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Analytical Report Number : 22-51965

Project / Site name:	Northstowe	**Samples received on:**	14/04/2022
Your job number:		**Samples instructed on/ Analysis started on:**	14/04/2022
Your order number:	14059900	**Analysis completed by:**	26/04/2022
Report Issue Number:	1	**Report issued on:**	26/04/2022
Samples Analysed:	4 water samples		

Signed: Reg. 13(1)

Reg. 13(1)
Technical Reviewer
For & on behalf of i2 Analytical Ltd.

Standard Geotechnical, Asbestos and Chemical Testing Laboratory located at: ul. Pionierów 39, 41 -711 Ruda Śląska, Poland.

Accredited tests are defined within the report, opinions and interpretations expressed herein are outside the scope of accreditation.

Standard sample disposal times, unless otherwise agreed with the laboratory, are :

soils	- 4 weeks from reporting
leachates	- 2 weeks from reporting
waters	- 2 weeks from reporting
asbestos	- 6 months from reporting

Excel copies of reports are only valid when accompanied by this PDF certificate.

Any assessments of compliance with specifications are based on actual analytical results with no contribution from uncertainty of measurement.
Application of uncertainty of measurement would provide a range within which the true result lies.
An estimate of measurement uncertainty can be provided on request.

Analytical Report Number: 22-51965
Project / Site name: Northstowe

Lab Sample Number				2239760	2239761	2239762	2239763
Sample Reference				BH2C101	WS2C108	WS2C114	BH2C102
Sample Number				None Supplied	None Supplied	None Supplied	None Supplied
Depth (m)				None Supplied	None Supplied	None Supplied	None Supplied
Date Sampled				Deviating	Deviating	Deviating	Deviating
Time Taken				None Supplied	None Supplied	None Supplied	None Supplied
Analytical Parameter (Water Analysis)	**Units**	**Limit of detection**	**Accreditation Status**				
General Inorganics							
pH	pH Units	N/A	ISO 17025	7.4	7 5	7.4	7 3
Total Cyanide	µg/l	10	ISO 17025	< 10	< 10	110	< 10
Free Cyanide	µg/l	10	ISO 17025	< 10	< 10	< 10	< 10
Sulphate as SO4	µg/l	45	ISO 17025	1310000	2070000	701000	1900000
Sulphate as SO4	mg/l	0.045	ISO 17025	1310	2070	701	1900
Alkalinity as CaCO3	mg/l	3	ISO 17025	230	250	440	300
Phenols by HPLC							
Catechol	µg/l	0.5	NONE	< 0 5	< 0 5	< 0 5	< 0 5
Resorcinol	µg/l	0.5	NONE	< 0 5	< 0 5	< 0 5	< 0 5
Ethylphenol & Dimethylphenol	µg/l	0.5	NONE	< 0 5	< 0 5	< 0 5	< 0 5
Cresols	µg/l	0.5	NONE	< 0 5	< 0 5	< 0 5	< 0 5
Naphthols	µg/l	0.5	NONE	< 0 5	< 0 5	< 0 5	< 0 5
Isopropylphenol	µg/l	0.5	NONE	< 0 5	< 0 5	< 0 5	< 0 5
Phenol	µg/l	0.5	NONE	< 0 5	< 0 5	950	< 0 5
Trimethylphenol	µg/l	0.5	NONE	< 0 5	< 0 5	< 0 5	< 0 5
Total Phenols							
Total Phenols (HPLC)	µg/l	3.5	NONE	< 3 5	< 3 5	950	< 3 5
Speciated PAHs							
Naphthalene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Acenaphthylene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Acenaphthene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Fluorene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Phenanthrene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Anthracene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Fluoranthene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Pyrene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Benzo(a)anthracene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Chrysene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Benzo(b)fluoranthene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Benzo(k)fluoranthene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Benzo(a)pyrene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Indeno(1,2,3-cd)pyrene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Dibenz(a,h)anthracene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Benzo(ghi)perylene	µg/l	0.01	ISO 17025	< 0.01	< 0.01	< 0.01	< 0.01
Total PAH							
Total EPA-16 PAHs	µg/l	0.16	ISO 17025	< 0.16	< 0.16	< 0.16	< 0.16

Analytical Report Number: 22-51965
Project / Site name: Northstowe

Lab Sample Number				2239760	2239761	2239762	2239763
Sample Reference				BH2C101	WS2C108	WS2C114	BH2C102
Sample Number				None Supplied	None Supplied	None Supplied	None Supplied
Depth (m)				None Supplied	None Supplied	None Supplied	None Supplied
Date Sampled				Deviating	Deviating	Deviating	Deviating
Time Taken				None Supplied	None Supplied	None Supplied	None Supplied
Analytical Parameter (Water Analysis)	**Units**	**Limit of detection**	**Accreditation Status**				
Heavy Metals / Metalloids							
Boron (dissolved)	µg/l	10	ISO 17025	1300	310	130	1100
Chromium (hexavalent)	µg/l	5	ISO 17025	< 5 0	< 5 0	< 5 0	< 5 0
Arsenic (dissolved)	µg/l	0.15	ISO 17025	0.49	0.39	1.65	0.41
Cadmium (dissolved)	µg/l	0.02	ISO 17025	0.04	0.05	0.09	0.02
Chromium (dissolved)	µg/l	0.2	ISO 17025	< 0 2	0.4	< 0 2	< 0 2
Copper (dissolved)	µg/l	0.5	ISO 17025	2 3	2 8	4.1	2.1
Lead (dissolved)	µg/l	0.2	ISO 17025	< 0 2	< 0 2	< 0 2	< 0 2
Mercury (dissolved)	µg/l	0.05	ISO 17025	< 0.05	< 0.05	< 0.05	< 0.05
Nickel (dissolved)	µg/l	0.5	ISO 17025	6 5	5.7	11	9 6
Selenium (dissolved)	µg/l	0.6	ISO 17025	4.1	16	20	13
Zinc (dissolved)	µg/l	0.5	ISO 17025	7.1	16	5 2	29
Monoaromatics & Oxygenates							
Benzene	µg/l	1	ISO 17025	< 1 0	< 1 0	< 1 0	< 1 0
Toluene	µg/l	1	ISO 17025	< 1 0	< 1 0	< 1 0	< 1 0
Ethylbenzene	µg/l	1	ISO 17025	< 1 0	< 1 0	< 1 0	< 1 0
p & m-xylene	µg/l	1	ISO 17025	< 1 0	< 1 0	< 1 0	< 1 0
o-xylene	µg/l	1	ISO 17025	< 1 0	< 1 0	< 1 0	< 1 0
MTBE (Methyl Tertiary Butyl Ether)	µg/l	1	ISO 17025	< 1 0	< 1 0	< 1 0	< 1 0
Petroleum Hydrocarbons							
TPH-CWG - Aliphatic >C5 - C6 $_{HS\_1D\_AL}$	µg/l	1	ISO 17025	< 1 0	< 1 0	< 1 0	< 1 0
TPH-CWG - Aliphatic >C6 - C8 $_{HS\_1D\_AL}$	µg/l	1	ISO 17025	< 1 0	< 1 0	< 1 0	< 1 0
TPH-CWG - Aliphatic >C8 - C10 $_{HS\_1D\_AL}$	µg/l	1	ISO 17025	< 1 0	< 1 0	< 1 0	< 1 0
TPH-CWG - Aliphatic >C10 - C12 $_{EH\_1D\_AL\_\#1\_\#2\_MS}$	µg/l	10	NONE	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic >C12 - C16 $_{EH\_1D\_AL\_\#1\_\#2\_MS}$	µg/l	10	NONE	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic >C16 - C21 $_{EH\_1D\_AL\_\#1\_\#2\_MS}$	µg/l	10	NONE	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic >C21 - C35 $_{EH\_1D\_AL\_\#1\_\#2\_MS}$	µg/l	10	NONE	< 10	< 10	< 10	< 10
TPH-CWG - Aliphatic (C5 - C35) $_{HS+EH\_1D\_AL\_\#1\_\#2\_MS}$	µg/l	10	NONE	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic >C5 - C7 $_{HS\_1D\_AR}$	µg/l	1	ISO 17025	< 1 0	< 1 0	< 1 0	< 1 0
TPH-CWG - Aromatic >C7 - C8 $_{HS\_1D\_AR}$	µg/l	1	ISO 17025	< 1 0	< 1 0	< 1 0	< 1 0
TPH-CWG - Aromatic >C8 - C10 $_{HS\_1D\_AR}$	µg/l	1	ISO 17025	< 1 0	< 1 0	< 1 0	< 1 0
TPH-CWG - Aromatic >C10 - C12 $_{EH\_1D\_AR\_\#1\_\#2\_MS}$	µg/l	10	NONE	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic >C12 - C16 $_{EH\_1D\_AR\_\#1\_\#2\_MS}$	µg/l	10	NONE	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic >C16 - C21 $_{EH\_1D\_AR\_\#1\_\#2\_MS}$	µg/l	10	NONE	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic >C21 - C35 $_{EH\_1D\_AR\_\#1\_\#2\_MS}$	µg/l	10	NONE	< 10	< 10	< 10	< 10
TPH-CWG - Aromatic (C5 - C35) $_{HS+EH\_1D\_AR\_\#1\_\#2\_MS}$	µg/l	10	NONE	< 10	< 10	< 10	< 10

U/S = Unsuitable Sample I/S = Insufficient Sample

Analytical Report Number : 22-51965
Project / Site name: Northstowe

Water matrix abbreviations:
Surface Water (SW) Potable Water (PW) Ground Water (GW) Process Waters (PrW) Final Sewage Effluent (FSE) Landfill Leachate (LL)

Analytical Test Name	Analytical Method Description	Analytical Method Reference	Method number	Wet / Dry Analysis	Accreditation Status
Metals in water by ICP-MS (dissolved)	Determination of metals in water by acidification followed by ICP-MS. Accredited Matrices: SW, GW, PW except B=SW,GW, Hg=SW,PW, Al=SW,PW.	In-house method based on USEPA Method 6020 & 200.8 "for the determination of trace elements in water by ICP-MS.	L012-PL	W	ISO 17025
Boron in water	Determination of boron in water by acidification followed by ICP-OES. Accredited matrices: SW PW GW	In-house method based on MEWAM	L039-PL	W	ISO 17025
Phenols, speciated, in water, by HPLC	Determination of speciated phenols by HPLC.	In house method based on Blue Book Method.	L030-PL	W	NONE
Hexavalent chromium in water	Determination of hexavalent chromium in water by acidification, addition of 1,5 diphenylcarbazide followed by colorimetry.	In-house method by continuous flow analyser. Accredited Matrices SW, GW, PW.	L080-PL	W	ISO 17025
Free cyanide in water	Determination of free cyanide by distillation followed by colorimetry.Accredited matrices SW, GW, PW.	In-house method based on Examination of Water and Wastewater 20th Edition: Clesceri, Greenberg & Eaton (Skalar)	L080-PL	W	ISO 17025
Speciated EPA-16 PAHs in water	Determination of PAH compounds in water by extraction in dichloromethane followed by GC-MS with the use of surrogate and internal standards. Accredited matrices: SW PW GW	In-house method based on USEPA 8270	L102B-PL	W	ISO 17025
Sulphate in water	Determination of sulphate in water after filtration by acidification followed by ICP-OES. Accredited Matrices SW, GW, PW.	In-house method based on MEWAM 2006 Methods for the Determination of Metals in Soil.	L039-PL	W	ISO 17025
TPHCWG (Waters)	Determination of dichloromethane extractable hydrocarbons in water by GC-MS, speciation by interpretation.	In-house method	L070-PL	W	ISO 17025
Total cyanide in water	Determination of total cyanide by distillation followed by colorimetry. Accredited matrices: SW PW GW	In-house method based on Examination of Water and Wastewater 20th Edition: Clesceri, Greenberg & Eaton (Skalar)	L080-PL	W	ISO 17025
BTEX and MTBE in water (Monoaromatics)	Determination of BTEX and MTBE in water by headspace GC-MS. Accredited matrices: SW PW GW	In-house method based on USEPA8260	L073B-PL	W	ISO 17025
pH at 20oC in water (automated)	Determination of pH in water by electrometric measurement. Accredited matrices: SW PW GW	In house method.	L099-PL	W	ISO 17025
Alkalinity in Water (by discreet analyser)	Determination of Alkalinity by discreet analyser (colorimetry). Accredited matrices: SW, PW, GW.	In house method based on MEWAM & USEPA Method 310.2.	L082-PL	W	ISO 17025

For method numbers ending in 'UK' analysis have been carried out in our laboratory in the United Kingdom.
For method numbers ending in 'PL' analysis have been carried out in our laboratory in Poland.
Soil analytical results are expressed on a dry weight basis. Where analysis is carried out on as-received the results obtained are multiplied by a moisture correction factor that is determined gravimetrically using the moisture content which is carried out at a maximum of 30oC.

Unless otherwise indicated, site information, order number, project number, sampling date, time, sample reference and depth are provided by the client. The instructed on date indicates the date on which this information was provided to the laboratory.

Analytical Report Number : 22-51965
Project / Site name: Northstowe

Water matrix abbreviations:
Surface Water (SW) Potable Water (PW) Ground Water (GW) Process Waters (PrW) Final Sewage Effluent (FSE) Landfill Leachate (LL)

Analytical Test Name	Analytical Method Description	Analytical Method Reference	Method number	Wet / Dry Analysis	Accreditation Status

Information in Support of Analytical Results

List of HWOL Acronyms and Operators

Acronym	Descriptions
HS	Headspace Analysis
MS	Mass spectrometry
FID	Flame Ionisation Detector
GC	Gas Chromatography
EH	Extractable Hydrocarbons (i.e. everything extracted by the solvent(s))
CU	Clean-up - e.g. by Florisil®, silica gel
1D	GC - Single coil/column gas chromatography
2D	GC-GC - Double coil/column gas chromatography
Total	Aliphatics & Aromatics
AL	Aliphatics
AR	Aromatics
#1	EH_2D_Total but with humics mathematically subtracted
#2	EH_2D_Total but with fatty acids mathematically subtracted
_	Operator - understore to separate acronyms (exception for +)
+	Operator to indicate cumulative e g. EH+HS_Total or EH_CU+HS_Total

Analytical Report Number : 22-51965
Project / Site name: Northstowe

This deviation report indicates the sample and test deviations that apply to the samples submitted for analysis.Please note that the associated result(s) may be unreliable and should be interpreted with care.

Sample ID	Other ID	Sample Type	Lab Sample Number	Sample Deviation	Test Name	Test Ref	Test Deviation
BH2C101	None Supplied	W	2239760	a	None Supplied	None Supplied	None Supplied
BH2C102	None Supplied	W	2239763	a	None Supplied	None Supplied	None Supplied
WS2C108	None Supplied	W	2239761	a	None Supplied	None Supplied	None Supplied
WS2C114	None Supplied	W	2239762	a	None Supplied	None Supplied	None Supplied

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ARCADIS Design & Consultancy for natural and built assets

NORTHSTOWE – PHASE 2 DEVELOPMENT

Geo Environmental Assessment Report / Outline Remedial Strategy (Infrastructure)

JUNE 2017

Incorporating

EC HARRIS BUILT ASSET CONSULTANCY

Hyder

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Northstowe – Phase 2 Development

Geo Environmental Assessment Report / Outline Remedial Strategy (Infrastructure)

Author	Reg. 13(1)
Checker	Reg. 13(1)
Approver	Reg. 13(1)
Report No	NOR-ARC-P2-XXX-RP-G-0137-P01
Date	JUNE 2017

VERSION CONTROL

Version	Date	Author	Changes
01	June 2017	AP	1st issue

CONTENTS

APPENDICES

1 Introduction

1.1 Terms of Reference

Arcadis Consulting (UK) Limited (Arcadis) was commissioned by the Homes and Communities Agency (HCA) ("the client") to undertake a data gap analysis, scope additional investigation required, and thereby assess the contamination status of the Phase 2 development of the new development Northstowe to the northwest of Cambridge ("the Site").

The Arcadis commission was for the main infrastructure of the Northstowe development which includes other disciplines such as structures, civils and drainage design.

1.2 Limitations

This report has been prepared for the client in accordance with the terms and conditions of appointment. Arcadis cannot accept any responsibility for any use of or reliance on the contents of this report by any third party. The copyright of this document, including the electronic format shall remain the property of Arcadis.

This report has been compiled from a number of sources, which Arcadis believes to be trustworthy. However, Arcadis is unable to guarantee the accuracy of information provided by others. The report is based on information available at the time. Consequently, there is a potential for further information to become available, which may change this report's conclusion and for which Arcadis cannot be responsible.

It should be noted that the investigation undertaken has been undertaken to provide a reasonable coverage of across the site, but sub soils are by their nature hidden from view and no investigation can be exhaustive to the extent that all soil contamination is revealed. The site has a long history as an airfield / base and therefore conditions may be present beneath the site that are not identified by the exploratory holes, in particular should narrow linear features or isolated pockets of differing ground conditions exist.

1.3 Proposed Development

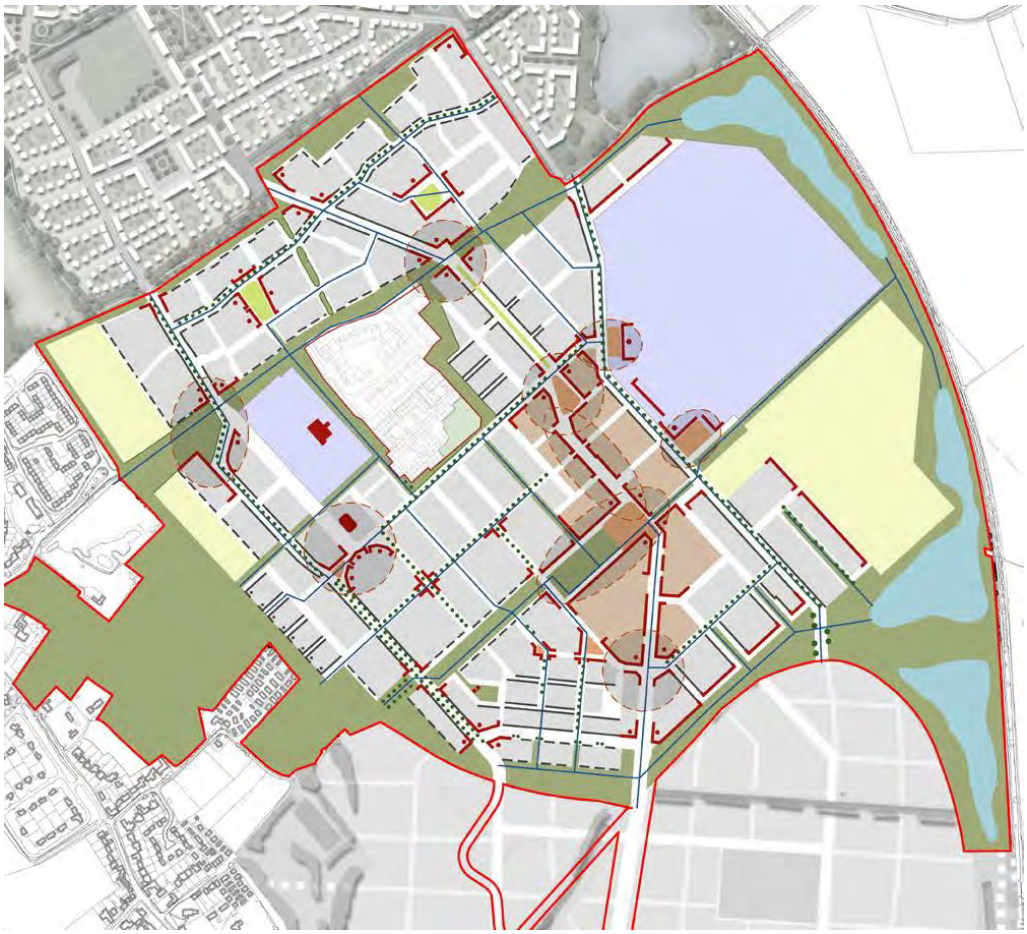
The Phase 2 Northstowe development scheme comprises the following;

- Development of the main Phase 2 development area into approximately 3,500 dwellings, schools, town centre including employment uses, formal and informal recreation space and landscaped areas, the eastern sports hub, the busway, a primary road to the southern access, construction haul route and engineering and infrastructure works, and

- Construction of a highway link (Southern Access Road (West) (SARW)) between the proposed new town of Northstowe and the B1050, improvements to the B1050 and associated landscaping and drainage.

Below is a schematic plan showing the proposed masterplan development within the main Phase 2 development area.

Plan 1 – Schematic layout of proposed masterplan for Phase 2 of Northstowe



1.4 Background Information / Previous Reports

The Northstowe development is centred on the former WWII Oakington Airfield and surrounding farm land. Previous specialist work, for example, ground investigations (undertaken between 2005-2007) and UXO surveys have been undertaken by others across the area which includes the Phase 2 development. The Phase 1 development which is to the north of this site is being currently being developed by Gallaghers.

In 2014, Hyder Consulting (UK) Limited ((Hyder) now known as Arcadis Consulting (UK) Limited) prepared a report entitled *Northstowe - Phase 2, Geo Environmental Assessment and Outline Remedial Strategy Report* (Ref 1).

This Hyder report provides a summary of the previous work undertaken by others and using the chemical data available, undertook a geo environmental assessment for the Phase 2 area. This report should be read in conjunction with the Hyder report to provide further information regarding the previous work and the site setting. Relevant points will be included in this report for completeness.

The Hyder report concluded that whilst elevated concentrations had been recorded in some areas when screened against the appropriate guidelines (in 2014), the site was not considered to be grossly contaminated.

In the 2014 report, with regards to the soil results, 4 inorganic contaminants (arsenic, vanadium, lead and nickel) had concentrations above the screening values for a residential with plant uptake scenario. In the case

of arsenic and vanadium these were high concentrations in natural soils and therefore may be naturally above the Soil Screening Values in this area.

The main organic contaminant was benzo(a)pyrene which had concentrations elevated across the site with approximately half being above the C4SL of 5mg/kg which is a value considered to identify a low risk. TPH contamination was mainly located within the area which was previously used for fuel storage and vehicle maintenance.

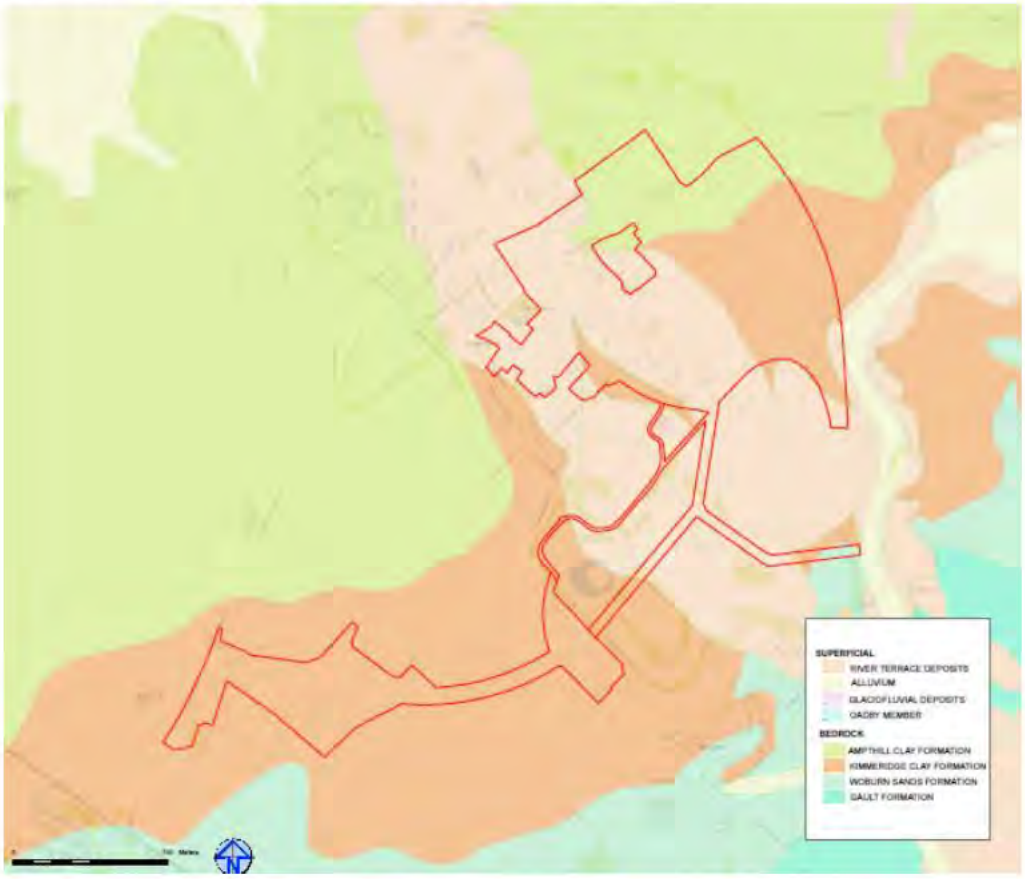
A risk assessment was completed which identified contaminant linkages relating to human health and controlled waters as summarised below.

- For human health contaminant linkages, a moderate risk was identified due to the development's private gardens and soft landscaping (i.e. sensitive land uses). Contamination was not found to be widespread and relates to relatively few exceedances. The risk from ground gases was considered to be moderate to high based on the information available. Across the majority of the site low gas concentrations were recorded but in some localised areas high readings were recorded suggesting uncertainty. The source of the gas is unknown, but may relate to hydrocarbon contamination found in the same area.
- Asbestos fibres had been detected in soils in 2 locations and therefore a moderate risk was presented which reduced to moderate / low in general areas where asbestos has not been currently identified.
- Radioactive materials have been detected in shallow soils in one specific area (burning pit) and a moderate risk was considered appropriate in this one area.
- The risk to controlled waters was considered to be moderate as groundwater testing had identified some elevated concentrations.
- The risk to proposed buildings was considered to be low from the contamination encountered within the soils, however the risk from ground gases is considered to be moderate increasing to high in areas where high gas concentrations have been recorded.

Following the assessment of the data obtained in the 2016 / 2017 investigation, this report will update the risk assessment, using additional data now available, to detail the current situation with the Phase 2 development area.

2 Site Information

Below is a summary of site information to assist with providing context to the report. Further baseline information can be found in the Hyder report (Ref 1).

Site Location / NGR / Area	The site is to the north west of Cambridge, between the villages of Longstanton an Oakington. Approximate Ordnance Survey National Grid Reference for the site is 541000, 266000. A location plan of the site is attached as Figure 1 in Appendix A. The area of the main Phase 2 development is approximately 165 hectares in size.
Site Description	The site is the former WWII Oakington airfield which included runways / airfield, a sewage treatment works (north east corner), buildings associated with bomb storage, barracks, offices, storage facilities, vehicle maintenance, garages and fuel storage areas. The majority of the buildings have been demolished to ground level with the floor slabs remaining in place. The airfield roads and the perimeter track remain and a number of listed pill boxes / water tower. Part of the site was used as the location of the Oakington Immigration Reception Centre but this has now closed and the majority of buildings demolished. Much of the grassed areas within the airfield are used by local farmers for grazing cattle. To the south and north of the former airfield, the area is mainly agricultural land with farmsteads / small buildings and outbuildings.
Published Geology	Based on Geological Mapping at 1:50,000 scale, Sheet 187 (drift) Huntingdon and Sheet 188 (solid and drift) Cambridge, the geological sequence underlying the site is River Terrace Deposits over Kimmeridge Clay and Amptill Clay. Below is a plan showing the published geology across the application site. 

	Details of the geology / ground conditions encountered during the investigations is included in Section 4 of this report.
Hydrogeology	The Environment Agency "What's-in-Your-Backyard" database indicates that the solid geology underlying the site is designated as unproductive strata. The superficial drift deposits underlying the site are designated with Secondary A aquifer status. According to the Environment Agency database, the site is not located within a Groundwater Source Protection Zone. Groundwater flow across the site is thought to largely associated with superficial drift deposits and be contained within the sand and gravel lenses in the River Terrace Deposits. On the northern half of the site, groundwater flow is likely to be to the north and northeast and it is considered likely that groundwater is in continuity with Beck Brook to the east of the site. Groundwater is often found to be close to the surface.
Hydrology	There are multiple surface water features on or in close proximity to the site including a large pond (Military Lake) to the south of the Phase 2 development area, unnamed ditches, small ponds. Beck Brook is located approximately 50m to the east of the site boundary and is considered to be main surface water receptor. A plan showing these features is included in the Hyder report (Ref 1).

3 Scope of Supplementary Ground Investigation

A review of the previous investigation and assessment was undertaken in order to prepare the scope for the supplementary ground investigation. The combined geotechnical and geo environmental supplementary investigation was to achieve the following;

- Complement and extend the existing chemical, geotechnical and groundwater information from previous investigations;
- Assist to inform the remediation strategy across the Phase 2 development areas;
- Assist to inform the design of the infrastructure and earthworks across Phase 2 development and the access roads. This includes sustainable drainage and the attenuation ponds on the eastern side of the development and the land raising required to the north.
- The investigation was also to better inform outline design of development plots and general earthworks.

It is acknowledged that as the development progresses in the Phase 2 development area, further detailed and area specific intrusive investigations will be required.

3.1 Scope

Due to the different historical land uses across the large Phase 2 site, the development area was split into different Land Use (LU) areas which related to the previous and proposed land uses. Figure 2 in Appendix A shows the LU areas. A sampling strategy was proposed for each LU which provided a balance between obtaining sufficient data for each area within the budget available and proportionate at this stage of the development.

It should be noted that the development of the Northstowe site will be phased. It is envisaged that the initial work will start on the eastern side of the site, moving southwards and then northwards, i.e. in a clockwise direction around the existing settlement of Rampton Drift. As a result of this phasing, the proposed investigation was concentrated more on the LU areas on the eastern side of the site (LU6, LU7, LU9, LU10 and LU11).

The archaeologists Cambridge Archaeologist Unit (CAU) are commissioned by HCA to undertake an archaeology survey in areas of interest across the Phase 2 site. This includes a large area in the south of the Phase 2 area and involved topsoil stripping and excavation into the shallow subsoil. The topsoil and subsoil have been stockpiled separately on the former runways. Due to this work, large areas of the site (in LU7 and LU6) were unavailable for investigation. Once the archaeology work has been completed, investigation will be planned in these areas.

The table below provides details of the sampling strategy undertaken during the supplementary investigation. Due to the size of the project and associated number of exploratory holes a number series has been applied to link the data to specific areas of the site (as detailed in the table below).

Table 3.1 Sampling Strategy for the Supplementary Ground Investigation

Land Use Area (Exploratory Hole series)	Rationale (Historical and Proposed Land Uses)	Sampling Strategy
Site Wide	Condition survey of the existing boreholes to determine if still present and in condition for sampling / monitoring of groundwater and gas.	Monitoring of specified wells to determine current groundwater quality.

Land Use Area (Exploratory Hole series)	Rationale (Historical and Proposed Land Uses)	Sampling Strategy
LU2 (200 series)	**Formerly**: Agricultural fields including a farm in northern part of the site. Farm on eastern side use to be associated with bomb store area. **Proposed**: Housing / open space	No access available to this area during the investigation period.
LU4 (400 series)	**Formerly**: Sports ground with barracks (1963) **Proposed**: Housing / open space	Soakaway testing (at this stage) for drainage design, with chemical testing.
LU5 (500 series)	**Formerly**: House on site from 1942 with garage built behind, Tennis court in front of house in 1983. Used as barracks / immigration centre.	No sample locations proposed in this area – will be done later in development programme.
LU6 (600 series)	**Formerly:** sewage treatment works (NE corner) and open fields to north of airfield. **Proposed:** education campus, sport fields, green space and drainage attenuation ponds	• Fill in the existing 100m sampling grid to confirm topsoil / natural soils quality. • Target areas of previously encountered contamination – Sewage works / bomb storage / BHs / MG • Shallow sampling topsoil / natural deposits. • Assess reuse of material from ponds in northern part of site. • Sample locations (BHs / CPT / trial pits and WS) to assess / design (e.g. new cut slopes) in the areas around the ponds for design. Determine the depth of groundwater
LU7 (700 series)	**Formerly**: Part of the base, next to runway, mainly undeveloped. **Proposed:** Housing Archaeology works being undertaken in this area which restricted the locations which would be undertaken.	• Fill in the existing 50m sampling grid to confirm topsoil / natural soils (sensitive land use). • Target feature between TPB71 and TPB73 and MG areas - due to the archaeology works this could not be undertaken. • Shallow sampling topsoil / natural deposits. • Soakaway testing • WS locations installed for gas and shallow groundwater monitoring. SPTs for geotechnical parameters.
LU8 (800 series)	**Formerly**: Barracks area / Oakington Immigration centre. Area not previously investigated **Proposed**: Housing.	Soakaway testing (at this stage) for drainage design, with chemical testing.
LU9 (900 series)	**Formerly**: Area part of base, grassed area, north eastern part supporting the bomb storage area. Housing **Proposed**: Housing	• Fill in the existing 50m sampling grid (sensitive land use) to confirm topsoil / natural soils. • Shallow sampling topsoil / natural deposits. • Soakaway testing

Land Use Area (Exploratory Hole series)	Rationale (Historical and Proposed Land Uses)	Sampling Strategy
		• WS locations installed for gas and shallow groundwater monitoring. SPTs for geotechnical parameters.
LU10 (1000 series)	**Formerly**: Area part of base / barracks, grassed area. **Proposed**: Town centre Area previously well covered with investigation and little contamination encountered when screened for a more sensitive land use.	• Fill in existing 100m sampling grid to confirm topsoil / natural soils quality. Target MG areas • Soakaway testing • BHs for geotechnical parameters / installed for gas / groundwater level and quality monitoring
LU11 (1100 series)	**Formerly**: Area of fuel storage tanks on RAF base / Maintenance workshops - Hydrocarbon contamination encountered previously in soils / groundwater. **Proposed**: Housing.	• Fill in existing SI / confirm topsoil / natural soils quality. Target MG areas • LIF probe (laser induced fluorescence) assessment to help determine the extent / zones of contamination • Soakaway testing • BHs for geotechnical parameters / installed for gas / groundwater level and quality monitoring • WS locations installed for gas and shallow groundwater monitoring. SPTs for geotechnical parameters.
LU12 (1200 series)	**Formerly**: Agricultural Land **Proposed:** Construction of haul road and upgrade to single carriage way and overbridge.	• TPs to fill in existing SI for road construction • BHs for proposed overbridge. Installed for groundwater / gas monitoring. SPT for geotechnical parameters.
LU13 (1300 series)	**Formerly** : Area part of the base / grassed areas **Proposed:** Part of Phase 3 area	• LIF probe (laser induced fluorescence) assessment to help determine the extent / zones of contamination

The ground investigation was undertaken by Arcadis Field Services (AFS) and detailed in their factual report (Ref 2). Due to the size of the factual report, it has not been appended to this report, but should be reviewed in conjunction with this report.

3.2 UXO and Radioactive Materials

Zetica are Unexploded Ordnance (UXO) specialists, commissioned by HCA to undertake a UXO survey across the site.

During their initial surveys, Zetica identified a number of burning pits associated with the former RAF base and near surface anomalies. As part of the AFS investigation, these burning pits and anomalies were investigated via trial pitting and trenching and soil samples taken for analysis. If suspected material was encountered, Zetica were available to undertake radiological screening on the affected areas.

In the Hyder report, it was noted that radioactive material was previously recorded in shallow ashy soils in TPB83 (0.15m and 0.35m depth). This sample location is within the area that has been stripped for the archaeology works. During the stripping process, ashy material was encountered and placed in a stockpile

of non-natural which will be disposed from site. The radiological issue in this location has therefore been removed from site.

No further screening was required during the intrusive works.

4 Ground Conditions

4.1 Stratum Encountered

In general the ground conditions encountered in the recent ground investigation are consistent with the published geology, with the solid geology comprising the Kimmeridge Clay, overlain by River Terrace Deposits (RTDs). The Ampthill Clay was not recorded.

In general the RTDs are overlain by topsoil, however Made Ground is present in the central, eastern and north eastern areas of the site. Figure 3 in Appendix A indicates the locations where Made Ground was encountered.

A Geotechnical Interpretative Report (GIR) (Ref 3) has been prepared for this site and should be read in conjunction with this report. The GIR will provide further details of the ground conditions encountered and geotechnical parameters.

Topsoil

In general the topsoil was encountered across the majority of the site between ground level and 0.3 m bgl. The topsoil comprised grass over soft to firm light brown to black gravelly or sandy CLAY with roots and rootlets. Gravel is subangular and subrounded fine to medium of mixed lithologies.

Made Ground

Made Ground was encountered in relatively localised areas mainly in LU11, LU10, LU09 and LU06 to a maximum thickness of 2.2 m bgl. The Made Ground typically comprised a dark brown gravelly CLAY or SAND. Gravel is sub angular to sub rounded, fine to coarse of mixed lithologies including flint, cloth, iron, brick, glass, metal, clinker, chalk and concrete.

A layer of concrete was encountered at the surface and overlying the Made Ground in 22 locations mainly in LU10, LU11, LU12. Typically this was 0.3 m in thickness.

River Terrace Deposits (RTDs)

The RTDs mainly consists of alternative layers of clays (cohesive) and sands and gravels (granular).

The RTDs are generally thinner and extend to shallower depths in the northern and southern areas of the site (approx. 0.5 – 3.6 m bgl) and are mostly cohesive, typically comprising very soft to stiff slightly sandy and/ or gravelly CLAY. Sand is fine to coarse. Gravel is angular to subangular fine to coarse flint and sandstone.

In the central area of the site (LU11), the granular RTDs are more prevalent and extend deeper (typically 5.0 – 6.8 m bgl), typically comprising clayey or sandy GRAVEL. Sand is fine to coarse, gravel is sub angular to rounded fine to coarse of flint and sandstone.

These deposits are, by the nature of deposition, likely to be highly heterogeneous, and variation in lithology should be anticipated both laterally and with depth beyond the locations of each exploratory hole.

Kimmeridge Clay

In the northern and southern areas of the site, the Kimmeridge Clay was encountered at shallower depths (0.8-2.0 m bgl) than in the central area of the site where it was encountered from 3.5 m bgl. The Kimmeridge Clay typically comprises a firm to stiff dark grey silty CLAY with bands of weathered grey siltstone approx.

0.2 m thick. Selenite crystals (<5mm), gypsum crystals, flint, siltstone, shells and pockets of sand were encountered at depth.

4.2 Groundwater

Groundwater strikes were recorded in 92 exploratory holes and trial pits (see Table 2-2 of Geotechnical Interpretative Report for detail (Ref 3)). During drilling, some of the boreholes utilised additional water to aid advancement of the holes and thus groundwater may not have been identified.

Hydraulic contouring of the groundwater level data has not been undertaken at this stage in the project.

Based upon the general topography and hydrology, the direction of groundwater movement is expected to be biased to north – north east (towards Beck Brook), however this has not been confirmed. Local Variations will exist and should be anticipated, being a function of the lithologies and variations noted within the RTDs.

River Terrace Deposits were found below Made Ground across the site. The deposit has been recorded from 0.1m to 6.4m in thickness within exploratory holes, but could extend deeper locally. The material mainly consists of alternate layers of granular and cohesive deposits.

The Geotechnical Interpretative Report (Ref. 3) presents particle size distribution curves for materials sampled from the RTDs. The materials present could be assigned to three broad types;

- **Slightly clayey sandy Gravel (Granular)**
- **Slightly gravelly sandy silty CLAY (Cohesive)**
- **Slightly sandy silty CLAY (Cohesive)**

The more granular deposits will tend to have higher permeability and greater transmissivity potential. Due to the heterogeneous nature of the RTDs rapid variation in permeability should be anticipated.

The River Terrace Deposits formation (Gravel/Sand, slightly silty/clayey) overlays the silty clayey Kimmeridge Clay Formation. Groundwater entry into exploratory holes was frequently recorded within the RTDs and is present typically at relatively shallow depth. **The regional ground water level typically occurs at 1 to 2m below ground level.**

Whilst groundwater entry into boreholes within the Kimmeridge Clay (silty clay) tends to occur at a slower rate, these deposits will generally be saturated and some groundwater mobility will be present. Standing water records of installations with response zones within the Kimmeridge Clay are contained within the factual and Geotechnical Interpretative reports, (Refs 2 and 3)

Some boreholes and trial pits record collapsed walls due to water ingress.

The potential for contamination to be mobilised during the construction, such as by groundwater control requirements, should be assessed and mitigation put in place where this presents an unacceptable risk.

4.3 Visual / Olfactory Evidence of Contamination

The majority of exploratory hole locations did not encounter visual/ olfactory evidence of contamination.

However visual/ olfactory evidence of contamination was noted during the site investigation, as detailed below:

- WSC032A 1.0 – 2.4 m bgl (CLAY): Strong hydrocarbon odour
- TP1106 1.75 – 2.20 m bgl (MADE GROUND): Hydrocarbon odour and oily sheen.
- WS1103 1.8-2.0 m bgl SAND) and 2.0-2.55 (GRAVEL): Strong hydrocarbon odour.
- WSC012 0.4-0.9 m bgl (CLAY). Strong hydrocarbon odour

- WSC027 0.15 – 0.35 m bgl (Made Ground) and 0.35-0.8 (CLAY): Slight hydrocarbon odour. 0.8-3.0 (CLAY) Moderate to strong hydrocarbon odour. Slight oily sheen on water seepage at 2.0.
- WSC033 1.3 – 2.9 m bgl (CLAY): Strong hydrocarbon odour.
- WWC03 0.3 – 1.1 m bgl (CLAY): Strong hydrocarbon odour.
- ZBP1 0.5 – 1.8 m bgl (MADE GROUND): Organic odour and decomposed plant matter and strong odour.
- TPC016A 0.25 – 1.1 m bgl, 0.25 – 1.1 m bgl (CLAY): Strong hydrocarbon odour.
- TPC016B 0.9 – 1.3 m bgl (CLAY): Strong hydrocarbon odour.
- TPC024A 0.15 – 0.6 m bgl (CLAY): Strong hydrocarbon odour.
- TPC051 0.2 – 0.4 m bgl (MADE GROUND): Very strong hydrocarbon odour and oily sheen. 0.4-0.9 m bgl (SAND): Strong hydrocarbon odour and sheen. 0.9 – 3.0 m bgl (CLAY) Strong hydrocarbon odour and oily sheen.
- TP1117 0.9 – 3.0 m bgl (SAND): Strong hydrocarbon odour and staining.

5 Geo-Environmental Assessment – Soil

5.1 Human Health Risk Assessment

5.1.1 Data Used

The investigation undertaken by AFS was designed to complement the investigations undertaken by WSP in 2007. The soil results relevant to the Phase 2 development from the WSP reports and the results from the recent AFS investigation have both been assessed as detailed below. The ability to identify the source of the data has been retained with the two chemical data sets been kept separate.

5.1.2 Soil Screening Values (SSVs)

As an initial screen, all the soil chemical data has been screened against the current LQM/CIEH Suitable for Use Levels (S4ULs)[1] (Ref. 4) for Human Health Risk Assessment for a residential with plant uptake scenario. In the absence of a S4UL for lead, the Category 4 Screening Level (C4SL) has been adopted (Ref. 5).

A Soil Organic Matter (SOM) content of 1% has been used in the assessment, based on the average measured concentration of total organic carbon in the samples (1.1%).

It should be noted that a few of the SSVs used in this assessment are different to those utilised in 2014 in the Hyder report (discussed in Section 1.3). One of the more significant revisions relates to the SSV for Vanadium; in 2014 the residential SSV was 75mg/kg, the current S4UL is 410mg/kg. The Vanadium concentrations encountered on site are below this revised value and Vanadium is no longer considered a Contaminant of Concern.

5.1.3 Tier 1 Screening Assessment

5.1.3.1 Inorganics

The chemical results were assessed against the SSV for a residential with plant uptake land use (i.e. the most sensitive land use). The table below provides a summary of the contaminants which have exceedances and the location where this was recorded. The exceedances are illustrated on Figure 4 in Appendix A. The Hazard Index (HI)[2] has been included to provide an indication of the relative severity of the exceedance.

Table 5.1 Contaminants with exceedances against the relevant residential with plant uptake SSV

Determinand	SSV (mg/kg) (Residential with plant uptake)	Location of exceedance / depth m (stratum)	Concentration (mg/kg)	Hazard Index (HI)
Arsenic	37	*WSC27 0.9-1.0 (NS)* *TPB2 0.15 (NS)*	*73* *45.7*	*2* *1.2*
Cadmium	11	TP626 0.4-0.7 (MG) TP627 0.1 (MG) TP627 0.35 (NS) BH601 0.3-0.8 (NS) *TPB73 0.45* (NS) *TPB2 1.1* (NS) *TPB1E 0.15 (MG)* *TPB1C 0.4 (MG)*	40 19 16 27 *28.9* *84* *16.5* *16.8*	3.7 1.7 1.5 2.5 2.6 **7.6** 1.5 1.5

[1] "Copyright Land Quality Management Limited reproduced with permission; Publication Number S4UL3223. All rights reserved"

[2] HI = Concentration encountered / SSV

Determinand	SSV (mg/kg) (Residential with plant uptake)	Location of exceedance / depth m (stratum)	Concentration (mg/kg)	Hazard Index (HI)
Chromium (hexavalent)	6	TP626 0.4-0.7 (MG)	7.8	1.3
Copper	2400	TP626 0.4-0.7 (MG)	12000	5.0
Lead	220	TP626 0.4-0.7 (MG)	1700	7.7
		ZTR3 0.0-0.1(MG)	670	3.0
		BH601 0.3-0.8 (NS)	830	3.8
		TP627 0.1(MG)	1000	4.5
		TP627 0.35 (MG)	580	2.6
		TPB2 1.1 (LU6) (NS)	1490	6.8
		ZBP3 1.0-1.1(MG) (LU6)	620	2.8
		ZTR7A 0.2-0.3 (MG)	530	2.4
		LIF1004 0.1-0.3 (MG)	470	2.1
		TPB73 0.45 (NS)	*330*	1.5
		TPC19 0.2 (MG)	*541*	2.5
		TPC13 1.1 -1.2 (MG)	*372*	1.7
		TPB1C 0.4m (MG)	*471*	2.1
		TPB1E 0.15m (MG)	*576*	2.6
Nickel	130	TP626 0.4-0.7 (MG)	180	1.4
		TPB2 1.1 (LU6) (NS)	*165*	1.3
		TPC13 1.1-1.2 (MG)	*372*	2.9
Zinc	3700	TP626 0.4-0.7 (MG)	4200	1.1
		ZBP3 1.0-1.1(MG)	40000	10.8
pH	6-9	ZTR3 0.0 – 0.1(MG)	10.1	n/a
		TP907 0.1 *(NS)*	5.7	
		LIF1004 0.1-0.3 (MG)	10	
		LIF1003 0.1-0.3 (NS)	11.5	
		LIF1102 0.1-0.3 (MG)	10.8	
		LIF1103 0.2-0.5 (MG)	11.5	
		WS1103 0.1-0.2 (NS)	11	
		TP1108 0.15-0.25 (MG)	10.1	
		TP1206 0.4 (NS)	9.4	
		TP1202 0.4 (MG)	9.7	
		WSC027 0.2 (NS)	11.3	
		WSC03 0.4 (MG)	11.2	
		TPB72 0.8 (MG)	*9.5*	
		TPB179F 1.5 (MG)	*10.20*	
		WSC16 0.4 (MG)	*9.3*	
		TPC28 0.46 (MG)	*9.2*	
		TPC10 0.8 (MG)	*10.3*	
		BHC21 1.5 (NS)	*10.7*	

Italics = WSP 2007 data MG = Made Ground NS = Natural Soils

As shown in the table above, within the Phase 2 development area there are several determinands which have concentrations above the appropriate SSV. These are discussed below per LU area. No exceedances were recorded for Vanadium, Cyanide, Mercury and Chromium III.

It should be noted that in excess of 500 samples were analysed for the above determinands and whilst elevated concentrations have been encountered they represent a small percentage, for example for lead 14 samples are above the residential SSV which relates to approximately 2.5% of samples analysed.

No exceedances above the SSV for a residential with plant uptake were recorded in site areas LU4, LU8, LU9 and LU12.

Land Use Areas

LU6
The majority of exceedances in LU6 are located in the north-eastern corner of the area which is the location of the former sewage works. Exceedances were recorded in TP626, TP627, TPB002, TPB001C, TPB001E, and BH601. In TP626 at 0.4-0.7m depth, six contaminants were recorded above the sensitive SSV. It is likely that the contamination which is generally in shallow soils is associated with this previous land use. This area is part of the proposed water park / pond area and therefore it is likely that the material will be excavated to form the ponds.

Mid way down the eastern boundary, one sample location ZBP03 recorded elevated zinc (40,000mg/kg recorded against SSV of 3700mg/kg) and lead (620mg/kg against SSV of 220mg/kg) concentrations at 1.0-1.1m depth. The HI for zinc was 10.8 which indicates the high level of exceedance at this location.

This is a location investigated by Zetica as a possible burning pit location. Made Ground was found at the sample depth which is described as sandy, slightly gravelly CLAY with occasional metal fragments. The metal is likely to be the origin of this elevated zinc value. Lead was also found to be elevated in this location with a HI of 2.8. This pit terminated at 1.4m depth within Made Ground.

LU7
One sample location TPB073 at 0.45m depth has recorded elevated concentrations of lead (330mg/kg against SSV of 220mg/kg) and cadmium (28.9mg/kg against a SSV of 11mg/kg). This was encountered in the shallow natural soils which are described as yellow brown gravelly Sand.

LU10
Lead concentrations above the residential SSV of 220mg/kg were found in 3 Made Ground samples in LU10 (ZBP3 1.0-1.1m (470mg/kg), ZTR7A 0.2-0.3m (830mg/kg), LIF1004 0.1-0.3m (1490mg/kg)) which is the location of the proposed town centre. The proposed end use in this area is considered to be a less sensitive land use and therefore it is appropriate that the concentrations are screened against the commercial / industrial land use screening value. For lead the CS4L is 2,300mg/kg which is higher than the three recorded exceedances. Provided this remains a lower sensitivity end use area, these three samples can therefore be discounted.

It should be noted that if residential housing is proposed in these areas (i.e. flats above retail properties) then a residential without plant scenario would be more appropriate. The C4SL for this land use is 310mg/kg and then the three concentrations would still be considered elevated.

LU11
In LU11 three sample locations are found to have exceedances above the residential SSV. These are TPC013 (lead (HI = 1.7) and nickel (HI = 2.9) at 1.1-1.2m depth), TPC019 (lead (HI = 2.5) at 0.2m depth) and WSC027 (Arsenic (HI = 2) at 0.9-1.0m depth).

The samples from TPC013 and TPC019 are described as Made Ground which is likely to be the origin of the elevated values. The sample from WSC027 is from a natural soil sample described as clay / silt with rare orange mottling. Further discussion about arsenic is in the paragraphs below.

Contaminant Specific

Arsenic and Bioavailability
Arsenic was found to be elevated in two samples WSC27 0.9-1.0m (73mg/kg) (LU11) and TPB2 (LU6) (45.7mg/kg). The elevated concentration was recorded in the natural soils.

In the previous assessment (Hyder report), arsenic concentrations above the SSV were recorded in the natural soils. To assess the risk of this contaminant further, bioavailability testing was undertaken to establish the likely fraction of arsenic that is taken up by humans. Four samples were analysed and the results ranged from 23.9% and 46.7%. This information has been put into the CLEA v1.07 model to derive a Site Specific Assessment Criteria for arsenic for the site. The criteria derived ranged from 57.6mg/kg to 86.1mg/kg. When the average percentage was used a SSAC of 68.4mg/kg was derived.

To take a precautionary approach if the lowest SSAC (57.6mg/kg) is used to screen the elevated arsenic concentrations. The concentration in TPB2 can be discounted as it is below this value, however the one in WSC27 remains marginally elevated. This is appears to be an isolated case and is not considered to be of concern.

pH
pH concentrations from the latest investigation ranged from 5.7 to 11.5. The majority of the samples were within the 6-9 units range with only one showing acidic conditions (TP907 at 0.1m depth). The other 17 soils samples outside the standard range indicated alkaline soils, however many of these are from Made Ground samples and are therefore possible associated with concrete fragments within this strata.

5.1.3.2 Organics

The soil samples were analysed for a suite of organic compounds including PAH compounds, TPH, Phenol and BTEX. VOC analysis was undertaken on a number of samples where contamination was recorded during the investigation.

Polycyclic Aromatic Hydrocarbons (PAH)

The chemical results were assessed against the SSV for a residential with plant uptake land use (i.e. the most sensitive land use). Due to the large number of exceedance encountered the table below provides a summary of the PAH compounds which have exceedances and the LU areas where they are recorded. A table detailing all the sample locations and concentrations (i.e. same format as Table 5.1) is included in Appendix B for reference. The exceedances are shown on Figures 5a and 5b in Appendix A.

Table 5.2 Summary of exceedances encountered for PAH compounds

Determinand	SSV (mg/kg) Residential with plant uptake (Commercial SSV mg/kg)	Number of exceedances - Land Use Area	Concentration Range above SSV (mg/kg) (Location of Max Concentration)
Naphthalene	2.3 (190)	2 LU11	6.9 – 54 (WSC009 0.5m (LU11))
Benzo(a)anthracene	7.2 (170)	12 LU6 / LU7 / LU9 / LU10 / LU11 / LU12	7.3 – 22 (TP1118 (0.0-0.25m) (LU11) / TP1201 0.1m (LU12) and ZTR7B 0.0-0.1m (LU10))
Chrysene	15 (350)	5	18 - 23 (TP1232 0.1m (LU12))

Determinand	SSV (mg/kg) Residential with plant uptake (Commercial SSV mg/kg)	Number of exceedances - Land Use Area	Concentration Range above SSV (mg/kg) (Location of Max Concentration)
		LU9 / LU11 / LU12	
Benzo(k)fluoranthene	77 (1200)	1 LU7	233 (TPB092 0.3m)
Benzo(b)fluoranthene	2.6 (44)	32 LU6 / LU9 / LU10 / LU11 / LU12 / LU13	2.9 – 29 (TPSA1201 0.1m (LU12))
Benzo(a)pyrene	2.2 (35)	36 LU6 / LU7 / LU9 / LU10 / LU11 / LU12 / LU13	2.4 – 25 (TP1118 0.0-0.25m (LU11))
Dibenz(a,h)anthracene	0.24 (3.5)	34 LU6 / LU7 / LU9 / LU10 / LU11 / LU12 / LU13	0.27 – 8 (TPB037 1.3-1.6m (LU9))

The table above shows that PAH compounds are elevated when screened against the sensitive land use SSVs. The majority of the exceedances are within LU6, LU10 and LU11 as discussed below. No PAH compounds were found to be elevated within the samples from LU4 and LU8.

To provide an indication of the origin of the PAH compounds on site, a double plot ratio has been undertaken using the 20 elevated PAH concentrations from the recent investigation. This plot compares the ratios of benz(a)anthracene : chrysene and fluoranthene: pyrene.

The plot which is included in Appendix C, indicates that the origin is mainly coal derived, however a number of samples are from on the line which divides coal and combustion products.

Contaminant Specific

Benzo(a)pyrene

Benzo(a)pyrene recorded the most exceedances with 36 which relates to less than 10% of all the samples analysed. The highest HI recorded for this determinant is 11.4 in TP1118 at a depth of 0.0-0.25m which relates to a concentration of 25mg/kg.

To note, the S4UL value for benzo(a)pyrene has been used as a screening value. A C4SL, which is representative of low risk, has also been derived for benzo(a)pyrene. The residential C4SL is 5mg/kg which is approximately twice the S4UL (2.2mg/kg). Out of the 36 samples recorded above the S4UL, 14 are recorded above the C4SL concentration which relates to less than 3% of the total samples analysed. Thus there are soils present that present above minimal and also above low risk, and these require further consideration.

Land Use Areas

LU6

Eight sample locations are recorded to have concentrations above the residential with plant uptake scenario in LU6. Three of these are located in the north-eastern corner of the site (TP626, TP627 and BHB002), 3

located along the eastern boundary (ZBP03, TPB053 and TPB055) and the other two are isolated sample locations (TP607 and TPB010) within this area.

The sample locations in the north-eastern corner are from Made Ground samples which are associated with the former sewage works. Exceedances of benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene and dibenz(a,h)anthracene are recorded in these areas with the highest HI being 3.3. Ash is recorded in TP627 which had elevated concentrations in samples from 0.1m depth and 0.35m depth.

Sample location ZBP03 on the eastern boundary is a location investigated by Zetica as a possible burning pit location. Two samples from 0.3-0.4m depth and 1.0-1.1m depth, both from the Made Ground, recorded elevated concentrations of benzo(a)pyrene, dibenz(a,h)anthracene and benzo(a)anthracene. The strata is described as sandy, slightly gravelly CLAY with occasional metal and brick fragments. This pit terminated at 1.4m depth within Made Ground.

The elevated concentrations in TPB053, TPB055 and TPB010 were all recorded in the shallow natural soils and are slightly above the SSV for a residential land use. The highest HI recorded was 1.7 (see table in Appendix B for details) which indicates that whilst contamination has been recorded, it is relatively marginal and unlikely to be significant.

The sample from TP607 (0.4m depth) is from the Made Ground which was encountered at this location to a depth of 0.53m. Benzo(a)pyrene was found to be at a concentration of 2.5mg/kg which only slightly exceeds the residential SSV of 2.2mg/kg. The Made Ground strata contains clinker, concrete and brick which is the likely source of the slightly elevated PAH compound.

LU7

Three shallow samples from LU7 have PAH compounds above the residential SSVs. These are

- BHC003 at 0.5-1.0m depth (Made Ground) with 4 PAH compounds recorded as elevated. The HI range is 1.4-5.8 with maximum recorded for dibenzo(ah)anthracene,
- TPB073 at 0.45m depth (natural soils) with 3 PAH compounds recorded as elevated. The HI range is 1.1 - 6.25 with maximum recorded for dibenzo(ah)anthracene,
- TPB092 at 0.3m depth (Made Ground) with 5 PAH compounds recorded as elevated. The HI range is 2.1-7.9 with maximum recorded for dibenzo(ah)anthracene. A sample was taken at 1.8m depth from the RTD and no exceedances were recorded.

LU9

There are three isolated sample locations within LU9 which have elevated concentrations above the residential SSVs. These are TPB022 (0.4m depth) and TPB037 (0.0-0.3m and 1.3 - 1.6m depth) and TPB028 (0.1m).

The shallow sample from TPB022 has elevated concentrations of 5 PAH compounds (benzo(b)fluoranthene, chrysene, benzo(a) anthracene, benzo(a)pyrene and dibenz(ah)anthracene). The HI for these compounds ranged between 1.2 (chrysene) and 6.4 (benzo(a)pyrene). The sample is from slightly gravelly Clay (terrace deposits) however Made Ground was encountered above this strata to a depth of 0.35m which contained brick and concrete.

In TPB037, the shallow sample is from a Made Ground strata and had slightly elevated concentrations recorded for benzo(a)pyrene (2.3mg/kg against SSV of 2.2mg/kg) and dibenz(ah)anthracene (0.28mg.kg against SSV of 0.24mg/kg). The sample from 1.3-1.6m depth is from the natural soils (terrace deposits) and recorded an elevated concentration of dibenz(ah)anthracene of 8mg/kg which has a HI of 33.3.

The Made Ground sample from TPB028 at 0.1m has elevated concentrations of 3 PAH compounds (benzo(b)fluoranthene (HI = 2.5), benzo(a)pyrene (HI = 3.4) and dibenz(ah)anthracene (HI = 3.2)). The Made Ground contained bricks and bitumen coated roadstone which are the likely source of the elevated

PAH compounds. A natural sample (clayey slightly gravelly Sand) analysed from 0.4-0.5m depth did not record any exceedances.

LU10

Exceedances of PAH compounds (benzo(b)fluoranthene, benzo(a) anthracene, benzo(a)pyrene and dibenz(ah)anthracene) are recorded in 5 sample locations in LU10. These are TPB045 (0.25m depth), TPB046 (0.6m depth), TPB047 (0.2m depth) and ZTR07B (0.0-0.1m and 0.3-0.4m depths) and TPC09 (0.7m). The exceedances are in natural soils except for the samples from ZTR07B and TPC09 which are in Made Ground.

The proposed development of LU10 is a town centre which is a less sensitive land use. The concentrations in the above samples have therefore been compared to the SSVs for a commercial / industrial land use which is considered more appropriate for the intended land use. No exceedances above these SSVs are recorded and therefore, provided the town centre proposed use remains, PAH compounds are not considered to be contaminants of concern in LU10.

As detailed above for lead, if residential housing is proposed in these areas (i.e. flats above retail properties) then a residential without plant scenario would be more appropriate. If the SSV for a residential without plant uptake scenario are utilised for the above PAH compounds some of the concentrations would still be considered elevated and require further consideration.

LU11

This land use area has the greatest number of elevated PAH results recording concentrations above residential SSVs. The elevated concentrations are mainly in the northern half of LU11. The elevated concentrations are within the initial 1m and are from a mixture of Made Ground and natural soil samples. Below is a summary of the elevated contaminants;

- Naphthalene – 2 samples elevated with a HI range of 3 – 23.5 (WSC09 0.5m Made Ground)
- Benzo(a)anthracene – 2 samples elevated with a HI range of 1.2 - 3.1 (TP1118 0.0-0.25 in natural soils)
- Chrysene – 1 sample elevated from TP1118 (0.0-0.25m depth in natural soils) with HI of 1.5
- Benzo(b)fluoranthene – 7 samples elevated with HI range of 1.3-2.2 (WWC03 0.7m depth in natural soils)
- Benzo(a)pyrene – 11 samples elevated with HI range of 1.1-11.4 (TP1118 0.0-0.25 in natural soils)
- Dibenzo(ah)anthracene – 8 samples elevated with HI range of 1.3-11.3 (TP1118 0.0-0.25 in natural soils)

The above summary indicates that many of the highest concentrations were recorded in TP1118 at shallow depth in natural soils which are described as dark brown slightly silty Sand.

LU12

Three sample locations with LU12 had concentrations above the residential SSVs. This is in the location of the proposed road and therefore these SSVs are stringent for this land use. The elevated results are in TP1201 (0.1 depth – 5 PAH compounds), TP1205 (0.1-0.3m depth – 3 PAH compounds) and TP1232 (0.1m depth – 4 PAH compounds) which are recorded as either Made Ground or Topsoil.

When the concentrations in these locations are compared to the less stringent commercial / industrial guidelines, no exceedances are recorded.

LU13

Two sample locations from LU13 which is to the south west of the Phase 2 development recorded elevated PAH compounds. These were in a Made Ground sample from LIF1307 at 0.0-0.2m depth (3 PAH compounds) and from two natural samples from TPC038 at 0.1m and 0.5m depth (4 PAH compounds).

Total Petroleum Hydrocarbons (TPH)

TPH analysis was undertaken on the majority of samples (230 in latest Arcadis investigation) and in most cases the results were below the limit of laboratory detection. Exceedances above the SSV for residential land use were however recorded which are detailed in Table 5.3 below and shown on Figure 6 in Appendix A.

To establish if the TPH contamination previously recorded had spread since the previous investigation in 2007, a LIF probe was utilised to detect TPH contamination in the ground. Locations within 50m of the previous contamination were investigated in LU6, LU8, LU10 and LU11 as shown on the plan in the factual report. LIF probes were also undertaken in the area to the south west of the Phase 2 development, in an area called LU13. The LIF probe did not detect TPH above the limit of detection of the probe in these locations. The LIF logs are included in the factual report.

A LIF probe was undertaken in WWC003 which was a location where contamination was previously recorded and a peak was recorded at a depth of 1.8m to 1.9m.

Following the LIF investigation, trial pits were excavated in the locations where contamination had previously been recorded to establish the current concentrations in these areas. The sample locations from the Arcadis investigation were named the same as the WSP investigation so a direct comparison could be made. Exceedances recorded are detailed in the table below.

Table 5.3 Summary of exceedances encountered for TPH fractions

Determinand	SSV (mg/kg) Residential with plant uptake	Location of exceedance / depth mbgl (stratum)	Concentration (mg/kg)	Hazard Index (HI)
TPH Aliphatic C8-C10	27	WS1103 1.9-2.0 (NS) TPC016B 1.5 (NS) *TPB001E 0.3 (MG)* *WSC033 1.1* (NS) *TPC019 (0.2m) (MG)* *TPC24A (0.65m) (NS)*	78 120 52 35.01 *339 (total C8-16)* *271 (total 8-10)*	2.9 4.4 1.9 1.3 12.6 10.0
TPH Aliphatic C12-C16	1100	TPC051 0.5 (NS)	1400	1.3
TPH Aromatic C8-C10	34	*TPB001E 0.3 (MG)*	100	2.9
TPH Aromatic C10-C12	74	*TPB001E 0.3 (MG)* *TPC24A (0.65m) (NS)*	290 *770 (total C10-12)*	3.9 10.4
TPH Aromatic C12-C16	140	TPC051 0.3 (NS) TPC051 0.5 (NS) TPC051 0.9 (NS) WSC027 1.1 (NS) WSC027 2.0 (NS) TP024A 0.8 (NS) WWC03 0.7 (NS) WWC03 1.2 (NS) TPC016A 1.2 (NS) *TPC24A (0.65m) (NS)* *TPC51 1.8m (NS)* *WSC33 1.1-1.3 (NS)*	320 1500 180 470 150 210 150 180 500 *1020 (total C12-16)* *1170 (total C16-24)* *541 (total C12-16)*	2.3 10.7 1.3 3.4 1.1 1.5 1.1 1.3 3.6 7.3 8.4 3.9
TPH Aromatic C16-C21	260	TP1232 0.1 (NS) TP1118 0.0-0.25 (NS)	280 320	1.1 1.2

Determinand	SSV (mg/kg) Residential with plant uptake	Location of exceedance / depth mbgl (stratum)	Concentration (mg/kg)	Hazard Index (HI)
		TPC051 0.3 (NS)	1100	4.2
		TPC051 0.5 (NS)	2600	10.0
		TPC051 0.9 (NS)	280	1.1
		WSC027 1.1 (NS)	750	2.9
		TPB028 0.1 (MG)	*480*	1.8
		WSC027 0.9 (NS)	*2110*	8.1
		TPC009 0.7 (MG)	*698 (total C16-21)*	2.7
		TPC019 (0.2) (MG)	*3000 (total C16-24)*	11.5
		TPC51 1.8m (NS)	*1170 (total C16-24)*	4.5
		TPC38 0.15-0.25 (MG)	*286 (total C16-21)*	1.1
TPH Aromatic C21-C35	1100	*TPB028 0.1(MG)*	2300	2.1
		TPB073 (0.45m)	*1140 (total C21-35)*	1.0
		TPC019 (0.2m)	*2430 (total C24-40)*	2.2
		TPC38 0.15-0.25 (MG)	*1400 (total C21-35)*	1.3
		TPC009 0.7 (MG)	1940 (total C21-35)	1.8
Benzene	0.087	*TPB001E 0.3 (MG)*	100	1149.4

Italics = WSP 2007 data MG = Made Ground NS = Natural Soils

TPH concentrations above the residential SSV have been recorded within the Phase 2 development areas, in 6 LU areas. These are discussed below per LU area. No exceedances were recorded in LU4, LU8 and LU10. Whilst elevated concentrations have been recorded in 40 samples this is a small proportion compared to the number of samples analysed, and therefore is indicative of localised impacts.

LU6

The shallow Made Ground sample from TPB001E at 0.3m had elevated concentrations from 3 TPH fractions and benzene. The HI for Benzene is 1,149 which indicates the level of contamination encountered is considerably higher than the residential SSV. This sample location is in the area of the former sewage works and is likely to be from this source. The log for this location indicated Made Ground to 0.55m depth which consisted of gravelly clay with pottery, glass and brick. This area has had many exploratory holes excavated and samples analysed for TPH but with no other exceedances recorded against the residential SSVs.

LU7

TPB073 has a slightly elevated concentration of the Aromatic C21-35 fraction (1140mg/kg against an SSV of 1100mg/kg) at 0.45m depth. From the log topsoil over natural terrace deposits were encountered at this sample location with no indication of the source of the slightly elevated concentration.

LU9

TPB028 is shown to be elevated with heavy end aromatic fractions (C16-21 (HI = 1.8) and C21-35 (HI= 2.1)) at 0.1m depth. From the log the Made Ground contains gravel which is covered with bitumen / flint and brick. The bitumen is likely to be the source of the TPH contamination. A natural soil sample at 0.4-0.5m depth was analysed for a TPH suite and no elevated results were presented. Whilst elevated results have been encountered the HI values indicate that the contamination is not severe.

LU10

Due to the archaeology works, sample location TPC009 (from the WSP investigation) could not be repeated during the recent Arcadis investigation. Elevated concentrations in the C16-21 and C21-35 fractions were previously recorded in a sample from 0.7m when compared to the aromatic residential SSVs.

As detailed above, the proposed development of LU10 is a town centre which is a less sensitive land use. The concentrations in the above sample have therefore been compared to the SSVs for a commercial / industrial land use which is considered more appropriate for the intended land use. No exceedances above these SSVs are recorded in TPC009 and TPH is not considered a Contaminant of Concern in this land use.

LU11

The majority of the elevated TPH results are from LU11 which is the location of the fuel storage and vehicle maintenance on the RAF base. Whilst contamination has been recorded it is not widespread within this area.

As detailed above, trial pitting was undertaken in the locality of the previous contamination (from WSP investigation) to establish the current concentrations in these locations. Elevations were still recorded, however in a number of locations the concentrations have decreased. For example, in WSC027 a previous concentration of 2110mg/kg of Aromatic C16-21 was recorded at 0.9m depth in the WSP investigation. In the recent Arcadis investigation, a concentration of 750mg/kg was recorded at 1.10m depth in a slightly gravelly slightly sandy CLAY.

In TPC019 contamination was previously recorded at 0.2m depth (C16-24 and C24-40), however in the recent Arcadis investigation a sample taken at a depth of 0.1-0.3m did not record any exceedances.

In TPC051 contamination was encountered at shallow depth (0.3m and 0.5m bgl). For the TPH Aromatic C12-C16 fraction, a sample taken from 0.9m was still above the SSV but the concentration was significantly lower than in the shallower samples. In the WSP investigation a sample from 1.8m depth was found to be above the SSV. In the Arcadis investigation a sample from 1.5m bgl was analysed and the TPH concentrations were below the current SSVs.

LU12

One slightly elevated result is recorded in TP1232 at 0.1m depth with an Aromatic 16-21 concentration of 280mg/kg recorded against a SSV of 260mg/kg. This is from a topsoil sample which has several PAH compounds elevated. When the concentration is compared with SSVs for a commercial / industrial land use, no exceedance is recorded.

During the investigation, observations of contamination were made on the exploratory hole logs which is detailed in Section 4.3. Below is a table which provides comments on these observations based on the analytical testing undertaken.

Table 5.4 Commentary of observations and analytical results

Location (LU)	Depth	Visual / Olfactory Observation	Comments based on analysis results
WSC032A	1.0 – 2.4 m bgl (CLAY):	Strong hydrocarbon odour	Samples analysed at 0.6m and 1.7m recorded no elevated values.
TP1106 (LU11)	1.75 – 2.20 (MADE GROUND)	Hydrocarbon odour and oily sheen	Sample analysed at 1.9-2.2m recorded no elevated values.
	1.8-2.0 (SAND)	Strong hydrocarbon odour	

Location (LU)	Depth	Visual / Olfactory Observation	Comments based on analysis results
WS1103 (LU11)	2.0-2.55 (GRAVEL):		Sample analysed at 1.9-2.0 indicated elevated Ali C8-10 fraction. Sample at 2.9-3.0 recorded no elevated concentrations.
WSC012	0.4-0.9 (CLAY).	Strong hydrocarbon odour	Sample analysed at 0.7m and 1.5m with no elevated results recorded
WSC027 (LU11)	0.15 – 0.35 (Made Ground)	Slight hydrocarbon odour. 0.8-3.0 (CLAY) Moderate to strong hydrocarbon odour. Slight oily sheen on water seepage at 2.0.	Samples analysed at 0.2m and 0.6m with no elevated results recorded. Samples at 1.1m and 2.0m depth showed elevated aromatic fractions
	0.35-0.8 (CLAY):		
WSC033	1.3 – 2.9 (CLAY):	Strong hydrocarbon odour	Samples analysed at 0.5m, 2.0m and 3.0m with no elevated results recorded.
WWC03	0.3 – 1.1 (CLAY):	Strong hydrocarbon odour.	Samples analysed at 0.4m and 0.7m with no elevated results recorded.
ZBP1	0.5 – 1.8 (MADE GROUND):	Organic odour and decomposed plant matter and Strong odour.	Samples analysed at 0.1-0.2m and 0.6-0.7m with no elevated results recorded.
TPC016A	0.25 – 1.1 (CLAY):	Strong hydrocarbon odour.	Samples analysed at 0.2m and 0.4m with no elevated results recorded. Sample at 1.2m indicated an elevated aromatic concentration.
TPC016B	0.9 – 1.3 (CLAY):	Strong hydrocarbon odour.	Samples analysed at 0.5m and 1.0m with no elevated results recorded. Sample at 1.5m indicated an elevated aliphatic concentration.
TP024A	0.15 – 0.6 (CLAY):	Strong hydrocarbon odour.	Sample analysed at 0.4m and 1.5m which recorded no elevated values. The sample in between at 0.8m recorded an elevated aromatic concentration.
TPC051 (LU11)	0.2 – 0.4 (MADE GROUND):	Very strong hydrocarbon odour and oily sheen.	Sample analysed at 0.5 indicated elevated aliphatic and aromatic fractions. Sample at 0.9m indicated elevated aromatic fractions. Sample at 1.5m and 3.0m recorded no elevated concentrations.
	0.4-0.9 (SAND):	Strong hydrocarbon odour and sheen.	
	0.9 – 3.0 (CLAY)	Strong hydrocarbon odour and oily sheen.	
TP1117 (LU11)	0.9 – 3.0 (SAND):	Strong hydrocarbon odour and staining occurred.	Sample analysed at 0.3-0.4m, 1.75-1.85, 2.0-2.1 and 3.0m recorded no elevated concentrations.

VOC / SVOC

13 soil samples were scheduled for VOC / SVOC analysis, mainly from LU11 which was the area where fuel tanks / vehicle maintenance was undertaken. Results above the limit of detection were recorded in 5 samples from the following locations;

- TPC051 (0.3m, 0.5 and 0.9m depth),
- TPC016B (0.5m depth) and
- TPC016A (0.4m depth).

The contaminants were from BTEX compounds, Isopropyl benzene, n-Propyl benzene, 135 Trimethylbenzene, 124 Trimethylbenzene, sec Butylbenzene, Butylbenzene, p-Isopropyl toluene and 2-Methylnaphthalene. These are locations from the WSP investigation where contamination was previously recorded. Where screening values are available, all the concentrations recorded are below the criteria for a residential land use.

In the WSP investigation elevated VOC concentrations (112 Trichloroethane and 1122 Tetrachloroethane) were recorded in WSC012. Samples were taken from this location and analysed, however the results were all below the limit of detection.

Asbestos

Soil samples were screened for asbestos fibres and the table below indicates the locations where fibres or fragments were encountered. These are illustrated on Figure 7 in Appendix A. If asbestos was detected above the laboratory analysis limit during the recent investigation, quantification testing was scheduled to obtain a percentage result for the asbestos present. This is presented in the table below.

Table 5.4 Locations where asbestos fibres were detected (above the limit of detection)

LU Area	Location / depth (m) / Strata	Type of asbestos	ACM Type Detected	Quantification Result
LU6	TP626 0.1-0.2m (MG)	Chrysotile	Insulation Lagging	<0.001%
	TP626 0.4-0.7m (MG)	Chrysotile-	Insulation lagging, loose fibres	<0.001%
	TP627 0.1m (MG)	Chrysotile-	Insulation lagging, loose fibres	0.014%
	TP627 0.35 (MG)	Chrysotile, Amosite	Insulation lagging	0.016%
	TP607 0.4 (MG)	Chrysotile	Loose fibres	<0.001%
	BH601 0.3-0.8	Chrysotile	Insulation lagging	<0.001%
	TPB1C 0.4m (MG)	*Crocodiolote, Amosite, Chrysotile*		0.1%
	TPB1D 0.4m (MG)	*Amosite*		0.1%
	TPB1B (MG)		*Asbestos Tile fragment*	
LU8	ZTR4b 0.3-0.4m (MG)	Chrysotile, Amosite	Loose fibres	<0.001%
LU10	ZTR9 0.0-0.1m (MG)	Chrysotile	Loose fibres	<0.001%

The above table indicates that asbestos fibres are not found to be widespread across the site with the majority of samples analysed (over 350 in the recent investigation) not detecting any asbestos above the laboratory limit. It is noted that where the asbestos was detected it was within the Made Ground recorded.

The samples associated with TP626, TP627, BH601, TPB1C, TPB1D and TPB1B are all located in the north eastern corner of the site which is the location of the former sewage treatment works. It is likely that asbestos was present within the buildings / structure and that this was released to the area during the demolition.

TP607 (loose fibres) is located to the south of the Phase 2 development area and near to the former runway.

ZTR04b and ZTR09 are features which were targeted by Zetica from anomalies that were detected in their geophysical survey. Both samples were from the shallow Made Ground. The sample from ZTR04b was from a layer consisting of gravelly sand with cobbles of brick / masonry / metal fragments, whilst the one from ZTR09 was from a clayey Sand layer with roots / rootlets.

5.2 Summary of Soil Results

To summarise the above assessment, the table below indicates which contaminants are elevated within each LU area.

Table 5.5 Summary of the Contaminants of Concern in each Land Use

LU Area	Land Use Type	Contaminant of Concern (Soil)
LU4	Residential	No exceedances recorded.
LU6	Residential	Lead, Zinc, Cadmium, Nickel, Copper, TPH, PAH compounds and asbestos
LU7	Residential	Cadmium, Lead, TPH, PAH compounds
LU8	Residential	Asbestos
LU9	Residential	TPH, PAH compounds
LU10	Commercial / Industrial	Asbestos
LU11	Residential	Arsenic, Nickel, Lead, PAH compounds, TPH
LU12	Commercial / Industrial	No exceedances recorded.
LU13	Residential	PAH compounds

6 Geo-Environmental Assessment – Controlled Waters

6.1 Water Quality Standards (WQS)

To assess the groundwater and the potential for soil leachate in terms of its potential as a source of contamination to Controlled Waters, the contaminant concentrations have been compared against appropriate Water Quality Standards (WQS). Given the location of the site above the Secondary A Aquifer and the close proximity of watercourses and especially Beck Brook (to the east), for completeness the results have been compared to both UK Drinking Water Standards (UK DWS) and Environmental Quality Standards for freshwater (EQS).

The EQS values have been taken from the Water Framework Directive (WFD) which provides stringent screening values to be protective to the water environment.

When considering EQS values, for a number of contaminants, the hardness of the receiving water must be considered to determine the EQS. The EQS values for slightly hard to moderately hard (CaCO3 <100-250mg/l) have been used in the initial screening as this is deemed appropriate for this area of the UK.

Only the results from the AFS investigation have been compared against the WQS as this will provide a current view of the water quality across the site.

Prior to the AFS site works commencing, a condition survey / groundwater sampling of the existing (WSP) boreholes was undertaken to provide up to date information. Out of the 40 existing wells on the site only 5 were able to be located and sampled. These results have been included in the assessment below.

6.2 Groundwater Assessment

From the condition survey and the first round of monitoring, 68 groundwater samples were analysed for a general suite of metals, non-metals and hydrocarbons (PAH, TPH, BTEX and phenol). In many of the boreholes, water was present in both the shallow and deep installations. Where present, water was sampled from both. Groundwater levels are detailed on the gas monitoring sheets in the Arcadis Factual report. It is noted that generally the standing level of the water in the shallow and deep wells was very similar which indicates a general continuity of groundwater between shallow and the slightly deeper strata ie generally non-confined conditions.

6.2.1 Inorganics

Table 6.1 provides a summary of the groundwater concentrations recorded across the site.

Table 6.1 Summary of groundwater analysis

Determinand	Range of Concentrations (ug/l)	WQS (EQS / DWS) (ug/l)	Exceedances (Yes / No) (Number)	Location of exceedance
Arsenic	<0.15 - 30.6	50 / 10	No EQS / Yes DWS (1)	**BH1103 (W2)**
Cadmium	<0.02 – 0.35	0.15	Yes (6)	BH610 W1, BH1003 (1), BH601 (1) **BH601 (2),** BH1206, BH1205
Chromium (hexavalent)	<5.0	3.4 / 50	No	-
Chromium	<0.2- 180	4.7 / 50	Yes (EQS -3, DWS -1)	BH602 (W1), BH609 (W1), **BH1103 (W2)**

Determinand	Range of Concentrations (ug/l)	WQS (EQS / DWS) (ug/l)	Exceedances (Yes / No) (Number)	Location of exceedance
Copper [3]	1.5 - 120	47 / 2000	Yes EQS (1)	**WS901 (W1)**
Lead	<0.2 - 29	12 / 10	Yes (EQS -1, DWS - 1)	**BH1103 (W2)**
Mercury	<0.05 - 0.44	0.5 / 1.0	No	-
Nickel	1 - 88	24 / 20	Yes (EQS - 3, DWS – 3)	Maximum recorded in **BH1103 (W2)**
Selenium	<0.6 - 1200	10 / 10	Yes (22)	Maximum recorded in **BH1103 (W2)**
Vanadium	<0.2 - 280	20 EQS	Yes (1)	**BH1103 (W2)**
Zinc	2.7 - 140	40 / 2000	Yes (EQS -14)	Maximum recorded in **BH1004 (W1)**
pH	6.6 - 8.8	6 - 9	No	-

The results indicate that inorganic contaminants were elevated in many sample locations. This is likely to be due in part to the stringent WQS that have been used which are based on the WFD. Maximum concentrations were recorded in BH1103 (W2) which is from the shallow well installed within the sand and gravel strata. When DWS values are compared there are less exceedances for than when EQS values are compared but for the generally the same contaminants.

6.2.2 Organics

The groundwater samples were analysed for organic compounds (TPH – total petroleum hydrocarbons, PAH – Polycyclic Aromatic Hydrocarbons, BTEX – Benzene, Toluene, Ethylbenzene and Xylene and phenol).

The results were generally below the limit of laboratory detection, however results above the appropriate EQS / DWS were found in the following samples;

- PAH compounds in WS1103 (W1) @1.75m depth
- Phenol in BH1103 (W2) @1.90m – concentration of 85ug/l recorded against a WQS of 7.7ug/l
- TPH aliphatic and aromatic fractions in WS1103 (W1) @1.75m depth. The aliphatic concentrations ranged between <10 to 12,000ug/l (C8-10) and the aromatic concentrations ranged between <10 to 730ug/l (C10-12) against a WQS of 10ug/l.
- TPH aliphatic fractions in BH1108 (W1) at 1.15m (C12-16 – 38ug/l, C16-21 -120ug/l, C21-35 -43ug/l) against a WQS of 10ug/l

The groundwater contamination recorded in WS1103 corresponds with the visual / olfactory evidence recorded at 1.8-2.0m depth.

6.2.3 Second Round

Due to the elevated results encountered during the initial monitoring visit, groundwater samples were taken from selected boreholes during the second monitoring visit and analysed to determine if the elevated results were consistent. The results are discussed below.

[3] the WFD guideline for copper, zinc and lead and nickel are based on bioavailability. Site specific PNECs (Predicted No Effect Concentration) has been calculated using the site specific pH (7.4), a Ca^{2+} value of 93mg/l (maximum value that can be used) and a DOC value of 10mg/l (assumed).

Inorganic

The results from the second round indicates as the previous round, that many of the inorganic compounds are found above the stringent WQS from the WFD. Cadmium, Chromium, Nickel, Selenium, Vanadium and Zinc all had elevated results.

It is likely that these concentrations represent background levels and do not indicate gross groundwater contamination across the site. Samples taken from the boreholes in LU12 to the south of the site and which would be considered as downgradient of the site have similar concentrations as those on site.

Organics

- All PAH compounds were recorded below the limit of detection in all the samples including WS1103 which had previously indicated positive results.
- Phenol was recorded in 3 sample locations; BH601 (shallow and deep) and BH610 with concentrations ranging between 21 – 48ug/l against a WQS of 7.7ug/l. The sample location BH1103 where phenol was previously recorded, indicated a concentration below the limit of detection in this round.
- TPH was found to be generally below the limit of detection, however aliphatic fractions above the 10ug/l threshold were recorded in the shallow well in BH1103 with concentrations ranging from 27ug/l (C12-16) to 1200ug/l (C21-35).
- VOC analysis was undertaken on two samples BH1108 (shallow) and WS1103. The compounds concentrations were generally below the limit of detection, except for two compounds; Cis 1,2 dichloroethene (2.6ug/l) and Trichloroethene (7.6ug/l). Both concentrations are below the relevant WQS of 25ug/l and 10ug/l respectively and therefore these concentrations are not considered to pose a risk to the wider water environment.

6.3 Soil Leachate Assessment

Soil leachate analysis was undertaken to establish the risk from potential contaminants within the unsaturated zones and potential for impact to occur to Controlled Waters. Analysis was undertaken on soil samples / strata that are likely to be excavated from the proposed ponds on the eastern boundary of the site. This analysis was undertaken to assess whether the soils would be suitable for use in other area of the site (i.e. are unlikely to cause significant harm to receptors) and the assessment can be used under the CL:AIRE Code of Practice for Sustainable Re-use of Soils.

29 soil samples (28 natural soils and 1 MG) were scheduled for soil leachate analysis. The leachate was analysed for a suite of metals / non metals to determine the fraction that is leachable. The table below provides a summary of the findings.

Table 6.1 Summary of leachate analysis

Determinand	Range of Concentrations (ug/l)	WQS (EQS / DWS) (ug/l)	Exceedances (Yes / No) (Number)	Location of exceedance
Arsenic	1.1 - 2.8	50 / 10	No	-
Cadmium	<0.08 – 2.4	0.15 / 0.15	Yes (1)	BH601
Chromium (hexavalent)	<5.0	3.4 / 50	No – All BLOD	-
Chromium	<0.4 – 8.5	4.7 / 250	Yes (4)	TPWS611, TP604, BH602, TP626
Copper	3.6 – 100	47 / 2000	Yes (1)	BH601
Lead	1 - 66	1.2 / 10	Yes (16)	Maximum TP629

Determinand	Range of Concentrations (ug/l)	WQS (EQS / DWS) (ug/l)	Exceedances (Yes / No) (Number)	Location of exceedance
Mercury	<0.5 – 0.9	0.5 / 1.0	Yes (1)	TP633
Nickel	0.3 – 14	4 / 20	Yes (4)	BH607, BH601 (2 samples), BH607
Selenium	<4.0 – 57	10 DWS	Yes (3)	BH607, BH601, BH607
Vanadium	<1.7 - 16	20 EQS	No	-
Zinc	1.1 - 320	12.1 / 2000	Yes (7)	Maximum BH601
pH	7.6 – 8.2	6 - 9	No	-

The maximum concentrations of many of the contaminants were recorded in BH601 (0.3-0.8m depth) which was from the Made Ground in this location and the likely source of the leachable contaminants. However concentrations above the WQS were recorded from leachate from natural samples, many taken from depths greater than 1m. This is likely to be due to the presence of background concentrations and the stringent WQS being used as a comparison.

Inorganic exceedances were noted in the groundwater which are comparable with the above leachate results. It should be noted that the leachate analysis is a test within the laboratory and is undertaken to simulate what may occur on site.

7 Geo-Environmental Assessment – Ground Gas

7.1 Introduction

To establish the ground gas regime for the site, the boreholes and window sample installations were monitored on three occasions between 13th February 2017 and 7th April 2017. There is considered to be no potential source of ground gases on site (e.g. no landfill sites or significant Made Ground) and therefore the monitoring is to confirm this.

The ground gas monitoring was undertaken using an infra-red gas analyser and flow pod. Concentrations of methane (CH_4), carbon dioxide (CO_2) and oxygen (O_2) in %, Hydrogen Sulphide (H_2S) and Carbon Monoxide in ppm and ground gas flow in litres per hour (l/h) were recorded during each visit. PID readings were also undertaken to establish if any volatile compounds were present.

After the monitoring was undertaken, each well was dipped to record the groundwater level in each location.

In the first monitoring round all the wells were monitored, however many were flooded (i.e. the groundwater level was above the response zone on the installations). It was therefore decided that on the second and third monitoring visit only the window sample installations and the shallow boreholes installations should be monitored to establish the gas regime across the development area.

7.2 Gas Monitoring Results

Below is a summary of the range of ground gas monitoring results recorded during the three monitoring rounds. Full details are provided in the factual report.

Table 7.1 Summary of gas monitoring data

	Range of Results		
	First	Second	Third
Methane (%v/v)	<0.1 – 1 (BH1004)	<0.1 – 0.1 (BH1205)	<0.1 – **1.9** (WS1102)
Carbon Dioxide (%v/v)	<0.1 - **2.9** (BH601)	<0.1-1.4 (WS1102)	<0.1 -2.8 (BH1202 / WS905)
Oxygen (%v/v)	**6.1** (BH611) - 21.2	17.3 (WS902) – 20.8	18.3 (WS905) – 22.9
PID (ppm)	<0.1 -**1.9** (BH1107)	<0.1	<0.1 – 1.6 (BH1002)
Carbon Monoxide (ppm)	<0.1 – 2.0	<0.1 - **3.0** (WS904)	<0.1
Hydrogen Sulphide(ppm)	<0.1	<0.1	-
Ground Gas Flow (l/h)	<0.1 – **30** (BH1003)	<0.1 – 1.5 (WS904)	<0.1 – 3.1 (WS903)
Atmospheric Pressure	1024 - 1031	1011 – 1028	1024 - 1034

Location in brackets represents the highest ground gas concentration or lowest Oxygen concentration

The water levels in the first round were recorded within the initial 2m of the standpipes, with many readings less than 1.0m depth. This indicates that the response zones within the standpipes are generally flooded.

A number of the flow rates on the initial visit were high (in excess of 10l/hr). These were mainly recorded in the deep installations with response zones in the Kimmeridge Clay strata and not accompanied by elevated concentrations of hazardous gases.

On examination of the borehole logs, groundwater was only recorded in the shallow gravel deposits or no groundwater strikes were recorded in any strata. During the drilling, the shallow groundwater would be sealed off by the drilling casing and so the deep wells were installed in the dry. Groundwater would then, over the intervening weeks, seeped into the deep installation. However as the well was sealed in the clay and at the surface by a gas tap, once the groundwater had reached the top of the response zone it would not have been able to move any higher as the air above it could not escape. Once the gas tap was opened to take the flow rate, it is believed that the groundwater would have rushed up the well as the trapped air in the standpipe was released, causing a high "false-positive" flow rate on the initial round.

The steady state of flow rate was much reduced from the initial reading.

The wells which indicated a high flow rate during the initial visit were re-monitored during the third visit to determine if the high rates were repeated. Low flow rates were recorded.

The results of the PID monitoring indicates that VOC vapours are generally not present on site. The highest reading of 1.9ppm was recorded in one of the wells in LU11. This is the area of the fuel storage and some hydrocarbon contamination has been detected in soils in this area and is the likely source of this maximum recorded PID value.

A maximum concentration of 3.0 ppm of Carbon Monoxide (CO) was recorded in WS904 during the second round of monitoring. Hydrogen sulphide was found to be below the limit of detection. The short term occupation exposure limit (15 minutes) for CO is 200ppm with the long term exposure limit of 30ppm (Ref 6). The concentrations recorded on site are considerably lower than these limits and therefore not considered to be significant.

In the Hyder report a high gas concentration was previously detected in WWC017. This is not within the Phase 2 development area and was not investigated during this recent investigation. The concentrations recorded on site indicate that this high concentration is not reflected within the Phase 2 area. As discussed in the Hyder report the high concentration was not typical and may have been caused by TPH contamination which was encountered in this area. This area should be examined during the Phase 3 investigation.

7.3 Hazardous Ground Gas Assessment

A ground gas risk assessment has been undertaken to evaluate the risk posed to potential receptors of the proposed development. As the proposed development is mainly residential properties, a risk assessment appropriate for this land use has been completed.

CIRIA guidance (*Assessing risk posed by hazardous gases to buildings,* CIRIA C665, 2006) (Ref. 7) has been used to inform the ground gas assessment which adopts the method proposed by Wilson and Card (Situation A) and NHBC (Situation B). For residential housing Situation B is appropriate. For this approach, the ground gas concentration and borehole flow rate are used to calculate a Gas Screening Value and define a traffic light scenario (Situation B).

A Gas Screening Value (GSV) is calculated using the following equation:

GSV (l/h) = borehole flow rate (l/h) x ground gas concentration (v/v %)

Using the maximum concentrations and flow rate the following GSVs have been calculated. With regards to the maximum flow rate, the high rates recorded in first visit have been dis-regarded due to the reason give above. The maximum rate recorded in the third round has been used as this is considered more realistic.

The GSVs calculated are;

- Methane = 0.0589 l/hr (1.9% and 3.1l/h flow)

- Carbon Dioxide = 0.0899 (2.9% and 3.1l/h flow)

Based on the values calculated, the methane GSV would be considered to be Characteristic Situation 1 (Situation A) or Amber 1 (Situation B) due to methane concentration over 1% being recorded. The carbon dioxide GSV equates to a Characteristic Situation 2 (Situation A) and Amber 1 (Situation B).

These results indicate a low gas risk on site and this finding is consistent with the conceptual site model i.e. no potential high hazard source of gas is believed to exist. The CS2 and Amber 1 situations requires basic gas protection measures to be incorporated into the design of new buildings. This comprises a membrane and ventilated sub floor void.

It is noted that this is based on 3 rounds of monitoring and more monitoring to gain a better understanding of the gas regime present and resultant hazard is warranted, especially in consideration of the numbers of homes to be built. Use of “continuous” gas monitoring equipment may be required to help confirm whether CS2 reflects the true gas regime across the whole site.

8 Conceptual Model – Contaminant Linkages

8.1 Introduction

The aim of this conceptual model and risk assessment is to provide an identification of the risks to controlled waters, proposed future site users and the surrounding area posed by any contamination present on site. The assessment is based on identification of 'contaminant linkages', i.e. contaminant source-pathway-receptor relationships.

It should be noted that for the purposes of this report, assessment of risks relating to the current site use have not been considered.

Further information on conceptual site models and risk assessment is provided within Appendix D.

As mentioned in the Introduction of this report, the majority of the site will be residential development. The sections below identify the potential receptors / pathways and contaminant sources for the proposed land use.

8.2 Contaminant Sources

Based on the chemical data from the WSP and Arcadis investigations, and the assessment against the appropriate SSVs, the following determinands have been identified to be contaminants of concern;

Soils

- Inorganics;
- Organics – PAH Compounds, TPH
- Ground Gases;
- Asbestos;

Groundwater

- Inorganics contaminants
- TPH, PAH compounds, Phenol

8.3 Receptors

The site is mainly a residential development, however there is a town centre and school facilities planned. The receptors for the site are therefore considered to be the following;

Human Health

- Future site users (residents, members of the public, visitors, school children / teachers, employees in town centre).
- Construction and maintenance workers

It should be noted that contamination risks to construction / site workers are not appraised by chronic (long term) exposure human health risk assessments. Site specific construction workers risk assessment and appropriate health and safety practices to adequately mitigate the potential risks are recommended for any future works. Works should be conducted in accordance with the Health and Safety Executive publication entitled "Protection of Workers and the General Public during the Development of Contaminated Land", 1991, the CDM Regulations (2015) or any other relevant guidance.

Controlled Waters

- Underlying Secondary A aquifer
- Beck Brook to the east of the site

Infrastructure

- Building foundations, Buried services and infrastructure
- Internal air quality and confined spaces from ground gases

8.4 Pathways

Potential pathways are the routes that link the receptor the contamination. The potential pathways for this site are provided in Table 8.1 below.

Table 8.1 Potential Contaminant Pathways

Receptor	Pathways
Humans health (future site users / maintenance workers)	Accidental ingestion of contaminants within soil, water and dust. Ingestion of contaminated vegetables and soil attached to vegetables Indoor and outdoor inhalation of dust, vapours and ground gases. Dermal contact with contaminants within soil, water and dust.
Controlled Waters	Leaching of contaminants from the unsaturated zone into underlying groundwater. Horizontal migration of contaminants into via groundwater into surface water. Surface runoff.
Infrastructure	Direct contact of building /structures / services with contaminants in the soil Gas and/or vapour accumulation in confined and poorly ventilated spaces.

8.5 Risk Assessment Methodology

Risk assessment is the process of collating known information on a hazard or set of hazards (to determine the potential severity of any impact) along with details on the likelihood of impact on detailed receptors. Risks are generally managed by isolating the sensitive receptor or by intercepting or interrupting the exposure pathway, thus no pollutant linkages are formed and there is no risk. The following risk assessment focuses on the potential contaminants identified on the site in the context of the proposed development of the site.

CIRIA guidance C552 (Ref. 8) states that the designation of risk is based upon a consideration of both:

- The likelihood of an event (probability); (takes into account both the presence of the hazard and the receptor and the integrity of the pathway).
- The severity of the potential consequence (takes into account both the potential severity of the hazard and the sensitivity of the receptor)

Under such a classification system the following categorisation of risk has been developed and the terminology adopted as follows:

Table 8.2 Summary of Risk Classification Categories

Term	Description
Very High Risk	There is a high probability that significant harm could arise to a designated receptor from an identified hazard at the site without appropriate remedial action.
High Risk	Significant Harm is likely to arise to a designated receptor from an identified hazard at the site without appropriate remedial action.
Moderate Risk	It is possible that without appropriate remedial action, harm could arise to a designated receptor but it is relatively unlikely that any such harm would be severe and if any harm were to occur, it is likely that such harm would be relatively mild.
Low Risk	It is possible that significant harm could arise to a designated receptor from an identified hazard but it is likely that at worst this harm if realised would normally be mild.
Very Low Risk	There is a low possibility that harm could arise to a receptor. In the event of such harm being realised, it is not likely to be severe.

8.6 Potential Contaminant Linkages

Based on the contaminant sources and the potential receptors and pathways identified in previous sections, the following tables provide an assessment of each identified contaminant linkage to establish the potential risk to the sensitive receptors for each proposed land use. A separate table has been produced for each land use.

Table 8.3 Conceptual Site Model for a Residential land use (LU4, LU6, LU7, LU8, LU9, LU11)

RCL No	Contaminant Source	Sensitive Receptor	Pathway	Hazard (Severity)	Likelihood	Potential Risk	Comments
RCL1	Inorganic contaminants (arsenic, lead, vanadium, nickel), PAH Compounds including benzo(a)pyrene (BaP), TPH in Made Ground and shallow Natural Soils	Human Health	Ingestion / Inhalation / Dermal Contact / Veg uptake	Chronic damage, carcinogenic compounds (**Medium**)	**Low to Likely** Contaminant concentrations have been found to be elevated in proposed residential areas, however the contamination is not widespread. In areas of proposed housing with private gardens, a large proportion of the site would be soft landscaping and therefore it is likely that receptors would come into contact with contaminants if present in the surface soils if no remediation / mitigation is undertaken.	**Moderate / Low to Moderate**	Contamination has been encountered in the near surface soils in specific sample locations across the site, however contamination is not found to be widespread. The level of remediation / mitigation required will depend on the final design of the development in the areas where elevated results have been encountered but some basic cover protection is likely to be warranted, focused in soft landscaping areas.
RCL2		Controlled Waters (Groundwater and Surface water)	Leaching and migration into water environment	Reduction of water quality, although unlikely to be a potable resource. (Mild - **Medium**)	**Likely.** Exceedances of WQS have been recorded in the groundwater analysis undertaken. This indicates that contaminants are available if infiltration occurs.	**Moderate / Low to Moderate**	Elevated contaminants concentrations have been encountered in the groundwater especially inorganic contaminants. The elevated concentrations may be associated with background levels and discussion with EA should be sought to understand if remediation is required.
RCL3		Buildings / Services	Contact of contaminants with buildings and	Damage to structures (**Mild**)	**Low.** Identified contaminants are unlikely to cause significant damage to new buildings, if appropriate concrete design is used.	**Low**	pH concentrations outside the normal range of 6-9 units have been detected, with one slightly acidic result of 5.7 units.

RCL No	Contaminant Source	Sensitive Receptor	Pathway	Hazard (Severity)	Likelihood	Potential Risk	Comments
			structures (excluding potable water supply pipes)		Contamination is not widespread across the site.		Appropriate concrete design should be used to safeguard the underground structures from the alkaline or acidic soil conditions.
RCL4	Asbestos	Human Health	Inhalation of fibres	Chronic damage, carcinogenic compounds (**Medium**)	**Low to Likely.** Asbestos fibres have been detected in sample locations (in LU8) within the residential development area. These were encountered within the soil matrix. Inhalation of fibres could occur if disturbed causing a risk to site end users if left on site. Low likelihood relates to majority of sampling positions where no asbestos was encountered.	**Moderate / Low to Moderate**	Mitigation / remedial action / watching brief will be required prior to development to ensure that the risk from asbestos is mitigated. Probably basic cover system in areas of soft landscaping. It is noted that this is not a widespread issue across the site.
RCL5	Ground Gases (methane and carbon dioxide - on-site source)	Human Health	Inhalation in confined spaces	Asphyxiation (**Severe**)	**Low.** Low concentrations of methane and carbon dioxide were recorded in areas across the site. Based on the current information, the risk to residential end users is considered to be moderate.	**Moderate**	Based on the recent ground gas monitoring data and using CIRIA guidance, basic ground gas precautionary measures (traffic light situation Amber 1) are likely to be required in proposed residential development. This gas regime recorded fits with the conceptual site model and SI findings – i.e. that there is no significant Made Ground or other potential sources such as landfill sites.
RCL6		Buildings (on-site)	Accumulation in confined spaces	Explosion (**Severe**)	**Low.** Low concentrations of methane and carbon dioxide were recorded in areas across the site. Based on the current information, the risk to the proposed buildings is considered to be low.	**Moderate**	

RCL No	Contaminant Source	Sensitive Receptor	Pathway	Hazard (Severity)	Likelihood	Potential Risk	Comments
RCL7	Elevated inorganic contaminants and TPH fractions (Aliphatic & Aromatic), PAH compounds,	Controlled Waters (Groundwater and Surface water)	Leaching and migration into water environment (off-site)	Reduction of water quality (**Medium**)	**Likely.** Contaminant concentrations have been detected in the groundwater. Groundwater flow is to the north east towards Beck Brook (50m to east) and therefore there it is considered likely that the contamination may migrate and discharge into the Brook.	**Moderate**	Discussions with the EA should be undertaken to determine their position. Monitoring of groundwater may be required during re-development to ensure that groundwater quality is not affected during site works.

RCL = Residential Contaminant Linkage

Table 8.4 Conceptual Site Model for a Commercial / Industrial land use (LU10 / LU12)

CCL No	Contaminant Source	Sensitive Receptor	Pathway	Hazard (Severity)	Likelihood	Potential Risk	Comments
CCL1	Contaminants in underlying soils	Human Health	Ingestion / Inhalation / Dermal Contact	Chronic damage, carcinogenic compounds (**Medium**)	**Unlikely** Contaminant concentrations in the proposed town centre are below the commercial end use screening values.	**Low**	Concentrations are below the less conservative screening values and therefore remediation in this area is unlikely to be required. The majority of this area will be covered in hardstanding, however consideration should be given to the soil used in soft landscaping areas to make sure that they are suitable for the proposed use. If residential properties are proposed above the commercial properties some mitigation may be required.
CCL2		Controlled Waters (Groundwater and Surface water)	Leaching and migration into water environment	Reduction of water quality, although unlikely to be a potable resource. (Mild - **Medium**)	**Likely.** Exceedances of WQS have been recorded in the groundwater analysis undertaken. This indicates that contaminants are available if infiltration occurs.	**Moderate / Low to Moderate**	Elevated contaminants concentrations have been encountered in the groundwater especially inorganic contaminants. The elevated concentrations are likely to be background levels and discuss with EA should be sought to understand if any remediation is required.
CCL3		Buildings / Services	Contact of contaminants with buildings and	Damage to structures (**Mild**)	**Low.** Identified contaminants are unlikely to cause significant damage to new buildings, if appropriate concrete design is used.	**Low**	pH concentrations outside the normal range of 6-9 units have been detected, with one slightly acidic result of 5.7 units.

CCL No	Contaminant Source	Sensitive Receptor	Pathway	Hazard (Severity)	Likelihood	Potential Risk	Comments
			structures (excluding potable water supply pipes)		Contamination is not widespread across the site.		Appropriate concrete design should be used to safeguard the underground structures from the alkaline or acidic soil conditions.
CCL4	Asbestos	Human Health	Inhalation of fibres	Chronic damage, carcinogenic compounds (**Medium**)	**Low to Likely.** Asbestos fibres have been detected in sample locations in the proposed town centre area. These were encountered within the soil matrix. Inhalation of fibres could occur if disturbed causing a risk to site end users if left on site. Low likelihood relates to majority of sampling positions where no asbestos was encountered.	**Moderate / Low to Moderate**	Mitigation / remedial action / watching brief will be required prior to development to ensure that the risk from asbestos is mitigated. Probably basic cover system in areas of soft landscaping. It is noted that this is not a widespread issue across the site.
CCL5	Ground Gases (methane and carbon dioxide - on-site source)	Human Health	Inhalation in confined spaces	Asphyxiation (**Severe**)	**Low.** Low concentrations of methane and carbon dioxide were recorded in areas across the site. Based on the current information, the risk to residential end users is considered to be low.	**Moderate**	Based on the recent ground gas monitoring data and CIRIA guidance, ground gas precautionary measures Characteristic Situation 2) are likely to be required in proposed commercial development. This gas regime recorded fits with the conceptual site model and SI findings – i.e. that there is no significant Made Ground or other potential sources such as landfill sites.
CCL6		Buildings (on-site)	Accumulation in confined spaces	Explosion (**Severe**)	**Low.** Low concentrations of methane and carbon dioxide were recorded in areas across the site. Based on the current information, the risk to the proposed buildings is considered to be low.	**Moderate**	

CCL No	Contaminant Source	Sensitive Receptor	Pathway	Hazard (Severity)	Likelihood	Potential Risk	Comments
CCL7	Elevated inorganic contaminants and TPH fractions (Aliphatic & Aromatic), PAH compounds,	Controlled Waters (Groundwater and Surface water)	Leaching and migration into water environment (off-site)	Reduction of water quality (**Medium**)	**Likely.** Contaminant concentrations have been detected in the groundwater. Groundwater flow is to the north east towards Beck Brook (50m to east) and therefore there it is considered likely that the contamination may migrate and discharge into the Brook.	**Moderate**	Discussions with the EA should be undertaken to determine their position. Monitoring of groundwater may be required during re-development to ensure that groundwater quality is not affected during site works.

CCL = Commercial Contaminant Linkage

9 Remedial Strategy

9.1 Introduction

Below is a remedial strategy detailing potential options that could be adopted within the Phase 2 area. This Strategy only relates to the infrastructure elements, such as the ponds / water park along the eastern boundary and the SARW road. This strategy is based on the information obtained from the investigations undertaken to date across the site.

Based on the investigations undertaken to date, the Phase 2 development area is not grossly contaminated, however areas of contamination have been encountered.

The Phase 2 development site covers a large surface area and if appropriate existing areas of hardcover could be utilised during the remediation of soils e.g. ex-situ remediation, bioremediation (windrows) and potentially the creation of a hub for a cluster site activity under the CL:AIRE Definition of Waste Code of Practice.

9.2 Contamination – Soils

Ponds / Water Park

In the current Phase 2 masterplan there is a series of ponds along the eastern boundary of the site. These will create a water feature but also will be part of the drainage strategy for the development. The ponds are located in LU6.

Contaminated soils have been encountered in LU6 in or in close proximity to the proposed ponds. The main area of contamination is in the north western corner of LU6 in the area of the former sewage works. Contamination includes metals, asbestos, PAH and TPH. The contamination is generally shallow (within top 1m) and with Made Ground. Other PAH contamination has been encountered towards the southern end of the Phase 2 site (TPB053 / TPB055 / TP607).

Prior to any excavation for the ponds in this area, the contaminated soils should be removed. This will ensure that these contaminated soils do not get spread across the site during the earthworks and cross contaminate “clean” soils. The contaminated soils should be stockpiled and removed from site to a suitably licensed landfill site. Further testing e.g. Waste Acceptance Criteria may be required prior to the material being disposed off site.

Contamination has also been encountered mid-way down the eastern boundary in ZBP3. This was an area identified by Zetica as a potential burning pit. Prior to any excavation in this area, the full extent of the burning pit should be established so that all the contaminated soils can be removed from this area at the same time.

Validation testing should be undertaken in all the areas that contaminated soils are removed. This should include testing at the sides and base of the pits created at appropriate intervals. If the analysis confirms that the contamination is still present, further soils may need to be excavated.

SARW

The Southern Access Road West (SARW) is to the south of the main Phase 2 development area and mainly crosses greenfield land and is within LU12. Due to the less sensitive nature of this part of the development, the chemical results were screened against a commercial / industrial land use. No exceedances were encountered. No specific remediation is required in the construction of the road.

9.3 Contamination - Groundwater

Contaminant concentrations (inorganic and organic) above the appropriate WQS have been recorded in the groundwater on site. The organic contamination is mainly in LU11 which relates to its past uses. In relation to the proposed infrastructure works, it is unlikely that remediation will be required, but confirmation should be obtained from the regulators (EA, LA).

If dewatering is required during the infrastructure works (in creation of ponds) care must be taken to ensure that the wider groundwater regime is not impacted. Water should be disposed of responsibly.

9.4 Ground Gases

For any confined spaces / service ducts in relation to the road construction, gas protection measures in line with current guidance (CIRIA 665 / BS 8485) will need to be adopted. The design should be approved with the regulators (Local Authority – Building Control / Contaminated Land Officer) prior to implementation.

9.5 Utilities

Contaminants encountered on site may pose a risk to underground service such as drinking water supply pipes and therefore this should be considered when utilities are designed for the development. Service providers should be contacted prior to development to determine that the appropriate underground services are used within the development.

In conjunction with the local service provider, the current guidance such as UK Water Industry Research (WIR) (Ref 9) should be used to determine the appropriate drinking water pipes to be used across the development.

9.6 Watching Brief / Unexpected Contamination

During the site enabling works, a watching brief should be maintained with regards to dealing with unforeseen contamination. If visually contaminated or odorous material is encountered on site, appropriate analysis shall be undertaken to confirm if the soil meets the required criteria to be protective of human health and controlled waters. .

Asbestos / Made Ground (including ashy material) has been encountered in some places across the Phase 2 development site during the investigations undertaken to date. There is however the potential for asbestos fibres / fragments to be present in other areas and workers should be extra vigilant in this respect during these works. If ashy material is encountered, this could represent a burning pit and additional screening (e.g. radiological screening) may be required.

Should potential contamination not previously encountered be identified during the enabling / construction phase, the Local Authority Pollution Control Team shall be notified as soon as possible. A suitably experienced Geo Environmental Engineer should be contacted to take samples of any potentially contaminated material to determine the risks present and the appropriate disposal route. Soils from such areas will be kept segregated from other uncontaminated materials in case a different disposal route is required.

9.7 Verification

Throughout the remedial works, validation sampling and analysis should be undertaken on any areas where contaminated material is removed to ensure that the area is fully remediated with all contamination removed. Any imported material should be tested prior to arriving on site to ensure it is chemically suitable for its intended use.

Although subject to scope, validation is likely to include the following;

- Records of re-use of materials and compliance with waste legislation where appropriate;
- Records of waste disposal, quantities, waste characterisation, waste transfer notes and receiving facilities;
- Record of the Watching Brief, findings and outcomes;
- Verification of hotspot removal and/or testing of soils (if required);
- Details of any on-site soil or groundwater treatment;
- Results of further groundwater testing (if required);
- Records of the chemical analysis and conformance of clean imported topsoil;
- Verification of correct installation of gas protections measures including photographic evidence (if undertaken);

Upon completion of all remedial works, all records will need to be collated into a Verification Report and presented to the Local Planning Authority for approval.

9.8 Waste Management

EU Directives, UK Government policy and regulations require that construction waste to landfill is minimised. Where possible all excavation arisings as a result of the proposed development should be re-used on site as either engineering fill or landscaping fill. This approach would be beneficial to the scheme as it will potential save costs on importing material on to site during the development.

To comply with current legislation and regulations any re-use of excavated materials within the site could be undertaken via either of two routes – Environmental Permitting (formerly Waste Exemptions); or in accordance with the CL:AIRE Definition of Waste: Development Industry Code of Practice (Ref. 10). Whichever route is chosen soils must be demonstrated to be “suitable for use” both chemically and geotechnically in the area to be deposited and a Materials Management Plan (or method statement) should be produced during the design phase for the scheme. The analysis undertaken (soils and soil leachate) during this investigation can be used to prepared the MMP especially in the areas that will be excavated to create the ponds on the eastern boundary. The MMP should be “signed off” by a CL:AIRE Qualified Person and declaration sent to the EA.

During construction of the proposed development should the excavated material not be physically or chemically suitable for use as backfill or as other engineering fill within the site or if there is an excess of materials, the material would need to be disposed off site to landfill, to a soil treatment hub, or a receptor site identified under the CL:AIRE protocol. Further testing and separation of waste for off-site disposal should be undertaken during the excavation works to minimise any treatment requirements. The testing will enable the classification of material to reduce wastes sent to non-hazardous and hazardous landfill.

Arisings should be stored in an appropriate manner to retain the desired properties, and prevent leaching of contaminants or fines from the material. This should be in a location on site away from any watercourses, stockpiles should be kept at a suitably height to ensure that they remain stable and integrity of the soils. If considered necessary the stockpiles should be covered to ensure that soils do not enter surface water runoff. Suspected inert, non-hazardous and hazardous material should be stored separately where appropriate to avoid cross contamination and avoid unnecessary disposal costs.

In order to determine the appropriate landfill site for disposal of the unwanted soils, the results obtained from the testing undertaken during the excavation works and the proceeding investigations should be assessed to determine if they are non-hazardous or hazardous. Waste Acceptance Criteria (WAC) analysis can also be undertaken to further classify the waste to determine if the material is inert or meets the hazardous criteria. Whenever possible this should be undertaken on the material that is actually going to be removed from site to make sure an appropriate classification is achieved.

10 Conclusions and Recommendations

10.1 Conclusions

An extensive ground investigation was undertaken by WSP across the proposed development site in 2007. An investigation has now been undertaken to supplement this and increase the data set of chemical testing. The development area has been divided into land use areas based on its past and proposed end use and appropriate sampling strategies derived. The recent investigation has investigated the previously contaminated areas (mainly in LU11) and has undertaken groundwater and gas monitoring to understand the current regimes within the proposed development area.

The soil analytical results from both investigations have been assessed against current guidelines (S4ULs / C4SL) and the groundwater concentrations have been compared to the appropriate WQS from the Water Framework Directive and Drinking Water Standards.

The assessments have shown that whilst elevated soil concentrations have been recorded in specific areas (mainly LU6 and LU11), the site is not grossly contaminated and the underlying soils are mainly suitable for the proposed end use without the need for remediation. Table 5.5 in Section 5.2 provides a summary of the Contaminants of Concern for each land use area, which include inorganic compounds, asbestos, TPH and PAH compounds.

The main organic contaminants were found to be benzo(a)pyrene and dibenzo(ah)anthracene which recorded concentrations above the SSV in over 30 samples. It is however noted that approximately half of the benzo(a)pyrene concentrations were below the residential C4SL (5mg/kg) which is a value indicating low risk.

TPH contamination was found in LU11 which is the location of the former fuel storage and vehicle maintenance. Samples were taken from pits excavated in similar places to the locations of previously recorded in contamination (in 2007) and whilst elevated concentrations were recorded, there were lower than previously recorded. The source of the TPH contamination has not been fully determined at this stage.

A risk assessment has been undertaken and conceptual site models (tables) for a residential and commercial end use have been presented which details the following contaminant linkages;

- For human health contaminant linkages a moderate / low to moderate risk (CL1) is identified due to the development's private gardens and soft landscaping (i.e. sensitive land uses). Contamination was not found to be widespread but relates to relatively few exceedances. The risk for a commercial end use scenario is considered to be low as no exceedances were recorded for this land use.
- The risk (CL5) from ground gases is considered to be moderate based on the recent monitoring data. Across the site low gas concentrations and flow rates were recorded which equate to Characteristic Situation 1 / Amber 1 scenarios. Further characterisation would be warranted to examine whether this risk level is fully appropriate and proportionate to risk to inform residential design*.
- Asbestos fibres have been detected in soils in several land uses and therefore a moderate risk is presented which reduces to moderate / low in general areas (CL4) where asbestos has not been identified.
- The risk to controlled waters (CL2 / CL7) is considered to be moderate / low to moderate as groundwater testing has identified some elevated concentrations above stringent guidelines from the Water Framework Directive.
- The risk to proposed buildings (CL3) is considered to be low from the contamination encountered within the soils, however the risk from ground gases in confined spaces (CL7) is considered to be low, but indicative that basic protection may be required (see text above*).

10.2 Recommendations

The following is recommended

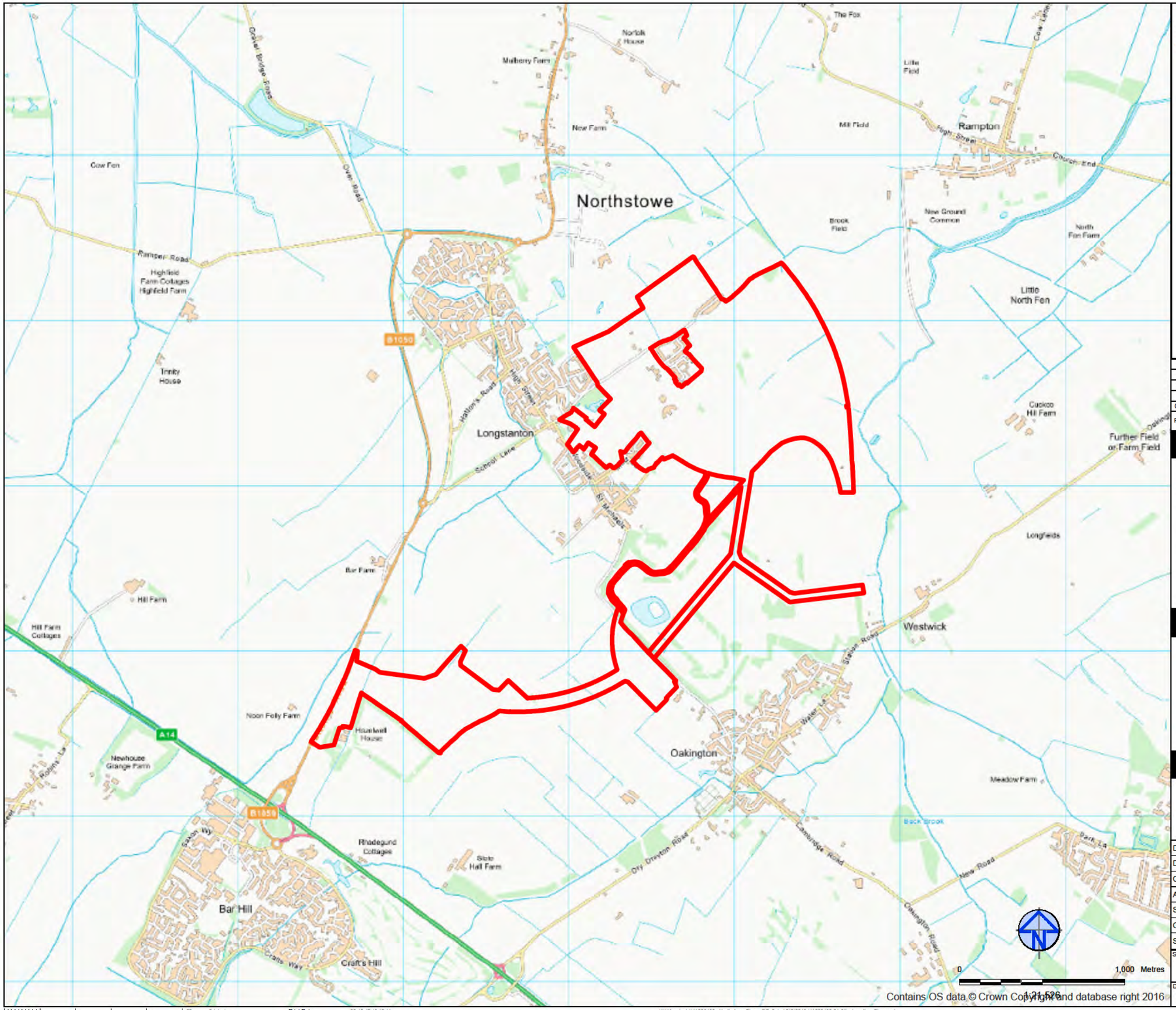
- A detailed remedial strategy is prepared for the areas where contamination has been encountered. Consideration should be given to removing the contamination in this area prior to the excavation taking place to ensure that natural (non-contaminated soils) do not become contaminated and potentially unsuitable for re-use on site.
- The EA should be contacted to gain their opinions on the groundwater contaminant values and if they represent background levels. Remediation of the groundwater is considered unlikely, however the EA's understanding will assist the potential to re-use the materials on site, even though soil leachate concentrations are above the WQS values.
- A Materials Management Plan (MMP) should be prepared prior to the excavation of the ponds to confirm that the excavated materials are suitable (chemically and geotechnically) and can be re-used on site. The MMP and appropriate documentation should be reviewed and certified by a CL:AIRE Qualified Person (QP).
- Zetica identified several areas of Made Ground burning pit. Delineation of these areas should be undertaken prior to excavation to establish the extent, costs associated with disposal or if the material can be treated and re-used on site.
- Once a development plan for each area is known, further investigation should be undertaken in the proposed gardens / landscaped areas to establish the contamination status in these areas.
- Further characterisation of ground gas risk would be prudent, considering the number of dwellings to be built.

11 References

1. Hyder Consulting (UK) Limited (2014) Northstowe – Phase 2 Geo Environmental Assessment and Outline Remedial Strategy Report (Report Number 5025-UA006156-UP31R-01)
2. Arcadis Consulting (UK) Limited (2017) Northstowe Phase 2, Ground Investigation Report (Report Number UA008426-AFS-GLR-G001)
3. Arcadis Consulting (UK) Limited (2017) Northstowe – Phase 2 Geotechnical Interpretative Report (Report Number NOR-ARC-P2-XXX-RP-G-0138-P01)
4. LQM / CIEH (2015) The LQM / CIEH S4ULs for Human Health Risk Assessment
5. Defra (2012) SP0101 Development of Category 4 Screening Levels Main Report
6. HSE (2011) EH40/2005 Workplace exposure limits ISBN 978 0 7176 6446 7
7. CIRIA C665. (2007) Assessing Risks Posed by Hazardous Ground Gases to Buildings
8. CIRIA C552 (2001) Contaminated land risk assessment. A guide to good practice

APPENDICES

Appendix A
Figures



Legend:

Phase 2 Planning Boundary

Rev	Date	Description	Drawn	Check	Approv
01	15/05/2017	1st Issue	FW	AP	GF

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Site

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SITE LOCATION PLAN

Designed	FW	Date: 15/05/2017	Signed
Drawn	FW	Date: 15/05/2017	Signed
Checked	AP	Date: 15/05/2017	Signed
Approved	GF	Date: 15/05/2017	Signed
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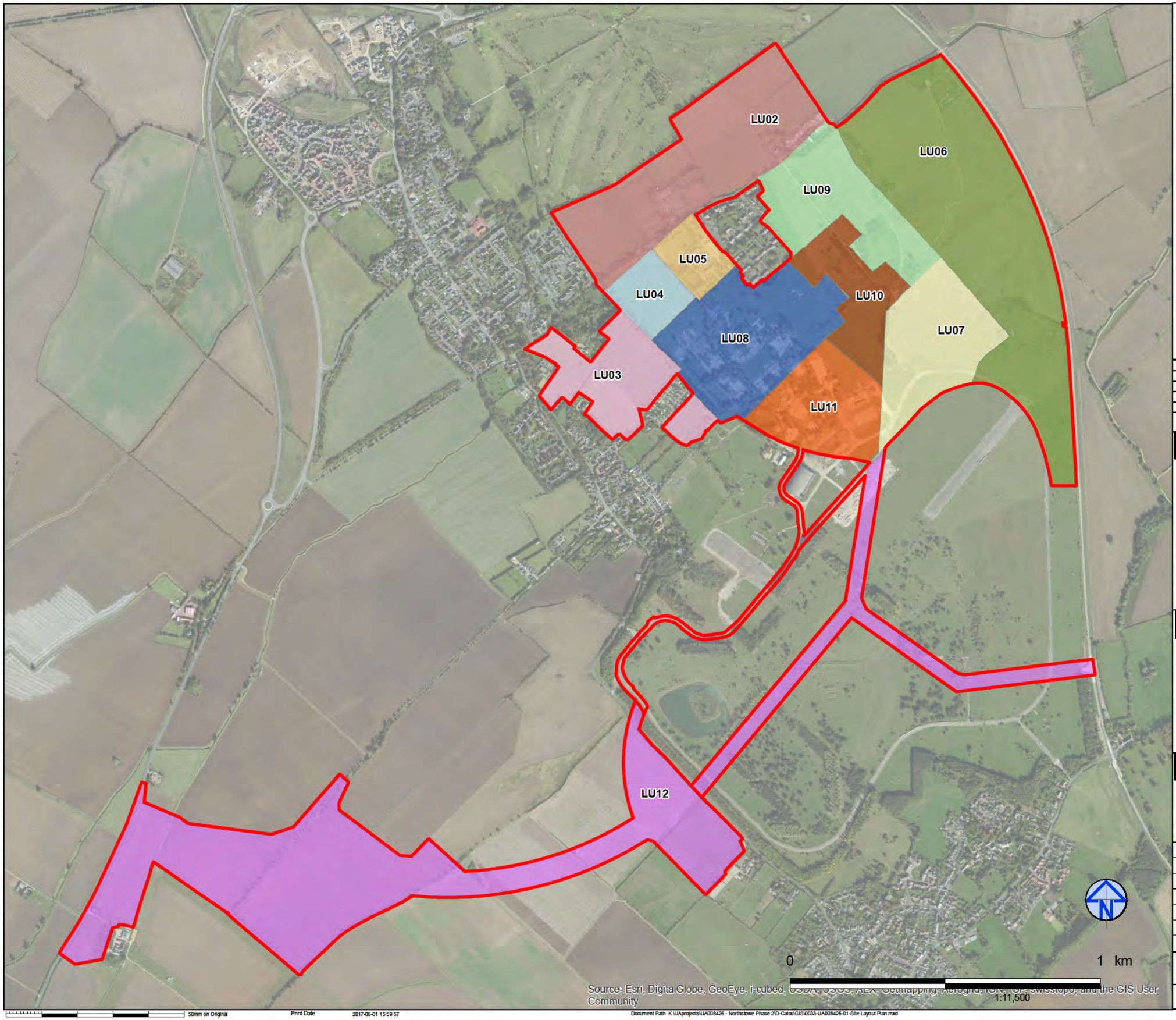

Land Use Areas

- LU02
- LU03
- LU04
- LU05
- LU06
- LU07
- LU08
- LU09
- LU10
- LU11
- LU12
- Phase 2 Planning Boundary

REV	Date	Description	Drawn	Check	Approv
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SITE LAYOUT PLAN

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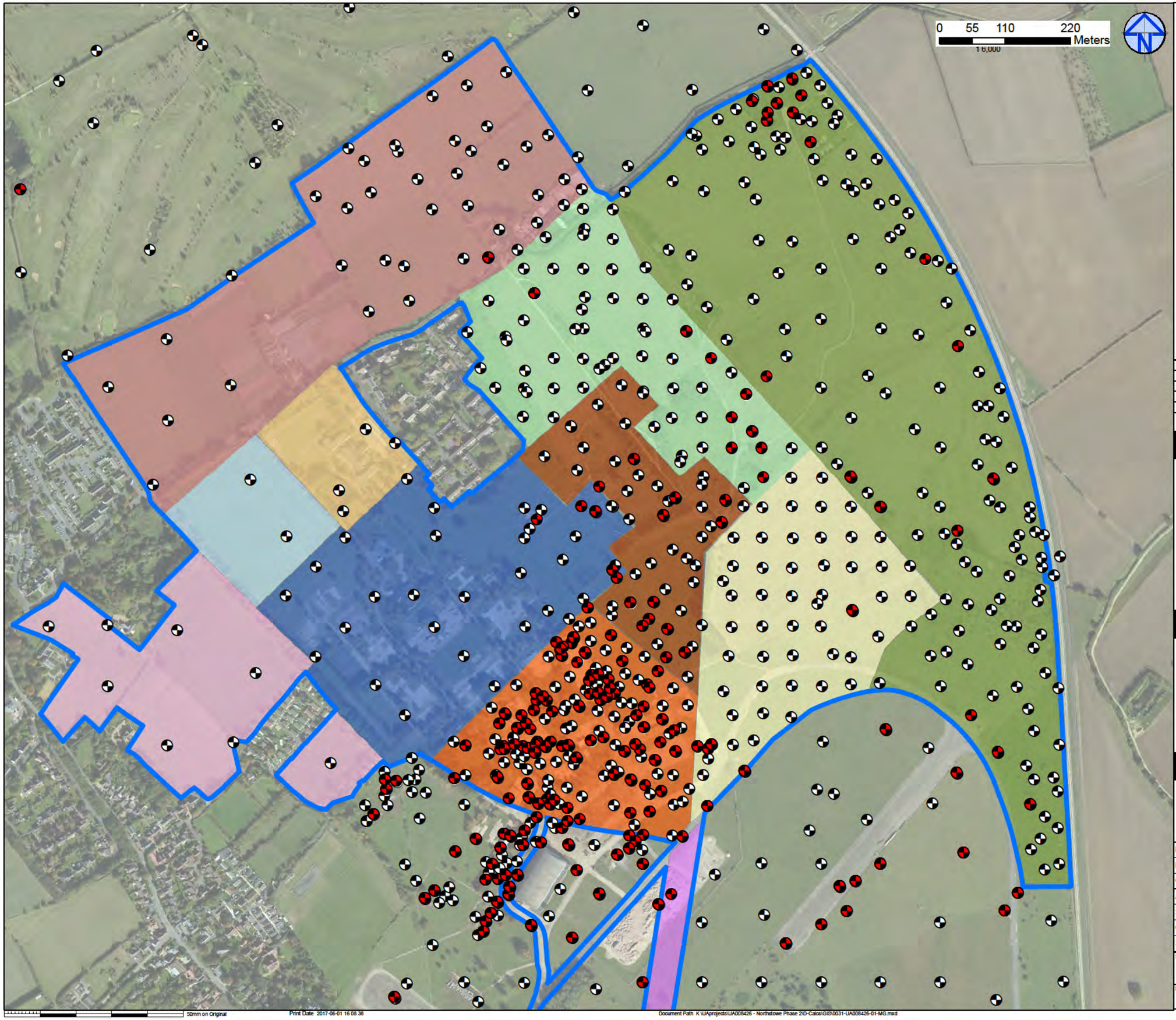

Location of Made Ground

- Made Ground encountered
- Made Ground not encountered
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Approved	GF	Date: 01/06/2017	Signed
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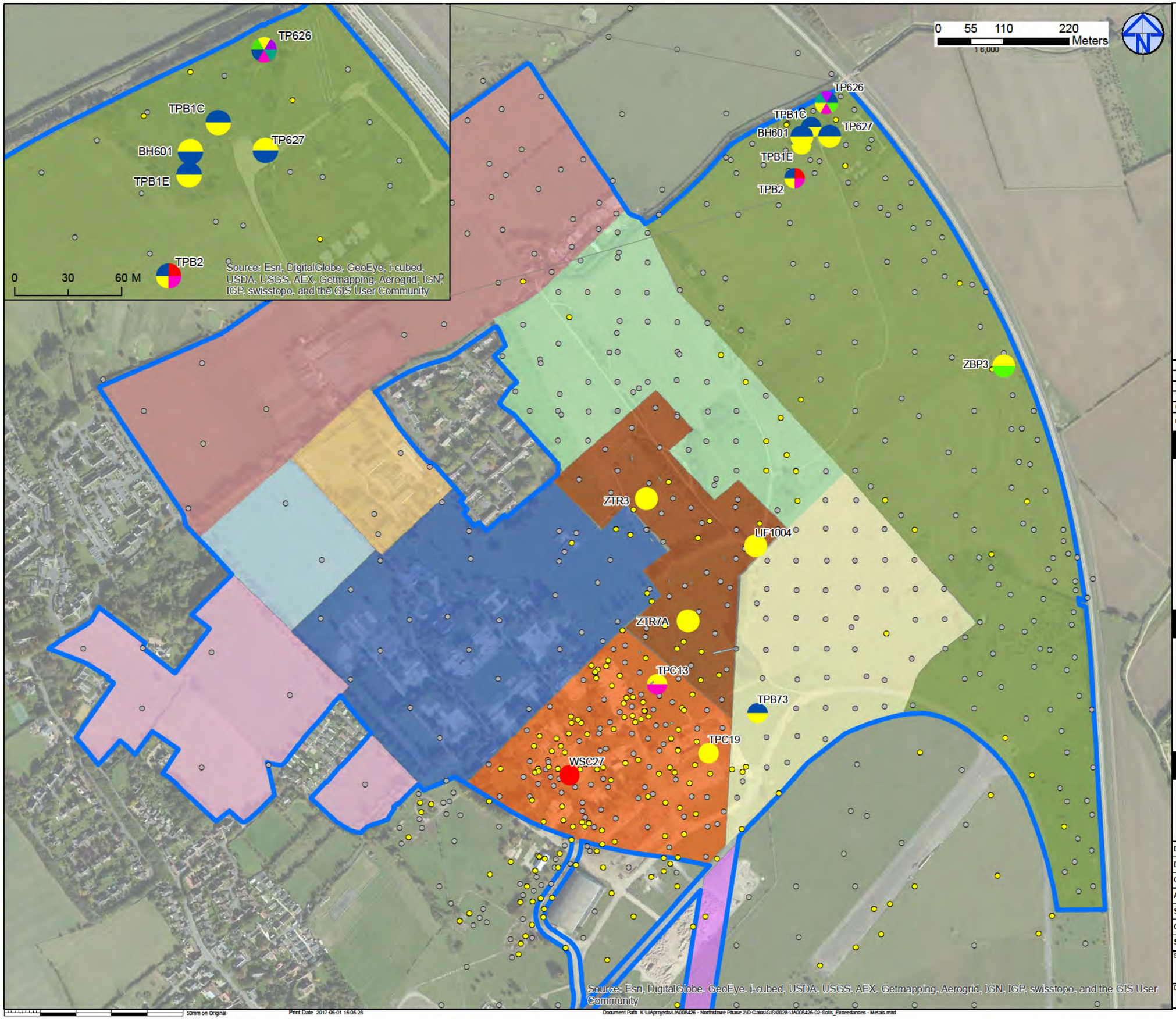

Exceedances of metals in soil samples analysed

- Arsenic
- Cadmium
- Chromium VI
- Copper
- Lead
- Nickel
- Zinc

Exploratory Holes

- Made Ground encountered
- Made Ground not encountered

Phase 2 Planning Boundary

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LOCATION OF METALS EXCEEDANCES IN SOILS

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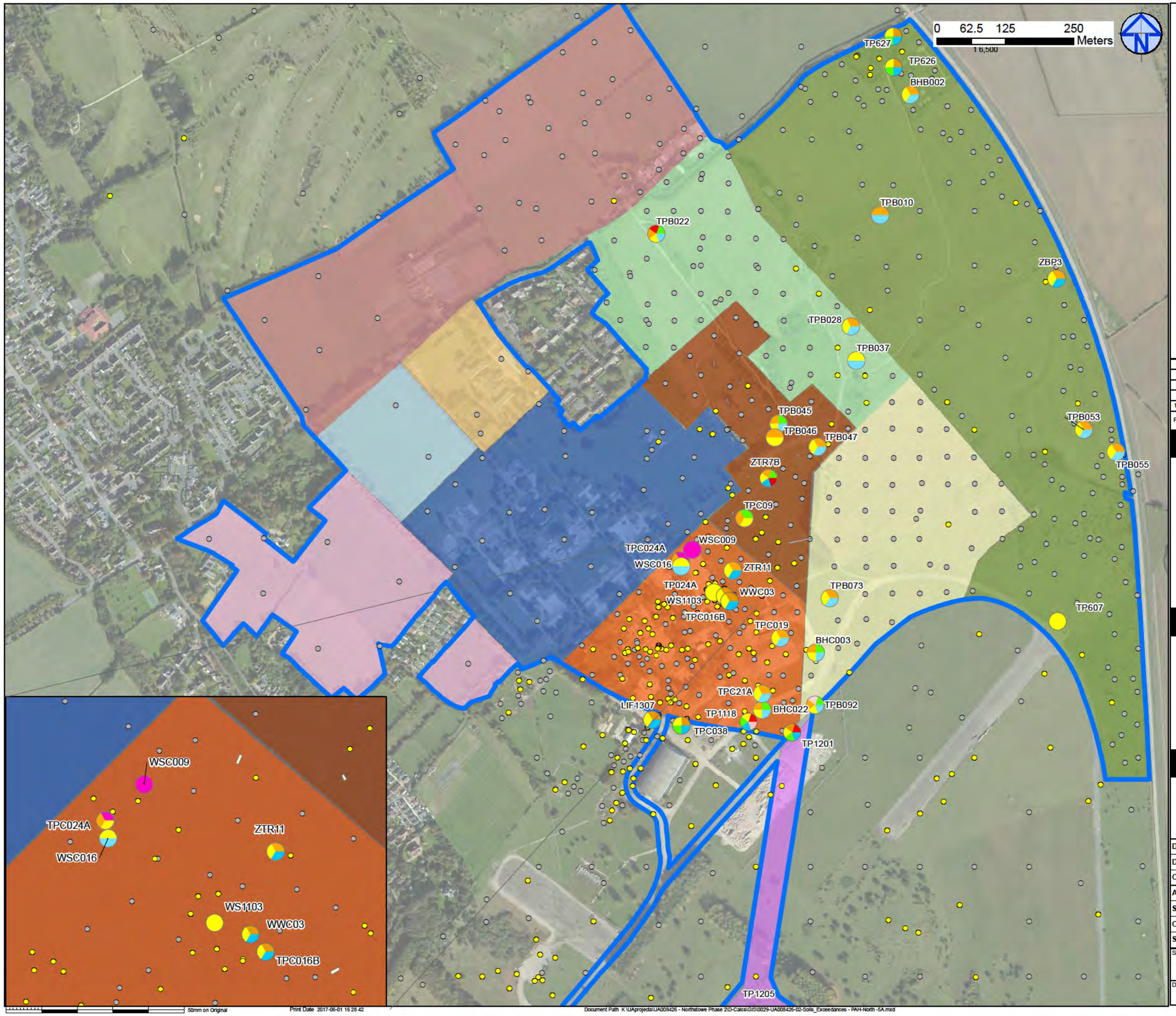

Exceedances of PAH in soil samples analysed

- Naphthalene
- Benzo-A-anthracene
- Chrysene
- Benzo-K-fluoranthene
- Benzo-B-fluoranthene
- Benzo-A-pyrene
- Dibenzo-AH-anthracene

Exploratory holes

- Made Ground encountered
- Made Ground not encountered

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LOCATION OF PAH EXCEEDANCES IN SOIL AND MADE GROUND - NORTHERN AREA

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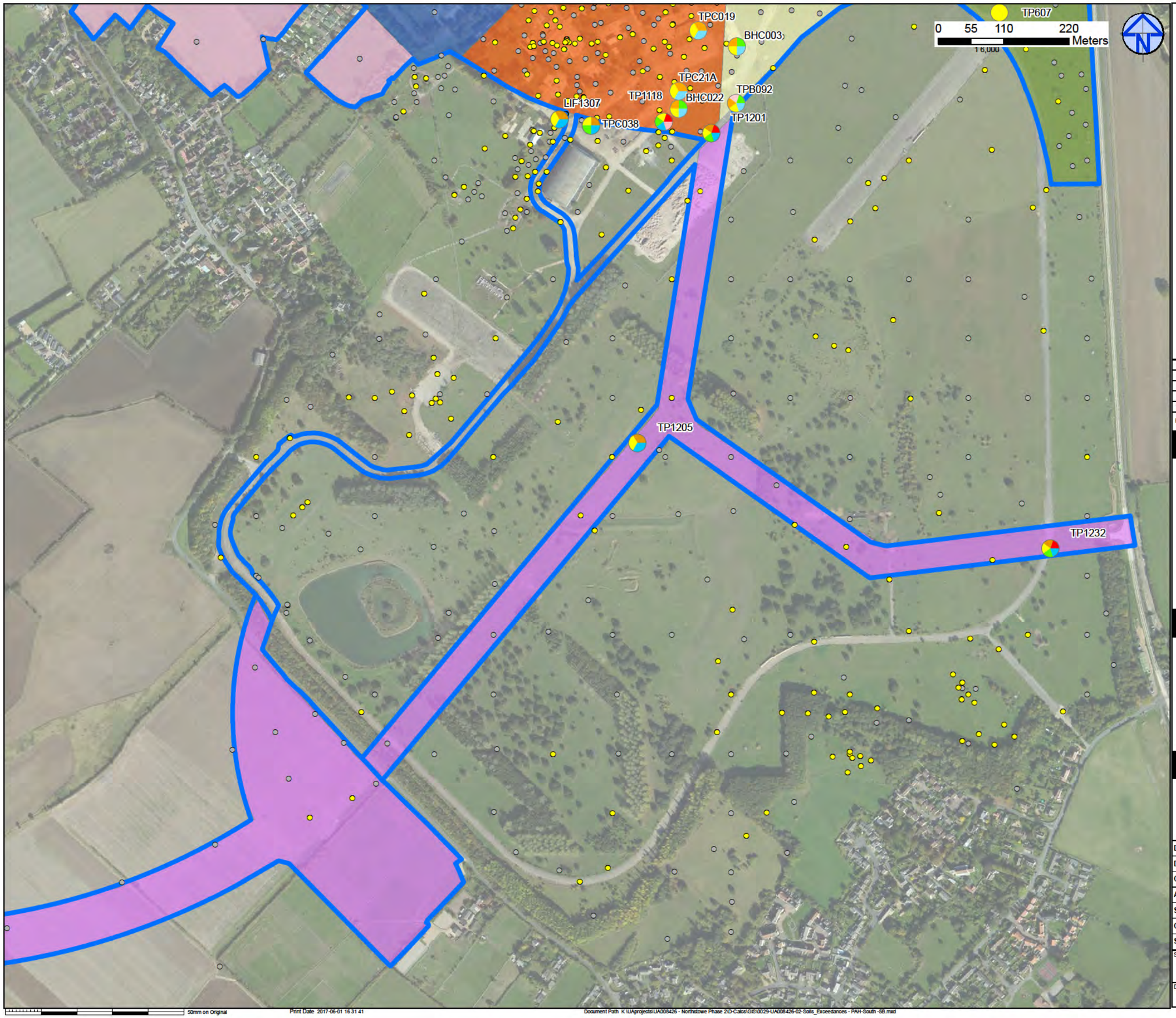
Revision: 01



Exceedances of PAH in soil samples analysed

- Naphthalene
- Benzo-A-anthracene
- Chrysene
- Benzo-K-fluoranthene
- Benzo-B-fluoranthene
- Benzo-A-pyrene
- Dibenzo-AH-anthracene

Exploratory holes

- Made Ground encountered
- Made Ground not encountered

Phase 2 Planning Boundary

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LOCATION OF PAH EXCEEDANCES IN SOIL AND MADE GROUND - NORTHERN AREA

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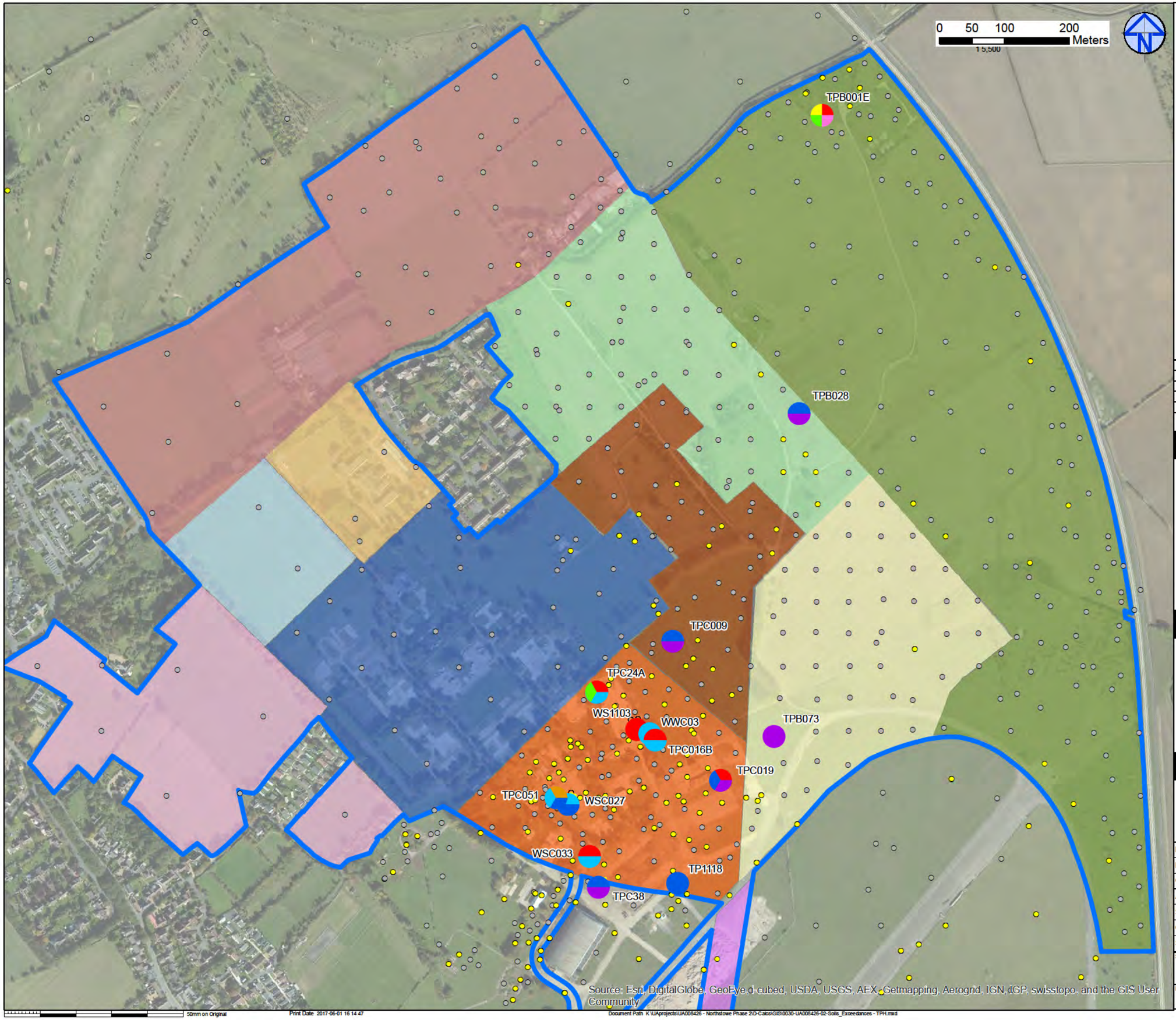

Exceedances of TPH in soil samples analysed

- Aliphatic C8-10
- Aliphatic C12-C16
- Aromatic C8-C10
- Aromatic C10-C12
- Aromatic C12-C16
- Aromatic C16-C21
- Aromatic C21-C35
- Benzene

Exploratory Holes

- Made Ground encountered
- Made Ground not encountered

Phase 2 Planning Boundary

REV	Date	Description	Drawn	Check	Approv
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LOCATION OF TPH EXCEEDANCES

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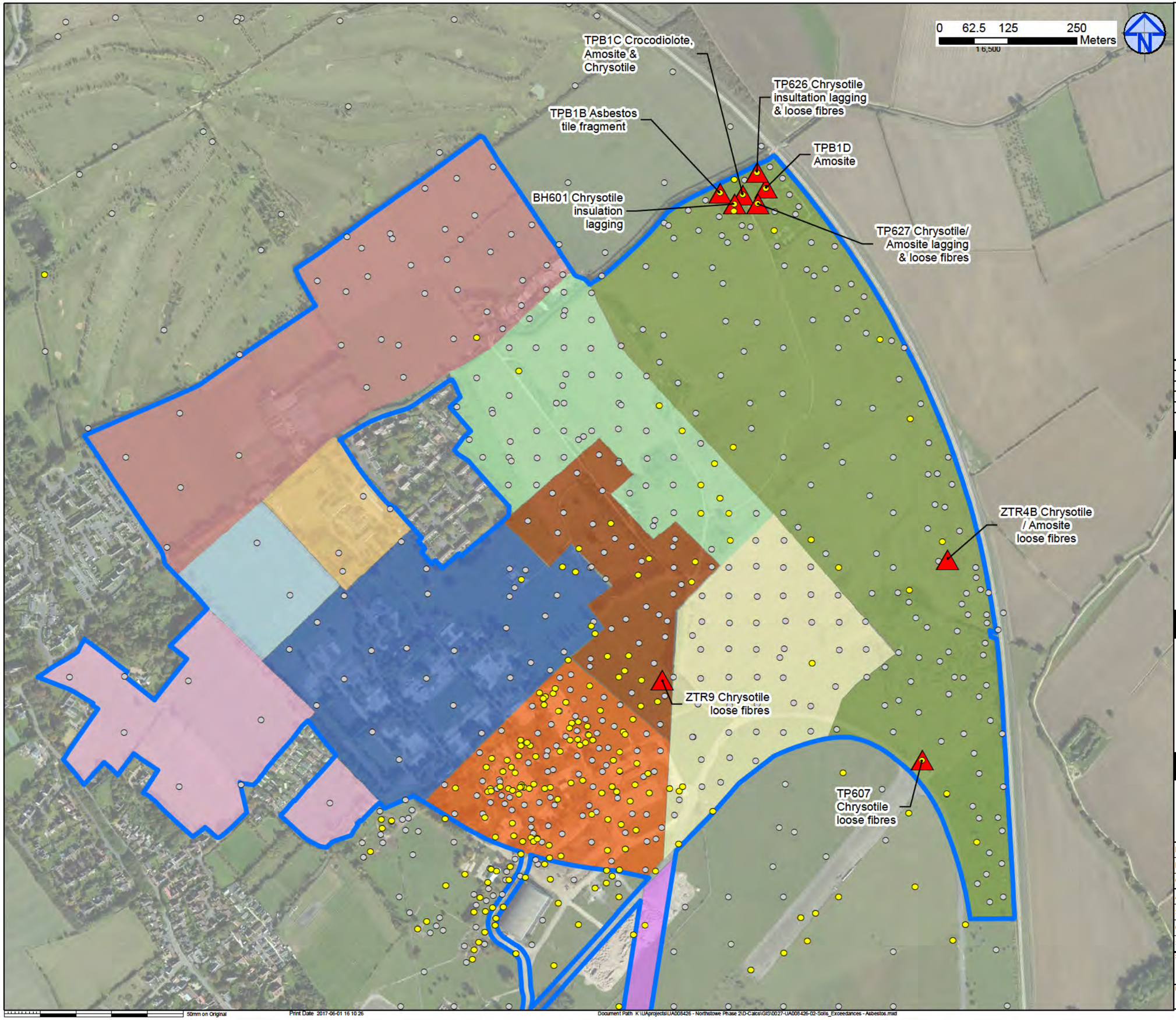

Asbestos presence

Asbestos identified in sample

Exploratory Holes

- Made Ground encountered
- Made Ground Not Encountered

Phase 2 Planning Boundary

Note: Asbestos was not tested for in every exploratory hole location

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LOCATION OF ASBESTOS IDENTIFIED IN SOIL SAMPLES

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Suitability Code	S2	Project Number:	UA008426

Suitability Description:
PRELIMINARY
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Drawing Number:
Figure 7

Revision:
01

Appendix B

Detailed PAH table

Italics = WSP 2007 data MG = Made Ground NS = Natural Soils

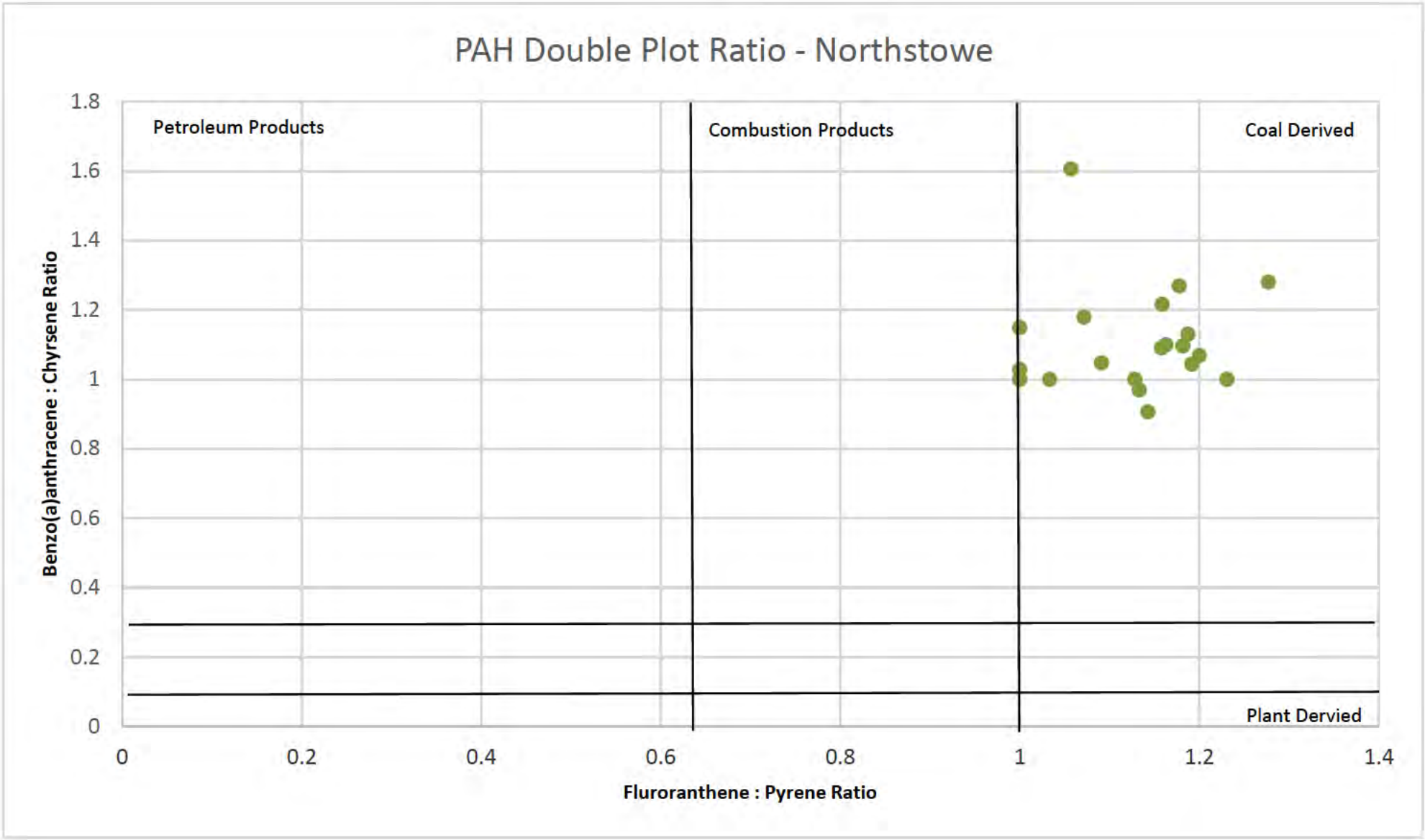
Determinand	SSV for Residential end use (Commercial SSV) (mg/kg)	Location of exceedance	Concentration (mg/kg)	HI
Naphthalene	2.3 (190)	TPC24A 0.65 (NS)	6.9	3.0
		WSC009 0.5 (MG)	54	23.5
Benzo(a)anthracene	7.2 (170)	TP1118 0.0-0.25 (NS)	22	3.1
		TP1201 0.1 (MG)	22	3.1
		TP626 0.4-0.7 (MG)	7.9	1.1
		TP627 0.35(MG)	7.3	1.0
		ZTR7B 0.0-0.1 (MG)	22	3.1
		TPC038 0.1 (NS)	9.7	1.3
		TPB022 0.4 (NS)	*19*	2.6
		TPB045 0.25 (NS)	*9.74*	1.4
		TPB092 0.3 (MG)	*15*	2.1
		BHC022 0.5-0.7 (MG)	*8.6*	1.2
		BHC003 0.5-1.0 (MG)	*10.0*	1.4
		TPC09 0.7 (MG)	*8.1*	1.1
Chrysene	15 (350)	TP1118 0.0-0.25 (NS)	22	1.5
		TP1232 0.1 (NS)	23	1.5
		TP1201 0.1(MG)	22	1.5
		ZTR7B 0.0-0.1 (MG)	20	1.3
		TPB022 0.4 (NS)	*18*	1.2
Benzo(k)fluoranthene	77 (1200)	*TPB092 0.3* (MG)	*233*	*3.0*
Benzo(b)fluoranthene	2.6 (44)	ZTR11 0.6-0.7 (MG)	3.5	1.3
		TP1232 0.1 (NS)	25	9.6
		TP1201 0.1(MG)	29	11.2
		TP626 0.4-0.7 (MG)	7.4	2.8
		TP627 0.1 (MG)	5.7	2.2
		TP627 0.35 (MG)	7.7	3.0
		ZBP3 0.3-0.4(MG)	5.9	2.3
		ZBP3 1.0-1.1(MG)	4.8	1.8
		ZTR7B 0.3-0.4 (MG)	3.8	1.5

Determinand	SSV for Residential end use (Commercial SSV) (mg/kg)	Location of exceedance	Concentration (mg/kg)	HI
		ZTR7B 0.0-0.1 (MG)	22	8.5
		LIF1307 0.0-0.2 (MG)	4.1	1.6
		TP1205 0.1-0.3 (NS)	5.9	2.3
		TPC038 0.1 (NS)	17	6.5
		TPC038 0.5 (NS)	5	1.9
		TP024A 0.4 (NS)	6.5	2.5
		WWC03 0.7 (NS)	5.8	2.2
		TPC016B 0.5 (NS)	3.9	1.5
		BHA07 0.0-0.4 (MG)	*10*	3.8
		TPB010 0.2 (NS)	*2.9*	1.1
		TPB022 0.4 (NS)	*9.4*	3.6
		TPB045 0.25 (NS)	*12.32*	4.7
		TPB046 0.6 (NS)	*3.31*	1.3
		TPB047 0.2 (NS)	*5.66*	2.2
		TPB053 0.2 (NS)	*3.71*	1.4
		TPB055 0.3 (NS)	*3.62*	1.4
		TPB092 0.3 (MG)	*8.3*	3.2
		BHB002 0.4-0.6 (MG)	*3.3*	1.3
		TPC019 0.2 (MG)	*5.1*	2.0
		TPC21A 0.15 (NS)	*3.7*	1.4
		TPC24A 0.65 (NS)	*3.5*	1.3
		BHC022 0.5-0.7 (MG)	*7.1*	2.7
		BHC003 0.5-1.0 (MG)	*9.7*	3.7
		TPB073 0.45 (NS)	*2.8*	*1.1*
		TPB028 0.1m (MG)	*6.6*	*2.5*
		TPC09 0.7 (MG)	*7*	*2.7*
Benzo(a)pyrene	2.2 (35)	TP1118 0.0-0.25 (NS)	25	11.4
		ZTR11 0.6-0.7 (MG)	2.5	1.1
		TP1232 0.1 (NS)	23	10.5
		TP1201 0.1(MG)	23	10.5
		TP626 0.4-0.7 (MG)	6.5	3.0
		TP627 0.1 (MG)	4.7	2.1
		TP627 0.35 (MG)	7.3	3.3
		ZBP3 0.3-0.4(MG)	4.9	2.2

Determinand	SSV for Residential end use (Commercial SSV) (mg/kg)	Location of exceedance	Concentration (mg/kg)	HI
		ZBP3 1.0-1.1 (MG)	4.1	1.9
		ZTR7B 0.3-0.4 (MG)	4.1	1.9
		ZTR7B 0.0-0.1 (MG)	20	9.1
		LIF1307 0.0-0.2 (MG)	3.8	1.7
		TP607 0.4 (MG)	2.5	1.1
		WS1103 0.1-0.2 (NS)	2.4	1.1
		TP1205 0.1-0.3 (NS)	5.1	2.3
		TPC038 0.1 (NS)	13	5.9
		TPC038 0.5 (NS)	3.8	1.7
		TP024A 0.4 (NS)	4.6	2.1
		WWC03 0.7 (NS)	4.8	2.2
		TPC016B 0.5 (NS)	3.3	1.5
		TPB022 0.4 (NS)	*14*	6.4
		TPB037 0.0-0.3 (MG)	*2.3*	1.0
		TPB045 0.25 (NS)	*9.56*	4.3
		TPB046 0.6 (NS)	*2.6*	1.2
		TPB047 0.2 (NS)	*5.52*	2.5
		TPB053 0.2 (NS)	*2.6*	1.2
		TPB055 0.3 (NS)	*2.94*	1.3
		TPB092 0.3 (MG)	*13*	5.9
		BHB002 0.4-0.6 (MG)	*3.7*	1.7
		TPC019 0.2 (MG)	*4.6*	2.1
		TPC21A 0.15 (NS)	*3.6*	1.6
		TPC24A 0.65 (NS)	*3.1*	1.4
		WSC016 0.4-0.8 (MG)	*2.6*	1.2
		BHC022 0.5-0.7 (MG)	*8.0*	3.6
		BHC003 0.5-1.0 (MG)	*9.0*	4.1
		TPB073 0.45 (NS)	*2.9*	1.3
		TPB028 0.1m (MG)	*7.5*	3.4
		TPC09 0.7 (MG)	*8.7*	3.9
Dibenz(a,h)anthracene	0.24 (3.5)	TP1118 0.0-0.25 (NS)	2.7	11.3
		ZTR11 0.6-0.7 (MG)	0.3	1.3
		TP1232 0.1 (NS)	2.4	10.0
		TP1201 0.1(MG)	3.2	13.3

Determinand	SSV for Residential end use (Commercial SSV) (mg/kg)	Location of exceedance	Concentration (mg/kg)	HI
		TP626 0.4-0.7 (MG)	0.58	2.4
		TP627 0.1 (MG)	0.46	1.9
		TP627 0.35 (MG)	0.67	2.8
		ZBP3 0.3-0.4 (MG)	0.49	2.0
		ZBP3 1.0-1.1 (MG)	0.35	1.5
		ZTR7B 0.3-0.4 (MG)	0.39	1.6
		ZTR7B 0.0-0.1 (MG)	2	8.3
		LIF1307 0.0-0.2 (MG)	0.41	1.7
		TP1205 0.1-0.3 (NS)	0.59	2.5
		TPC038 0.1(NS)	1.9	7.9
		TPC038 0.5 (NS)	0.47	2.0
		TP024A 0.4 (NS)	0.45	1.9
		WWC03 0.7 (NS)	0.3	1.3
		TPC016B 0.5 (NS)	0.46	1.9
		TPB010 0.2 (NS)	*0.27*	1.1
		TPB022 0.4 (NS)	*1.5*	6.3
		TPB037 0.0-0.3 (MG)	*0.28*	1.2
		TPB037 1.3-1.6 (NS)	*8*	33.3
		TPB045 0.25 (NS)	*1.1*	4.6
		TPB047 0.2 (NS)	*0.8*	3.3
		TPB053 0.2 (NS)	*0.34*	1.4
		TPB055 0.3 (NS)	*0.4*	1.7
		TPB092 0.3 (MG)	*1.9*	7.9
		BHB002 0.4-0.6 (MG)	*0.7*	2.9
		TPC019 0.2 (MG)	*1.1*	4.6
		TPC21A 0.15 (NS)	*0.64*	2.7
		WSC016 0.4-0.8 (MG)	*0.4*	1.7
		BHC022 0.5-0.7 (MG)	*1.0*	4.2
		BHC003 0.5-1.0 (MG)	*1.4*	5.8
		TPB073 0.45m (NS)	*1.3*	6.25
		TPB028 0.1m (MG)	*0.76*	3.2

Appendix C
Double Plot Ratio


PAH Double Plot Ratio - Northstowe
Petroleum Products
Combustion Products
Coal Derived
Plant Dervied
Benzo(a)anthracene : Chyrsene Ratio
Fluroranthene : Pyrene Ratio
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8

Appendix D

Risk Assessment Information

Risk Assessment Information

Based on information presented in

- CIRIA C552 (2001) Contaminated Land Risk Assessment: A guide to good practice, and
- NHBC / EA/ CIEH (2008) R&D Publication 66: (Volume 1) Guidance for the Safe Development of Housing on Land Affected by Contamination

Risk assessment considers the identified sources, the potential receptors and the pathways linking them together.

The designation of risk is based upon the consideration of both:

a. the **severity of the potential consequence**
(this takes into account both the potential severity of the hazard and the sensitivity of the receptor)

b. the **magnitude of probability** (ie likelihood)
(this takes into account both the presence of the hazard and receptor and the integrity of the pathway)

Severity (consequence) can be defined as the adverse effects (or harm)arising from a defined hazard, which impairs the quality of human health or the environment in the short or longer term. Definitions of different categories of severity are detailed in Table 1 below.

Probability can be defined as the chance of a particular event occurring in a given period of time. Definitions of different categories of probability are detailed in Table 2 below.

A pollutant linkage must first be established before tests for probability and consequence are applied. If there is no pollutant linkage then there is no potential risk.

Table 1 - Classification of Potential Consequence (Severity)

Classification	Human Health	Controlled Water	Built Environment	Ecosystems
Severe	Irrevers ble damage to human health. Short term (acute) risk to human health. Concentrations present likely to result in "significant harm" as defined by Part 2a.	Substantial pollution of sensitive water resources.	Catastrophic damage to buildings, structures or the environment.	Major damage to aquatic or other ecosystem, which is likely to result in a substantial adverse change in its functioning or harm to a species of special interest.
Medium	Chronic damage to human health. Concentrations present that could result in significant harm.	Pollution of sensitive water resources or small scale pollution of sensitive water resources	Significant damage to buildings, structures or the environment	Significant damage to aquatic or other ecosystems.
Mild	Slight short term health effects to humans. Exposure to human health unlikely to lead to significant harm.	Pollution to non-sensitive water resources	Minor damage to sensitive buildings, structures services or the environment.	Minor or short lived damage to aquatic or other ecosystems.
Minor	Non permanent health effects to human health (easily prevented by means such as personal protective clothing etc)	Insubstantial pollution to non-sensitive water resources	Easily repairable effects of damage to buildings or structures	Harm (although not necessarily significant harm which may result in financial loss or expenditure to resolve. eg loss of plants in a landscape scheme).

Table 2 Classification of probability

(only applies if there is a possibility of a pollutant linkage being present)

High likelihood	There is a pollution linkage and an event that either appears very likely in the short term and almost inevitable over the long term or there is evidence at the receptor of harm or pollution.
Likely	There is a pollution linkage and all the elements are present and in the right place, which means that it is probable that an even will occur. Circumstances are such that an event is not inevitable, but possible in the short term and likely over the long term.
Low Likelihood	There is a pollution linkage and circumstances are possible under which an even could occur. However it is by no means certain that even over a longer period such an event would take place and is less likely in the shorter term.
Unlikely	There is a pollution linkage but circumstances are such that it is improbable that an event would occur even in the very long term.

Classification of Risk

Once the severity and probability have been classified for a pollutant linkage they can be compared to produce a risk category from very high risk to very low risk as shown in the matrix below.

Potential Consequence				
Severe	Moderate/Low	Moderate	High	**Very High**
Medium	Low	Moderate/Low	Moderate	High
Mild	Very Low	Low	Moderate/Low	Moderate
Minor	Very Low	Very Low	Low	Moderate/Low
Likelihood	**Unlikely**	**Low**	**Likely**	**High**

Table below describes the risk classifications

Risk Term	**Description**
Very High Risk	There is a high probability that significant harm could arise to a designated receptor from an identified hazard at the site without appropriate remedial action or there is evidence that significant harm to a designated receptor is already occurring.
High Risk	Harm is likely to arise to a designated receptor from an identified hazard at the site without appropriate remedial action. Remediation works may be necessary in the short-term and are likely over the longer term.
Moderate Risk	It is possible that harm could arise to a designated receptor from an identified hazard. However it is either relatively unlikely that any such harm would be severe or if any harm were to occur it is more likely that such harm would be relatively mild. Some remediation work may be required in the longer term.
Low Risk	It is possible that harm could arise to a designated receptor from an identified hazard, but it is likely, at worst, that this harm if realised would normally be mild. Any subsequent remediation works are likely to be relatively limited.
Very Low Risk	It is a low possibility that harm could arise to a receptor, but it is likely at worst, that this harm if realised would normally be mild or minor.

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