottleVac sampling kit.
- Hydrogeological testing in specified boreholes (rising/falling head test) to provide data for DQRA.
- Reporting to include Phase IIA report, DQRA for human health and controlled waters, remediation method statement and waste characterisation.
- Provision of budget costs for Phase III works.

4.0 PHASE II CONCEPTUAL MODEL

The Phase II conceptual model produced by BWB is illustrated below.

Source	Pathway	Receptor	Consequence	Probability	Risk	Mitigation
Area B: Arsenic and chromium concentrations in the south western section of the site.	Ingestion and/ or inhalation of contaminated soil particulates	Site occupiers	Medium	Likely	Moderate	It is recommended that a clean growing medium is imported to break the pollutant linkage. A membrane or hard to dig layer is also recommended beneath any imported topsoil. The thickness should be agreed with the regulatory authorities.
		Ground workers	Mild	Likely	Moderate/ Low	Guidance given in 'HSG 66 Protection of Workers and the General Public During Redevelopment of Contaminated Land' should be followed during ground works for the development.
Area B: Elevated complex cyanide concentrations in the soils in the south western section of the site	Ingestion and/ or inhalation of contaminated soil particulates	Site occupiers	Medium	Likely	Moderate	It is recommended that a clean growing medium is imported to site to break the pollutant linkage. A membrane or hard to dig layer is also recommended beneath any imported topsoil. The thickness should be agreed with the regulatory authorities.
		Ground workers	Mild	Likely	Moderate/ Low	Guidance given in 'HSG 66 Protection of Workers and the General Public During Redevelopment of Contaminated Land' should be followed during ground works for the development.
	Leaching to the groundwater followed by groundwater migration	The underlying Secondary A Aquifer	Medium	High	High	DQRA required to assess the magnitude of the contamination and to establish remedial target concentrations (if required).
		The underlying Secondary A Aquifer underlying adjacent sites	Medium	Likely	Moderate	

Source	Pathway	Receptor	Consequence	Probability	Risk	Mitigation
		The Wharf Brook	Medium	Low	Moderate/Low	
Area B: Elevated PAH and TPH concentrations in the made ground across the site	Ingestion and/ or inhalation of contaminated soil particulates	Site occupiers	Medium	High	High	It is recommended that a clean growing medium is imported to site to break the pollutant linkage. A membrane or hard to dig layer is also recommended beneath any imported topsoil. The thickness should be agreed with the regulatory authorities.
		Ground workers	Mild	Likely	Moderate/Low	Guidance given in 'HSG 66 Protection of Workers and the General Public During Redevelopment of Contaminated Land' should be followed during ground works for the development.
	Inhalation of vapours (indoors)	Site occupiers	Medium	Likely	Moderate	Vapour proof membranes should be installed as part of the residential development proposed.
	Leaching to the groundwater followed by groundwater migration	The underlying Secondary A Aquifer	Medium	High	High	DQRA required to assess the magnitude of the contamination and to establish remedial target concentrations (if required).
		The underlying Secondary A Aquifer underlying adjacent sites	Medium	High	High	
		The Wharf Brook	Medium	Likely	Moderate	
	Direct contact	Water supply pipes	Mild	Likely	Moderate/Low	Provide soil contamination results to the water service providers for their recommendations.

5.0 PHASE IIA FIELDWORK

5.1 INTRODUCTION

The Phase II intrusive investigation was undertaken between the dates 8th and 10th of October 2013 under the supervision of Ivy House Environmental and Geo-Environmental Engineering Ltd (Drilling contractor) and in general accordance with the Code of Practice for Site Investigations BS5930: 1999+A2:2010.

The Phase II investigation incorporated the following:

- The excavation of 9No trial pits and trenches to a maximum depth of 3.4mbgl.
- The advancing of 13No window sample boreholes to maximum depth of 4.45mbgl.
- 6No groundwater and gas monitoring standpipes within the window sample boreholes.
- The analysis of 24No soil samples for a screening suite (e.g. metals, speciated PAH's, inorganics), TPHCWG, SVOC, VOC, EPH, Metals, speciated phenols, complex and free cyanide, thiocyanate and asbestos fibre screen.
- The analysis of 6No groundwater samples for a screening suite, TPHCWG, SVOC, VOC, EPH, speciated phenols, complex and free cyanide and thiocyanate.
- The taking of vapour samples from 3No boreholes for VOC analysis.

5.2 RATIONALE

The Phase IIA investigation has been designed to meet the requirements of ESBC as detailed in section 2.4. The aim of the investigation was to provide sufficient data to facilitate an assessment of the whole site area, including the skip yard, and locate the base of the historical gas holders to assess the integrity of the structures and their contents.

The investigation has also been designed in consideration of the current site layout and access restrictions, the development proposal and health and safety issues, the rationale behind the location of each exploratory hole is detailed in table 4.1 below:

Table 4.1: Phase II Rationale

Hole ID	Location	Notes
TPA, TPB & TPB1	Gas holder in skip yard	Trial trenches. Identify gas holder footprint, in-situ contamination and external soil quality.
TPG – TPI	Eastern site area – tip/backfilled ground	Assess mound and backfilled areas.
TPK	Eastern area, brook bank	Assess ground conditions along the bank.
WSA, WSA1 & WSA2	Gas holder in commercial area	Identify gas holder footprint, in-situ contamination and external soil quality.
WSB - WSD	General grid across skip yard	Assess potential plume relating to gas holder.
WSE & WSF	Central, along brook bank.	Assess ground conditions on the bank.
WSG & WSL	Southern section of car park	General grid
WSH	To west of refuse tip	Assess ground conditions to east of off site gas holder.
WSI	Eastern area.	Assess ground and water quality in backfilled area.
WSJ & WSK	Refuse Tip	Assess ground conditions across the refuse tip.
HDB – HDD	Skip Yard	Additional samples for shallow made ground.

5.3 LABORATORY ANALYSIS & TESTING

Selected soil, water and gas samples were analysed at specialist environmental and geotechnical laboratories or by field monitoring equipment as detailed in the following sections.

5.3.1 Chemical Analysis

A total of 17No samples of made ground, 8No samples of natural strata (Alluvium) and 6No groundwater samples were sent for analysis at a UKAS/MCERTS accredited laboratory. The scheduled parameters are detailed in the tables below.

Date Sampled	Client Sample ID	Depth (m)	Additional references	No. of Containers	Sample Type	Suite Name / Analysis Required									
						Ivy House Suite	TPHCWG	SVOC	VOC	Speciated Phenols	EPH	Standard Metals	CN Complex	CN Free	Thiocyanate
08.10.13	TPA	1.4m @ 4m		2	S		X	X	X	X		X	X	X	X
		1.0m @ 7m		2	S		X	X	X	X		X	X	X	X
	TPB	1.4m @ 3m		2	S		X	X	X	X		X	X	X	X
	TPB1A	2.6m @ 5m		1	S			X	X	X	X				
	TPG	+1.0 m		1	S	X					X				
		1.6m		1	S		X	X	X	X		X	X	X	X
		3.2m		1	S		X	X	X	X		X	X	X	X
	TPI	1.0m		1	S	X									
		3.2m		1	S			X	X	X	X				
	TPH	0.7-1.6m		1	S	X					X				
	3.4m		1	S			X	X	X	X					
TPJ	0.50		1	S	X					X					
TPK	2.1m		2	S		X	X	X	X		X	X	X	X	
	3.2m		2	S		X	X	X	X		X	X	X	X	

Date Sampled	Client Sample ID	Depth (m)	Additional references	No. of Containers	Sample Type	Suite Name / Analysis Required									
						Ivy House Suite	TPHCWG	SVOC	VOC	Speciated Phenols	EPH	Standard Metals	CN Complex	CN Free	Thiocyanate
09/10.10.13	WSA1	2.00		2				X	X	X	X	X	X	X	X
	WSA2	0.70		2			X	X	X	X	X	X	X	X	
	WSB	2.00		2		X			X		X				
	WSC	2.1-2.3		2			X	X	X	X		X	X	X	
	WSC	2.5-3.0		2			X	X	X	X		X	X	X	
	WSD	1.0-1.6		2		X			X		X				
	WSE	3.70		2		X			X		X				
	WSG	1.15		2			X	X	X	X		X	X	X	
	WSG	2.0-2.4		2			X	X	X	X		X	X	X	
	WSH	1.00		1		X					X				
WS7	0.5-1.0		1		X										
18.11.13	HDB	0.30		1		x									
	HDC	0.40		1		x									
	HDD	0.25		1		x									

Date Sampled	Client Sample ID	Depth (m)	Additional references	No. of Containers	Sample Type	Suite Name / Analysis Required								
						Ivy House Suite	TPHCWG	SVOC	VOC	Speciated Phenols	CN Complex	CN Free	Thiocyanate	
25.10.13	WSA2			2	W	X	X	X	X	X		X	X	X
	BWBBH7			2	W	X	X	X	X	X		X	X	X
	WSB			2	W	X	X	X	X	X		X	X	X
	WSL			2	W	X	X	X	X	X		X	X	X
	WSE			2	W	X	X	X	X	X		X	X	X
	WSI			2	W	X	X	X	X	X		X	X	X

Date Sampled	Client Sample ID	Depth (m)	Additional references	No. of Containers	Sample Type	Suite Name /		
						Ivy House Suite		
18.11.13	HDB	0.30		1		X		
	HDC	0.40		1		X		
	HDD	0.25		1		X		

5.3.2 Gas Monitoring and Sampling

Monitoring installations were installed in 6No window sample boreholes. Only one of the three monitoring boreholes installed by BWB in 2010 could be located (BWBBH07).

Monitoring of the boreholes for groundwater levels and gas volumes was undertaken using a Solinst Dip Meter and a GA2000 gas monitor, which detects concentration by volume (%v/v) of Methane (CH₄), Carbon Dioxide (CO₂) and Oxygen (O₂) and flow rate and air pressure. The programme of three monitoring visits has now been completed.

Additional gas samples were taken from monitoring points WSA2, WSB and WSI using a *BottleVac* sampling system. The BottleVac system connects a vacuum canister via a valve to the gas tap, vapours are subsequently drawn into the canister when the valve is opened. Each sample was scheduled for VOC analysis.

The gas monitoring results are contained in Appendix H; the vapour analysis results are contained in Appendix G.

6.0 GROUND CONDITIONS

For the purpose of reporting ground conditions across the site, this section divides the site up into three distinct areas:

- General Site Area – refuse tip and car parking/open ground to skip yard and commercial units.
- Historical Gas Holders – in skip yard and commercial car park.
- South-Eastern Area – infilled and mounded ground.

The observed made ground, natural strata and potential sources of contamination are described for each section, along with the presence of groundwater and other pertinent observations. The exploratory hole location plan, borehole and trial pit logs are contained in Appendix D.

6.1 GENERAL SITE AREA

Ground conditions described in this section include the operational refuse tip, the southern section (80%) of the skip yard and the open hardstanding to the commercial units. Exploratory holes located in this section of the site include:

- WSB, C, D, E, F, G, H, J, K & L

No trial pits were excavated in this area so as to not disturb the surface and effect traffic movements.

6.1.1 Made Ground

Made ground materials were present across the whole of this section at ground level to a maximum of 3.2mbgl and comprised:

- Clayey sandy gravel of concrete, brick, roadstone, ash, clinker and coal.

6.1.2 Natural Strata

Natural strata was observed from 0.6 – 4.45mbgl and comprised:

- Slightly clayey sand and gravel.
- Very sandy clay.
- Gravelly fine to coarse sand.
- Very sandy gravelly clay.
- Stiff sandy clay.

6.1.3 Potential Contamination

Incidences of potential contamination include:

- WSC: 0.45 – 1.0mbgl: Made ground, light tar stain.
1.7 – 3.0mbgl: Sand and gravel/sandy clay with tar stain & odour.
- WSE: 2.2 – 3.95mbgl: Sandy gravelly clay with black tar stain & odour
- WSG: 0.1 – 1.7mbgl: Ash/clinker fill.
2.0 – 2.4mbgl: made ground with oily stain & sheen.
- WSI: 0.13 – 0.7mbgl: made ground with rare asbestos tiles.
1.3 – 3.0mbgl: made ground and sandy clay with black ash, clinker, tar odour and staining.
- WSJ: 0.1 – 1.30mbgl: made ground with possible asbestos tile noted.

6.2 HISTORICAL GAS HOLDERS

The location of the historical gas holder is illustrated on Figure 4, Appendix B. Due to the entrance to the commercial site being in constant use, three window sample boreholes were drilled in and around the location of the easterly gas holder; trial trenches were utilised for

investigating the westerly gas holder. Exploratory holes located in this section of the site include:

- WSA, A1, A2, TPA, TPB, TPB1

6.2.1 Made Ground

Made ground materials were present across the whole of this section at ground level to a maximum of 3.2mbgl and comprised:

- Fill of ash, clinker, bricks, concrete, wood, coal, black, tar stained and strong tar odour.

6.2.2 Natural Strata

Natural strata (very sandy clay) was observed in the base of trench TPA at 1.6mbgl and beyond the outer brick wall to the gas holder in TPB1 at approximately 1.5mbgl.

Slightly clayey sand and gravel from 0.6 – 1.4mbgl and very sandy clay at 1.4 – 3.0mbgl were observed in borehole WSA1.

6.2.3 Potential Contamination

Potential contamination within the western gas holder included all made ground to a maximum depth of 2.5mbgl. From the trenches excavated the gas holder was estimated to be approximately 15m in diameter, with an average thickness of made ground of 2.0m.

Potentially contaminated made ground in the eastern gas holder was identified within boreholes WSA and WSA2 extended to 3.2mbgl. It was not possible to estimate the dimensions of the gas holder, but it is assumed that they will be similar to the neighbouring unit.

6.3 SOUTH-EASTERN AREA

This section of the site is largely overgrown and has been subject to tipping to ground level, with an area in the central section raised to approximately two metres above ground level. Exploratory holes located in this section of the site include:

- WSI, TPG, TPH, TPI, TPJ & TPK.

6.3.1 Made Ground

Made ground materials were present across the whole of the eastern area at >2m above ground level to a maximum depth of 3.2mbgl and comprised:

- Clayey sand and sandy clay fill with waste materials (e.g. polythene, road cones, rope), brick, concrete, kerbstones, asbestos sheet fragments, pottery, ash and clinker in trial pits TPG, TPI, TPJ, TPK and borehole WSI.
- Ash and clinker with sulphurous odour in trial pit TPH.

Ground at the southern end of this area appears to have been backfilled with ash and clinker, whilst the eastern and northern sections contain general fill materials and some tarry residues.

6.3.2 Natural Strata

Natural strata was observed in all boreholes and trial pits at depths of between 1.5 – 3.5mbgl. The strata were described as:

- Sandy gravelly clay.
- Clayey sand with gravel.
- Very sandy clay with gravel.

6.3.3 Potential Contamination

The majority of the fill materials in this section of the site are potentially contaminated. However, there are a number of distinct horizons:

- WSI: 0.13 – 0.7mbgl: Clayey sand and sandy clay fill with waste materials and asbestos fragments.
1.3 – 3.0mbgl: Very sandy clay with gravel, tar odour and slight stain.
- TPG: >2m above GL – 1.75mbgl: Clayey sand and sandy clay fill with waste materials and asbestos fragments.
1.75 – 2.0mbgl: Black/grey sandy gravelly clay with slight tar odour.
- TPI: GL – 1.7mbgl: Clayey sand and sandy clay fill with brick, concrete and waste materials.
1.7 – 3.2mbgl: Clayey sandy and gravel with slight tar odour.
- TPJ: GL – 3.2mbgl: Clayey sand and sandy clay fill with brick, concrete and wood.
- TPK: GL – 3.0mbgl: Clayey sand and sandy clay fill with ash, brick, wood and concrete.
- TPH: GL – 2.9mbgl: Ash and clinker with sulphurous odour

6.4 GROUNDWATER

Table 5.2 illustrates groundwater observations within the exploratory holes. Table 5.3 provides a summary of the groundwater monitoring completed to date.

Table 5.2: Groundwater Observations

Location	Depth (mbgl)	Comment
WSA	0.8	Strike & Standing water at 0.8mbgl.
WSA2	0.7	Strike & Standing water at 0.7mbgl.
WSB	0.75	Strike & Standing water at 0.75mbgl.
WSI	1.3	Seepage & standing water at 1.3mbgl.
TPA	1.4	Seepage.
TPB	1.4	Seepage, heavy flow at 2.2mbgl.
TPB1	2.1	Ingress.
TPG	2.0	Seepage.
TPK	2.5	Seepage.

Table 5.3: Groundwater Monitoring

Location	Depth to water (mbgl)	Groundwater Datum (mAOD)
BWB BH7	22.65 – 2.71	82.03
WSA2	0.51 – 0.55	84.24
WSE	1.91 – 2.085	82.715
WSB	0.6	84.3
WSI	0.6 – 0.64	83.2
WSK	DRY	N/A
WSL	1.765 – 1.93	82.635

The production of accurate groundwater contours has not been possible due to the lack of accurate levels for the monitoring positions. However, groundwater levels within the deeper boreholes would seem to suggest a gradient commensurate with the flow within the Wharf Brook towards the east.

NOTE: Groundwater levels are subject to seasonal variations and may be affected by flow levels within the Wharf Brook.

7.0 CONTAMINATION ASSESSMENT

Guidance published by DEFRA and the Environment Agency has been followed to ensure that the risk posed to identified receptors, as detailed in the conceptual site model, is reported according to accepted compliance criteria.

The Contaminated Land Exposure Assessment (CLEA) guidance and published Soil Guideline Values (SGV) have been incorporated with Generic Assessment Criteria (GAC), for determinands which do not have a published SGV, to provide a competent Tier 1 Assessment. The soil chemical analysis results are presented in Appendix E; the GAC are contained in Appendix I.

Where Tier 1 human health values are exceeded, Tier 2 values will be developed using the CLEA v1.06 quantitative risk assessment model; for controlled waters, the risk assessment will utilise the Environment Agency's R & D P20 spreadsheets for any subsequent DQRA.

7.1 HUMAN HEALTH

As per the CLEA methodology, statistical analysis of the data set for the soil samples taken from site has been undertaken to assess the risk posed to human health for the residential with gardens land use.

The analysis results reported in 2010 by BWB have also been used in the assessment of the site. The summary in Table 7.1 illustrates contaminants of concern at concentrations which pose a risk to human health; the statistical analysis spreadsheets are contained in Appendix I.

Table 7.1: General Contamination Summary

Determinand	SGV/GAC (mg/kg)	Exceedances	Comment
Arsenic	32	TP137 (50.8mg/kg) WS7 (44.2mg/kg)	Outliers
Lead	450*	TP137 (594mg/kg)	Outlier
Cyanide (Complex)	213**	TP137 (22,200mg/kg)	Outlier
Naphthalene	8.7	TP137 (44.7mg/kg) HDB (14.2mg/kg)	Outlier
Benzo(a)anthracene	5.9	UCL 10.38mg/kg	Outliers removed
Chrysene	9.0	TP136 (16.7mg/kg) TP137 (63.2mg/kg) WS5 (17.7mg/kg) WS6 (64.1mg/kg)	Outliers
Benzo(b)fluoranthene	7.0	UCL 16.18mg/kg	Outliers removed
Benzo(k)fluoranthene	10	TP137(27.1mg/kg) WS6 (29.3mg/kg) HDB (15.0mg/kg)	Outliers
Benzo(a)pyrene	1.0	UCL 9.86mg/kg	Outliers removed
Dibenz(a,h)anthracene	0.9	UCL 1.57mg/kg	Outliers removed
Indeno (1,2,3-cd) pyrene	4.2	UCL 6.84mg/kg	Outliers Removed

NOTES:

* Withdrawn SGV

**BWB 2010 value

7.1.1 CLEA Summary

The contamination assessment provided in Table 7.1 illustrates that significant levels of contamination (i.e. PAH and Cyanide) are present at sample locations TP137 and WS6 and that the site as a whole is contaminated with PAH's, including benzo(a)pyrene, dibenz(a,h)anthracene and benzo(a)anthracene.

7.1.2 Hydrocarbon Contamination

Samples taken from within the footprint of the former gas holders and a number of samples from across the general site area and the eastern section were scheduled for a combination of the following determinands:

- EPH, TPHCWG, SVOC, VOC, Speciated Phenols.

An assessment of the analysis results for the above determinands against the GAC is detailed in Table 7.2 below:

Table 7.2: Hydrocarbon Contamination Summary

Determinand	SGV/GAC (mg/kg)	Exceedances	Comment
EPH	500*	WS2 (510mg/kg) WS3 (3710/1170mg/kg) WS4(2640/1080mg/kg) WS5 (789mg/kg) WS6 (3090mg/kg) WSC (1045mg/kg) WSD (901mg/kg)	In made ground across general site area from 0.1 – 2.0mbgl
		TPG (707mg/kg) TP135 (896mg/kg) TP136 (1830/1210mg/kg) TP137 (773/8970mg/kg)	South-Eastern Site Area
		WSA2 (565mg/kg) TPA (4993mg/kg)	Gas holders
Aliphatic C10 – C12	110	TPA (119mg/kg)	Western gas holder
Aliphatic C12 – C16	540	TPA (606mg/kg)	
Dibenzofuran	0.815	WSC (15.9mg/kg) WSG (1.1mg/kg)	In made ground across general site area from 0.1 – 2.0mbgl
		TPA (10.3mg/kg) TPB (13.2mg/kg) WSA2 (3mg/kg)	Gas holders
		TPG (6.6mg/kg)	South-Eastern Site Area

7.1.3 Hydrocarbon Summary

The data presented above illustrates that the site as a whole is subject to hydrocarbon contamination. Contamination relating to the historical gas works use, including VOC, SVOC, TPH and Phenols, is not present at concentrations which may have been expected based on the observations made during the investigation of the gas holders and the extent of tar impacted made ground and natural strata observed across the whole site.

7.1.4 Asbestos

The presence of asbestos fibres was reported in one sample taken from trial pit TPG (+1.0m). Fragments of asbestos cement sheet were reported within the fill materials in the northern section of south-eastern area (WSI, TPG) and in borehole WSJ in the refuse tip section of the site.

7.1.5 Ground Gas

For boreholes BH7 – BH9 located across the site area, BWB reported the following maximum gas readings (4 visits between July & Sept 2010):

- Carbon Dioxide: 3.1% v/v
- Methane: 0.1% v/v
- Oxygen: 17.2 – 20.6% v/v
- Flow: 0.4/hr

For the three monitoring rounds completed between 25.10.13 and 18.11.13 the following maximum gas readings have been reported (Appendix H contains the monitoring data sheets):

- Carbon Dioxide: 6.6% v/v
- Methane: 0.2% v/v
- Oxygen: 6.4 – 21.1% v/v
- Flow: 0.2/hr

The calculation of a Gas Screening Value (GSV) for the site is illustrated below.

- Methane: $0.2\% \times 0.4 = 0.0008$
- Carbon Dioxide: $6.6\% \times 0.4 = 0.0264$

According to the *NHBC Traffic Light System*, the GSV's categorise the site as *Green*, and protection measures are not required. However, as the carbon dioxide concentrations are >5% by volume, then upgrading to *Amber 1* (membrane, ventilated sub-floor void) should be considered to ensure that the risk posed by carbon dioxide is mitigated.

7.1.6 Soil Vapours

Three samples were taken from boreholes WSA2, WSB and WSI using the *Bottlevac* vapour sampling system. The samples were subsequently analysed at an accredited laboratory for VOC's, the analysis results for which are contained in Appendix G.

The methodology for assessing the risk posed by soil vapours uses the information and data presented in the following document:

- EH40/2005 *Workplace Exposure Limits*. HSE, Second Edition, 2011.

The exposure assessment is based on workplace exposures for adults and is based on Long Term Exposure (LTE) of eight hours and Short Term Exposure (STE) of 15 minutes. Table 7.3 below illustrates LTE and STE for VOC's present in the samples:

Table 7.3: Vapour Risk Assessment

Determinand	LTE (ppm/mg.m ⁻³)	STE (ppm/mg.m ⁻³)	Exceedances
Benzene	1/3.25	N/A	None
1,2,4/1,3,5 Trimethylbenzene	25/125	N/A	
Toluene	50/191	100/384	
Dichloroethene	100	250/1010	
Ethylbenzene	100/441	125/552	
Styrene	100/430	250/1080	
Xylenes	50/220	100/441	

A review of the results contained in Appendix G and the above assessment illustrates that the sum of all reported VOC's for each sample is within 1ppm or 1mg.m⁻³.

It should be noted that the workplace exposure limits are based on exposure to adults in the workplace and are not specific to the residential housing model. However, it should be noted that the GAC for hydrocarbon compounds takes into consideration the risk posed by vapours, so, at this stage, there is no requirement for vapour protection within the residential units.

7.2 CONTROLLED WATERS

The site is underlain by a Secondary A aquifer and the Wharf Brook, which flows through a concrete culvert, bisects the centre of the site from west to east.

A total of 6No groundwater samples were taken from the window sample boreholes installed by Ivy House Environmental and one existing BWB borehole and scheduled for a screening suite (e.g. metals, speciated PAH's, inorganics), TPHCWG, SVOC, VOC, EPH, speciated phenols, complex and free cyanide and thiocyanate. The groundwater analysis results are presented in Appendix F. One sample of made ground from trial trench TPB was scheduled for a leachate suite containing a similar set of determinands (Appendix E).

Table 7.4 illustrates an assessment of the groundwater analysis results presented in Appendix F against the GAC.

Table 7.4: Groundwater Contamination Summary

Determinand	SGV/GAC (µg/l)	Exceedances	Comment
Sulphate	250mg/l	WSA2 (985mg/l) WSB (1250mg/l)	Skip yard, eastern gas holder and eastern section.
PAH(UKDWS4)	0.1	WSA2 (0.28 µg/l) WSB (26.75 µg/l) BH8 (15.96 µg/l) BH9 (20.25µg/l)	
TPH	10	WSA2 (149µg/l) WSB (496µg/l) WSI (40µg/l) BH8 (823µg/l) BH9 (1880µg/l)	Skip yard, eastern gas holder & eastern section
Phenols	0.5	WSA2 (0.5µg/l) WSB (37.8µg/l)	Skip yard & eastern gas holder
Benzene	1	WSB (384µg/l)	Skip yard
Dibenzofuran	N/A	WSA2 (5.2µg/l) WSB (3.3µg/l) WSI (2.3µg/l)	No thresholds available.
Carbazole	N/A	WSI (1.5µg/l)	
2,4 dimethylphenol	N/A	WSB (36.6µg/l)	
Cyanide	50	BH8 (957µg/l) BH9 (1630µg/l)	

An assessment of the leachate results illustrates that the materials sampled from within the western gas holder contain leachable concentrations of the following contaminants:

- TPH: 287µg/l
- Benzene: 43µg/l
- Ethylbenzene 20µg/l

The assessment illustrates that the site poses a risk to controlled waters and remediation will be required.

8.0 PHASE IIA CONCEPTUAL SITE MODEL

The conceptual model for the site considers the development proposal for residential with gardens use and the information gathered during the Phase I, II and IIA assessments.

The site's present and former uses as a gas works, refuse tip, vehicle servicing garage, skip yard and printers and the information contained with the 2010 Site Investigation report have been considered with respect to potential and reported sources of contamination.

Contaminants of concern for human health include Arsenic, Lead, PAH's, TPH, Dibenzofuran and asbestos fibres. Elevated concentrations of carbon dioxide have been reported.

Pathways for the end user of the site include the ingestion of contaminated soil and contaminated vegetables, direct contact (dermal) with contaminated soil and soil dust; ingestion and inhalation of contaminated soil dust; inhalation of soil vapours and ground gas.

The primary receptors for the site are construction workers and residents of the completed development. The risk posed to human health receptors is considered to be high, therefore remediation will be required.

For the environment (controlled waters) the primary receptor is the underlying secondary aquifer and the Wharf Brook.

Contaminants of concern for the environment include Sulphate, PAH's, TPH, Phenols, VOC (including benzene) and SVOC.

The primary pathway for controlled waters is the leaching and vertical migration of contaminants through the vadose zone to the saturated zone and lateral migration of contamination into the Wharf Brook. The risk posed to controlled waters by contaminated made ground and natural strata is considered to be moderate to high.

The development of the conceptual model is illustrated on Figure 8.1.

Figure 8.1: Phase IIA Conceptual Site Model

HUMAN HEALTH			
SOURCE	PATHWAY	RECEPTOR	SOLUTION
Made ground and natural strata contaminated with Arsenic, Cyanide, Lead, PAH's, TPH, Dibenzofuran and asbestos fibres.	Ingestion of contaminated soil and contaminated vegetables, direct contact (dermal) with contaminated soil and soil dust; ingestion and inhalation of contaminated soil dust.	Construction Workers	Basic PPE for all workers (overalls, gloves, dust mask if required) and wash facilities/personal hygiene
	Inhalation of Carbon Dioxide and asbestos fibres.	End Users (Residents)	Remediation required in the form of off site disposal of grossly contaminated soils and provision of a clean capping layer in gardens. Removal of asbestos containing materials. Upgraded membrane and vented void required for each plot. No requirement for vapour protection. DQRA and remediation in the form of bio-remediation or stabilisation of gas works related contamination.
	Leaching into water supply pipes	Water Supply/End Users	Requirement for upgraded water pipes, e.g. aluminium sheathed or steel pipes.
CONTROLLED WATERS			
Made ground and natural strata contaminated with Inorganics, TPH, VOC and SVOC.	Leaching and vertical migration through the vadose zone to the saturated zone and lateral migration towards the surface watercourse.	Secondary A Aquifer & Wharf Brook	DQRA and remediation in the form of bio-remediation or stabilisation of gas works related contamination.

9.0 RISK MANAGEMENT & REMEDIATION

Previous sections have quantified the risk posed to identified receptors which, in some instances, require remediation to protect or reduce levels of risk. The following section details basic measures and recommendations for dealing with risks associated with soil, gas and groundwater contamination in respect to the proposed residential housing development.

A separate, more detailed *Remediation Method Statement* (RMS) will be produced in line with the recommendations made in this report. This document will be compiled after consultation with the contaminated land officer for ESBC and specialist remediation contractors.

The remediation method statement will take into consideration the approved development proposal, the location of all associated services and the landscaping requirements for the Wharf Brook.

9.1 REMEDIATION TO PROTECT END USERS

As there is no topsoil on site, there is a basic requirement for a cap of non-contaminated topsoil in each residential garden and landscaped area. A recommended topsoil layer of 350mm in back gardens should be underlain by a minimum of 400mm of non-contaminated sub-soil.

With respect to the hydrocarbon and PAH contaminated made ground reported across the site, the remediation of this material will be required to protect human health. The detailed RMS will include provisions for the segregation of grossly contaminated materials from those which are not contaminated or are only subject to minor levels of contamination.

The re-use of remediated materials across the site will be subject to attaining site specific Remedial Target Values (RTV's), which will be published in the RMS. As all materials scheduled for re-use on site will not pose a risk to human health, it is not anticipated that additional capping requirements (e.g. anti-dig layer) will be required for residential gardens.

Gross contamination such as the cyanide reported within trial pit TP137 and the observed asbestos cement sheet fragments in WSJ, WSI and TPG will have to be removed from site and disposed of at a licensed landfill facility. The removal of the ash/clinker fill identified as the source of the cyanide and the fill containing the asbestos will be subject to controlled supervision by a remediation contractor.

The RMS will include provisions for all of the above issues, with additional detail emphasising the requirement to manage the various types of contaminated materials on site subject to agreed re-use criteria, health and safety provisions and engineering design criteria for roads and foundations.

9.2 REMEDIATION TO PROTECT CONTROLLED WATERS

The risk posed by contaminated groundwater and leachable hydrocarbon contamination to the Wharf brook will be increased during development by the removal of the concrete culvert and the re-profiling of the brook according to the requirements of the Environment Agency. The RMS will, therefore, consider the requirement to remediate contaminated made ground according to the RTV's produced by a Detailed Quantitative Risk Assessment.

At this stage, the ex-situ remediation of the gas works related contamination may be achieved using bio-remediation or stabilisation techniques. Consultation with the EA on approved RTV's and with specialist contractors to produce a scope of works and budgets costs will be reported in the RMS.

9.3 REMEDIATION TO PROTECT CONSTRUCTION WORKERS

Site specific health and safety policies, risk assessments and method statements will be produced by all principal contractors operating on site. These will act to reduce the risk posed to employees to acceptable levels whilst also dealing with accident reduction and the risk posed to neighbours and controlled waters via the emission of fugitive dusts and run-off.

9.4 REMEDIATION TO PROTECT CONSTRUCTION MATERIALS

A specification for buried concrete in line with the BRE Special Digest will be made post remediation, as potential treatment methods will alter the chemical constituency of remediated ground and, as such, the concrete specification will have to be specified accordingly.

9.5 WASTE MANAGEMENT

Although only minimal instances of gross contamination have been identified across the site, the remedial and construction phases are likely to involve the offsite disposal of contaminated materials.

The RMS will include a Materials Management Plan, which will characterise made ground and natural strata across the site according to the provisions of the Waste Framework Directive. The RMS will also consider whether contaminated materials will require remediation to reduce the waste classification from hazardous down to non-hazardous or inert. Due to the potential volumes of hazardous waste present on site, even post treatment down to levels protective of human health and controlled waters, construction works may require the excavation of treated soils to accommodate foundations, roads, drainage and other services. If such material is classified as hazardous then the anticipated disposal costs could affect the project's feasibility.

10.0 RECOMMENDATIONS

Recommendations for further assessment of the site include:

- A Remediation Method Statement (RMS) will be required to define measures to protect human health and controlled waters.
- The RMS should also include a Materials Management Plan (MMP) to ensure that contaminated materials across the site are characterised according to the provisions of the Waste Framework Directive and are subject to the appropriate re - use or disposal criteria.
- A copy of this report should be reviewed by the contaminated land officer for ESBC and the Environment Agency.
- A copy of this report, the 2010 BWB report and the RMS should be provided to foundation/groundworks engineers to confirm appropriate foundation design criteria for the residential housing.
- A programme of gas monitoring should be implemented post remediation to assess the requirement for gas and vapour protection.
- A copy of the approved residential scheme should be provided to all parties to ensure that all future works are in line with the proposal.
- A post demolition assessment of the building footprints should be implemented.

11.0 CONCLUSIONS

The Phase IIA assessment has illustrated that the site poses a risk to identified receptors and that remediation will be required to reduce this risk.

The investigation has proved the location of two historical gas holders and an area of significant tipping in the south-eastern section of the site. The contents of the gas holders, although not grossly contaminated, will require remediation and the waste materials in the south-eastern section will need to be excavated and segregated prior to remediation or off site disposal due to the presence of significant ash and clinker deposits containing high levels of cyanide, buried asbestos, tar residues and general waste.

Although a potential plume of gas works related contamination, evidenced by black stained and odorous natural strata at depth, was observed across the site during the fieldwork, the risk assessment reports that concentrations of contaminants of concern present in natural strata do not pose a risk to controlled waters and that the primary risk is posed by contaminated made ground.

A remediation method statement and DQRA will be developed to provide information for the contaminated land officers at the Environment Agency and ESBC, this document will also enable specialist contractors to formulate site specific method statements and confirm project budgets.

To conclude, the site is suitable for the proposed residential development, subject to confirmation of the final development scheme and remedial methodologies and costs.