NORTHSTOWE
PHASE 2 PLANNING APPLICATION

Geo Environmental Assessment and Outline Remedial Strategy

August 2014

Homes & Communities Agency

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Northstowe – Phase 2

Geo Environmental Assessment and Outline Remedial Strategy Report

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Homes and Communities Agency

Northstowe – Phase 2

Geo Environmental Assessment and Outline Remedial Strategy Report

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Appendices

1 Introduction

1.1 Terms of Reference

Hyder Consulting (UK) Limited (Hyder) received instruction from the Homes and Communities Agency ("the Applicant") to prepare an interpretative Geo-environmental Assessment Report for the Phase 2 development of Northstowe to the northwest of Cambridge ("the site").

The purpose of this document is to support the planning application for the Phase 2 development of Northstowe.

1.2 Proposed Development

Planning permission is sought for development of Phase 2 of Northstowe with details of appearance, landscaping, layout, scale and access reserved (save for the matters submitted in respect of the Southern Access Road (West)) comprising:

1) development of the main Phase 2 development area for approximately 3,500 dwellings, two primary schools, a secondary school, the town centre including employment uses, formal and informal recreational space and landscaped areas, the eastern sports hub, the remainder of the western sports hub (to complete the provision delivered at Phase 1), the busway, a primary road to link to the southern access, construction haul route, engineering and infrastructure works; and

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

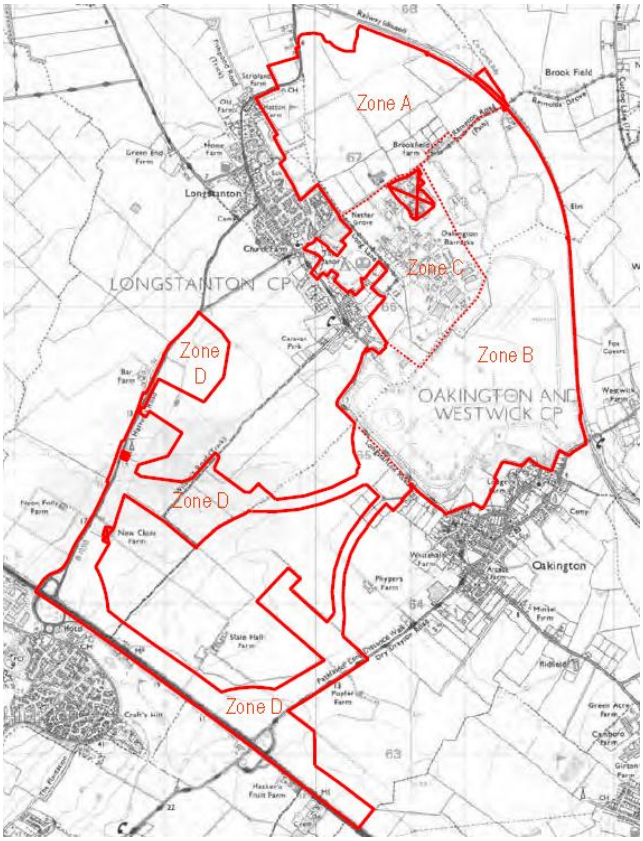
Plan 3 submitted with the application shows the application areas.

1.3 Background / Information

The Northstowe development is centred on the former WWII Oakington Airfield and surrounding farm land and previous specialist work e.g. ground investigations and Unexploded Ordnance (UXO) surveys has been undertaken by others across the area. This is discussed in Section 3 of this report. For the purpose of evaluation the Northstowe development was split into 4 zones as follows and illustrated on the plan below;

- Zone A – Cambridge Golf Course and Driving Range and farmland
- Zone B – Airfield
- Zone C – Former barracks of the airfield
- Zone D – open farmland between A14, Hatton's Road and Dry Drayton Road.

Zones A, B and C comprise the 'Core Area' of the proposed development and Zone D comprises the 'Off-Site Infrastructure Area.



Plan 1 – Plan showing the 4 Zones across the Northstowe Development – taken from WSP Interim Factual report Zone A. Please note that the red line boundary is different from the submitted application, however the extent of the study area means that the findings remain valid for the submitted application.

The majority of Zone A is being developed by Gallagher as Phase 1 of the Northstowe development (Planning application number S/0388/12/OL).

The application boundary of Phase 2 (which is the subject of this report) is provided in Plan 1 above and comprises the southern part of Zone A, northern portion of Zone B, Zone C and parts of Zone D.

Between 2005 and 2007 ground investigations were undertaken across the 4 zones by WSP Environmental (for English Partnership and Gallagher Longstanton Ltd). Interim Factual Reports were prepared by WSP for each zone (Refs 1-4 and referred to as 2007 WSP Reports) detailing the work undertaken and providing the results for each zone. The data from these 2007 WSP Reports have been used within this assessment report to determine the land quality risks across the Phase 2 development.

Please note that in order to produce a concise report, a summary of relevant findings from the 2007 WSP Reports have been provided within this report. It is however recommended that the 2007 WSP Reports are read in conjunction with this report to provide context and further details. These are appended on a CD in Appendix B.

2 Site Information

2.1 Site Location

The site is located to the north west of Cambridge, between the villages of Longstanton and Oakington. The approximate Ordnance Survey National Grid Reference for the site is 541000, 266000 and the plan below shows the approximate location.

Plan 2 Plan showing Site Location

2.2 Site Description and Surrounding Area

The area for the main Phase 2 development is approximately 165 hectares in size. As detailed in Section 1.2 above, the Phase 2 application area comprises the southern part of Zone A, northern portion of Zone B, all of Zone C and parts of Zone D will form the off-site infrastructure. Below are brief descriptions of each of these areas.

- **Zone A** – the area of Zone A in Phase 2 is agricultural land (2 fields). A golf course (Cambridge Golf Club) forms the majority of Zone A and this is being developed as Phase 1 by Gallagher Estates.
- **Zone B** – comprises the former airfield. A sewage works which has been demolished to ground level was located on the north-eastern corner of the site which also supported the former bomb storage area and associated infrastructure to the north. These are located within the Phase 2 application boundary.

Several structures remain across this zone: the airfield perimeter track, and a number of listed Oakington pill boxes. A lake is located in the south western corner of this zone, however this is not within the Phase 2 application boundary.

- **Zone C** – comprises the former army barracks which included former living quarters and associated welfare / training facilities / offices / storage / vehicle maintenance garages and fuel storage areas. The majority of these buildings have been demolished to ground level with the floor slabs remaining in place.

  The northern half of Zone C was later used as the location of the Oakington Immigration Reception Centre. Within the northern section of Zone C, there is an existing residential area, roughly rectangular in shape, Rampton Drift, however this is not within the application boundary.

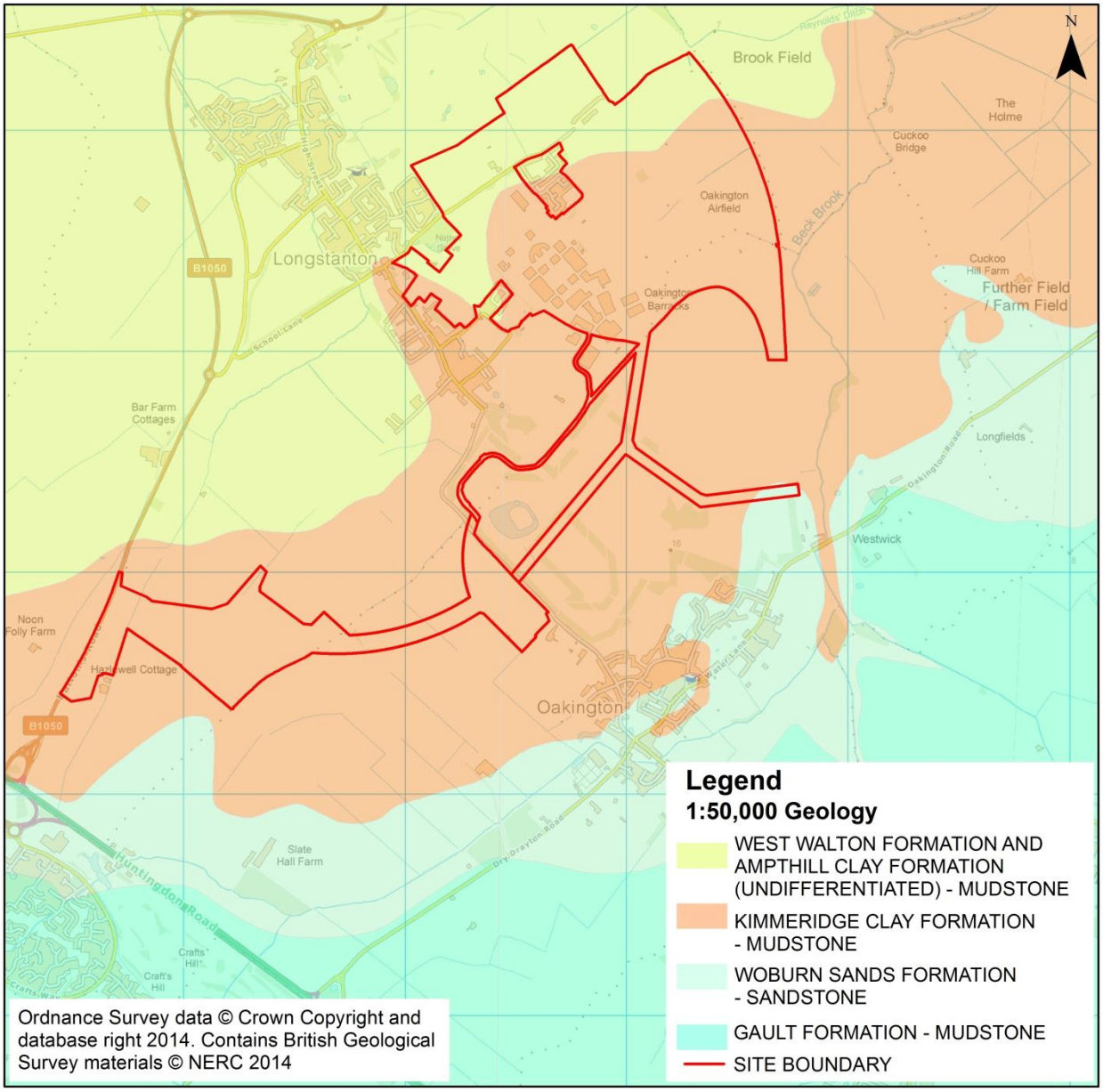
- **Zone D** – comprises agricultural land with several farmsteads and businesses present as well as smaller outbuildings.

- **Surrounding Area** – comprises agricultural land with Longstanton village to the north west, Oakington village to the south, with the outskirts of Cambridge beyond.

2.3 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 solid geology across the application site.

Plan 3 Inferred Geology across the zones



The following provides a summary of the ground conditions encountered in the WSP ground investigations in each zone. Full details are provided in the 2007 WSP Reports.

Zone A

- Made Ground was encountered to a depth of 0.4m in BHA7 which is located on the boundary of Zone A and Zone C. The Made Ground comprised dark brown slightly sandy gravelly clay with brick, granite and flint gravel.

- River Terrace Deposits were encountered mainly on the eastern side of this area to 8m depth and were predominantly medium dense to dense orange brown sandy flint and chalk gravel, sand and gravel or gravelly sand with variable amounts of clay.
- Ampthill Clay was encountered beneath the River Terrace Deposits in the east or at shallow depth in the western part of this zone. A maximum depth of 8.2m was recorded but the base was not proven (thickness >6.9m). The strata was described as firm to hard grey or blue grey clay and occasionally mottled brown or orange brown with bands of siltstone and slightly sandy with selenite (gypsum) at some locations.

Zone B

- Made Ground was encountered to a maximum depth of 3.7m, which was in an earth mound (TPB108) and therefore not representative for this zone. Where made ground was encountered this was generally less than 1m in depth and was mainly associated with the former runway and infrastructure. This strata was highly variable and comprised clay with variable amounts of sand or sand with differing amounts of clay and gravel. The gravel included brick, concrete roof slate, glass, metal fragments, burnt timber. Several areas of deeper made ground (to 2.9m depth) were encountered to the south of this zone (outside the development application boundary) which were associated with the backfilling of former mineral extraction pits.
- River Terrace Deposits were encountered to depths of 7m bgl. This strata was encountered beneath the topsoil at the majority of locations. This was generally orange or brown with variable amounts of clay, sand and gravel.
- Ampthill Clay and Kimmeridge Clay was encountered beneath the superficial deposits but the depth of these strata were not proven. The Ampthill Clay was grey / blue with bands of light grey very weak to moderately strong siltstone at some locations. The Kimmeridge Clay was stiff to very stiff grey / blue clay with occasional mottled brown or yellow clay with bands of grey weak to moderately strong siltstone. Selenite crystals, pyrite and fossil shell fragments were observed.

Zone C

- Made Ground was encountered to a maximum depth of 2.7m bgl. This generally comprised granular sub-base beneath hardstanding including concrete slabs or granular reworked natural strata with flint, brick, concrete, clinker, coke, tarmac and cobbles of brick.
- The River Terrace Deposits were encountered to 7m bgl. This strata was variable in nature and was occasionally clayey gravelly sand, sand and gravel or sandy gravel interbedded with grey mottled orange sandy silt or clay. Gravel was flint or chalk. Locally organic material (wood fragments, organic clays/ silts / peat) was encountered.
- Soils from the Ampthill Clay and Kimmeridge Clay were as described above in Zone B.

Zone D

- Made Ground was encountered to a maximum thickness of 0.9m and comprised Soft to firm or firm dark brown sandy gravelly clay containing flint, chalk, brick and plastic sheeting or stiff reworked sandy clay
- The River Terrance Deposits were encountered to a depth of 5.0m and were highly variable in strength and colour but generally comprising clay with variable amounts of sand and flint and chalk gravel. The strata was occasionally granular in nature comprising sand with a variable gravel and clay content.
- Gault Clay was encountered on the southern part of the site to a depth of 0.9m and was described as soft to stiff grey occasionally mottled yellow or orange clay, Pyrite crystals and fossils present at some locations.

- Lower Greensand was encountered to a depth of 7m, but in some locations the depth was not proven. Variable in colour but generally orange, dark brown to dark grey, dark green / grey or dark green / brown. The strata comprises generally fine to medium or fine to coarse glauconitic and arenitic sand or poorly cemented sandstone with variable amounts of clay and gravel. The gravel was generally found to comprise fine to medium, sub-angular to subrounded flint and quartzite.
- Soils from the Ampthill Clay and Kimmeridge Clay were encountered near to the surface in the northern part of the site and are as described above in Zone B.

Cross sections across the zones are provided within the corresponding 2007 WSP Report (Appendix B).

2.4 Hydrogeology

The Environment Agency "What's-in-Your-Backyard" database indicates that the bedrock underlying the site is designated as unproductive strata. The superficial drift deposits underlying the site are designated with Secondary A aquifer status. These are described as "permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers." According to the Environment Agency database, the site is not located within a Groundwater Source Protection Zone.

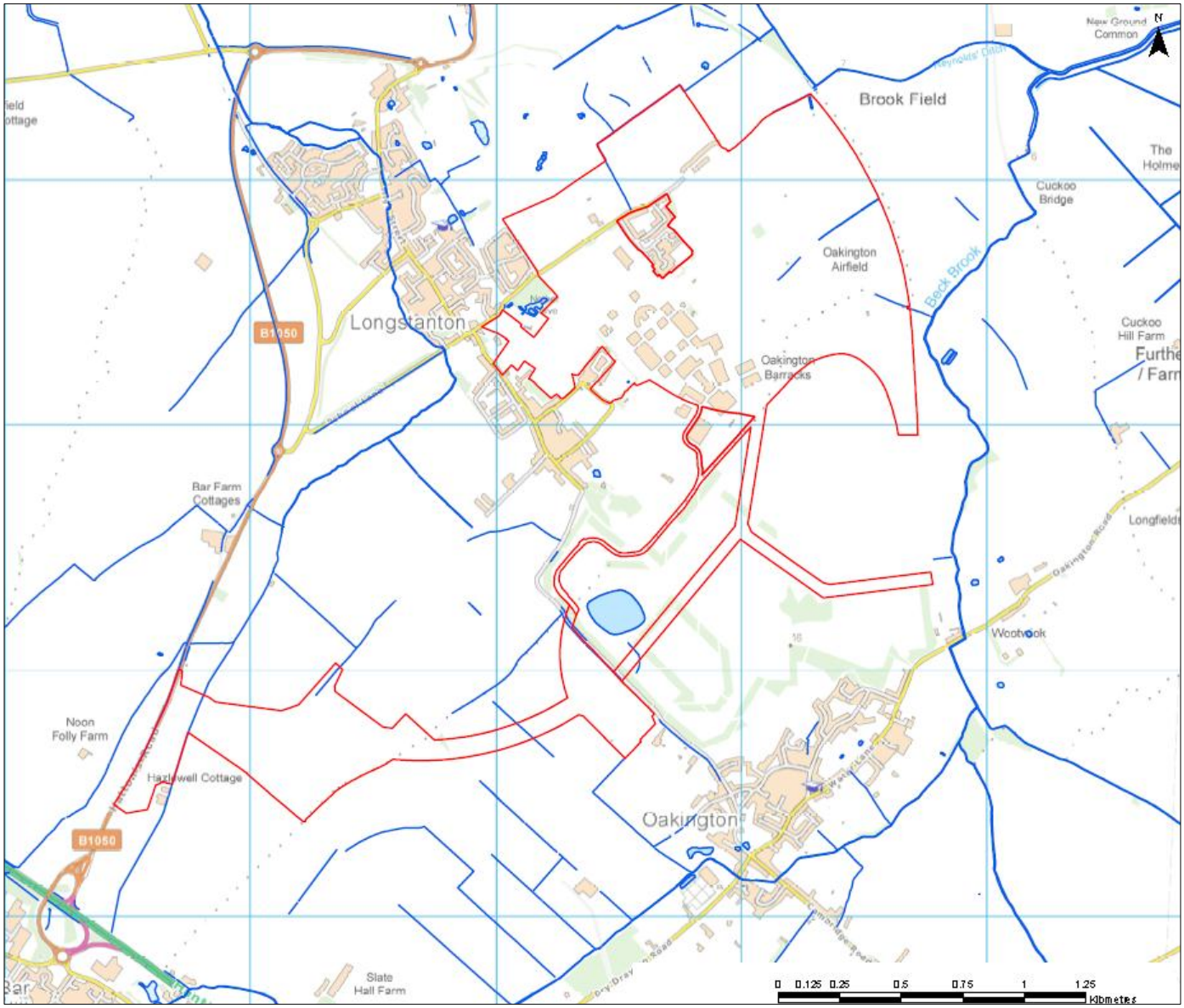
Groundwater flow across the site is thought to largely be contained within the sand and gravel lenses in the River Terrace Deposits. On the northern half of the site, groundwater flow is likely to be to the north and northeast and it is considered likely that groundwater is in continuity with Beck Brook to the east of the site.

2.5 Hydrology

There are multiple surface water features on or in close proximity to the site including a large pond (Military Lake) within the southern part of Zone B, 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.

Plan 4 below shows the surface water features across and in the locality of the application site.

Plan 4 Plan showing the existing surface water features



Legend

Water Features

Site Boundary

3 Previous Investigations

3.1 Entec (1999)

In 1999 Entec undertook a Phase 1 Desk Study and Phase 2 Intrusive Survey across Zones B and C. Information from these reports is detailed in the corresponding 2007 WSP Reports (Appendix B) including history of the zones and potential contaminative issues. Below is a brief summary of the findings of the completed investigations;

Zone B

- Included 59 trial pits and 2 boreholes including targeting earth mounds located on the airfield and areas of suspected made ground (infilled former gravel pits / dumping ground in bomb storage area).
- Infilled gravel pits comprised reworked natural strata with minor constituents of inert building rubble (maximum depth of 2.5m but generally less than 1m).

  In 4 pits (locations not stated) 20 gallon steel drums containing green hydrocarbon based substance were encountered along with broken glass, steel glass, asbestos sheeting and general refuse. Elevated TPH (5900mg/kg) was encountered in one of the trial pits where drums were located and PAH compounds were identified in the groundwater above screening values. It is unknown if this area was remediated. It is understood from WSP that they trial pitted in this area and found Made Ground but not any drums.
- Elevated inorganic compounds were identified in the vicinity of the sewage treatment works in the northern part of the zone, which may be due to sludge from this activity.

Zone C

- Included 34 trial pits and 6 boreholes including targeted investigation of former fuel storage and chemical storage areas.
- Hydrocarbon contamination (BTEX, chlorinated solvents and TPH) was identified in the vicinity of the MT Garages and Aircraft Hangar (Building 93 – southern part of Zone C). Visual and olfactory evidence of contamination was identified in excavations around the southern fuel installation (south of 93).
- Detectable concentrations of hydrocarbons were identified in the soils around the majority of the tanks on site, however concentrations were relatively low. A high TPH concentration (18,000mg/kg) was recorded in shallow soils in one location near to the MT garage. BTEX and chlorinated solvents was also present at this location.
- Hydrocarbon odours identified around the elevations of groundwater indicate that hydrocarbons have impacted the groundwater in this area.
- The report indicates that there is evidence for relatively localised hydrocarbon impact to soils and groundwater in the vicinity of the bulk fuel storage installation, flammable stores, vehicle maintenance garages and vehicle wash areas across the site.

3.2 WSP Investigations (2005 – 2007)

In the period between 2005 and 2007 WSP undertook ground investigations which were designed to provide information on the general ground and groundwater conditions at the site. Exploratory holes were positioned to provide general information across the site and holes were targeted in areas associated with Made Ground and potential contaminative uses (fuel, chemical storage etc / workshops, maintenance garages).

The following table details a summary of the investigation work undertaken across each zone, relative to the Phase 2 application, to provide an indication of the work undertaken.

Table 3.1 Summary of Investigation work undertaken across the zone

Investigation Method	Zone A*	Zone B	Zone C	Zone D
Cable Percussion	9	52	47	43
Window Sampling	-	20	51	-
Trial Pits	6	191	112	100
Cone Penetrometer Tests (CPT)	4	32	7	14

* Only includes sample locations which are relevant to the Phase 2 development

Plans showing the locations of the exploratory holes within each zone are included in the 2007 WSP Reports.

In Zone B due to the positive identification of live ordnance within the former bomb storage area in the northern part of this zone (see Section 4.2.7), investigation on this part of the zone was restricted until further ordinance survey work could be undertaken by RAF. It is understood (from WSP) that this was carried out but the information was passed to Gallagher Estates.

In Zone C access to the northern part of the site comprising the Oakington Immigration Reception Centre was restricted and the intrusive works was limited to the Technical Area which forms the southern part of the site. Additional survey work required to fill this gap is included in the strategy and actions section below. It should however be stated that given the previous use of this area i.e. former residential area of barracks it is considered likely that the contamination levels and other risks such as UXOs will be lower in this area.

Further information about methods used is provided in the 2007 WSP Reports.

Selected soil samples were analysed for a general suite of contaminants which included the following:

- Arsenic, cadmium, chromium, copper, nickel, lead, zinc, mercury, selenium, boron and sulphate
- Cyanide
- Speciated Polycyclic Aromatic Hydrocarbons (PAHs) and Phenols
- Total Petroleum Hydrocarbons (TPH) / Total Petroleum Hydrocarbons Criteria Working Group (TPHCWG)
- Sulphate and pH.

Targeted soil samples were also analysed for the following:

- Volatile Organic Compounds (VOCs) and Semi VOCs
- Radiological Screen
- Asbestos Screen
- Microbiological Analysis
- Explosive Suite.

Groundwater samples were analysed for the following contaminants:

- Arsenic, cadmium, chromium, copper, nickel, lead, zinc, barium, vanadium, mercury, selenium, and boron
- Cyanide
- Speciated PAHs and Phenols
- TPH / TPHCWG
- Sulphate, pH, chloride, ammonium, nitrate and nitrite.

Monitoring wells were installed within the cable percussive boreholes and window sample exploratory holes. Gas and groundwater monitoring was undertaken between February 2006 and October 2007 (12 visits) and the results are discussed in Section 6 of this report.

4 Soil Contamination Assessment

4.1 Human Health Risk Assessment

4.1.1 Soil Screening Values

The following sections detail the approach undertaken with regards to selecting the appropriate Soil Screening Values (SSVs).

At the first tier of risk assessment, "Tier 1", sometimes referred to as soil screening, or Generic Risk Assessment, the relevant scientifically based authoritative criteria to assess soils are the Soil Guideline Values (SGV) published during and post 2009, which were derived using the Contaminated Land Exposure Assessment (CLEA v1.06) model (Ref 5) by the Environment Agency. This report follows this approach. To date, SGV for eleven contaminants (arsenic, nickel, mercury, selenium, cadmium, benzene, toluene, ethylbenzene, xylene, dioxins, polychlorinated biphenyls, and phenol) have been published. Where SGV are not available Hyder has utilised the LQM/CIEH Generic Assessment Criteria (GAC) for Human Health (2009) and the EIC/AGS/CL:AIRE GAC 2009, derived in accordance with UK legislation.

An SGV (or GAC) represents a cautious estimate of concentration of contamination in soil at which there is considered to be no risk to human health or a minimal chronic (long term) health risk. This however, does not mean an unacceptable risk actually exists at the recorded concentrations – there may be site-specific conditions that prevent the risk reaching an unacceptable level. The SGV/GAC therefore provides a value of soil contamination above which triggers further actions that should be undertaken to make sure that human health is protected; such actions may be further investigation or simple forms of remediation or investment in detailed quantitative risk assessment. They are not statutory standards that must not be exceeded. Although an SGV is an authoritative, scientifically based value published by the Environment Agency, a GAC has no less science applied; it is however derived by a non-Environment Agency source.

Recently Category 4 Screening Levels (C4SLs) have been published with regards to the contaminated land regime under Part 2A of the Environmental Protection Act 1990 and are considered to represent low risk. Where appropriate the C4SL values have been used within the assessment. In the case of Lead, previously the withdrawn SGV (450mg/kg) has been utilised, however as a C4SL has been published, it is deemed more appropriate to use this value (200mg/kg) for the initial screen.

For organic contaminants SGVs/GACs are dependent on the Soil Organic Matter (SOM) content, with an increase in SOM corresponding with an increase in SGV/GAC. The SGV/GACs have been derived at 1%, 2.5% and 6% SOM, to correspond with low organic Made Ground (1%) and topsoil (6%) and intermediate material (2.5%). Accordingly, for conservatism, this assessment herein has been undertaken using SSVs calculated for a 1% SOM.

The majority of the Phase 2 development comprises residential development and therefore all the chemical results (from the WSP investigations) have been assessed for a residential with plant uptake scenario (i.e. residential properties with private gardens where food may be grown). This is the most conservative scenario for a residential development. It should be noted that if alternative development is proposed such as allotments, then the assessment should be reviewed as for some contaminants the SSVs are more stringent than for a residential scenario.

In general many of the contaminants were found to be below the relevant screening values. The section below highlights the contaminants that are elevated above the appropriate screening values. These are termed the "Contaminants of Concern".

4.1.2 Averaging Area

On the basis of the site wide history i.e. that the majority of the site was used as an airfield, for the initial screening process the whole site has been considered as one averaging area. All the data has therefore been assessed together against the appropriate SSVs.

4.2 Soil Assessment – Tier 1 Screening

The chemical results from the 2007 WSP Reports have been reviewed to assess the land quality across the site. Plans showing the locations of the exceedances are included in Appendix C.

All the data within Zones B, C and D and the data from exploratory hole locations within the Phase 2 development in Zone A has been assessed and in the tables below the exceedances have been presented for samples taken from locations within the Phase 2 application area.

4.2.1 Inorganics

The chemical results were assessed against the SSV for a residential with plant uptake land use (i.e. the most sensitive land use) and the majority of the determinands were not found to exceed the SSVs with the exception of those outlined below in Table 4.1. These are illustrated in Appendix C.

Table 4.1 Summary of contaminants above the SSVs for a residential with plant uptake scenario

Determinand	SSV	Range of Concs above SSV (mg/kg) *	No of Exceedances**	Location of Max Conc in Phase 2 application area ***
Arsenic	32	33- 45.7 (200)	3 (22)	TPB2 (TPD88J)
Vanadium	75	76-110 (139)	15 (15)	WSC43 (TPD998)
Lead	200+	330-1490 (755)	4 (4)	TPB2 (TPB177)
Nickel	130	165	1	TPB2

+ C4SL value for Lead

* concentration in brackets is the maximum concentration recorded outside the Phase 2 application area

** value in brackets is the number of exceedances outside the Phase 2 application area.

*** location in brackets is the location of the maximum concentration recorded outside the Phase 2 application area

Within the application area, there are exceedances of 4 determinands. Vanadium has the most exceedances which are scattered across the application site, with 8 in the main development area and 7 within the off-site infrastructure area. Whilst these are generally within the shallow topsoil / made ground layer, some elevated results are encountered within the natural soils at depth (e.g. TPC5 at 1.4m and TPC71 at 3.4m depth) in off-site infrastructure areas of the site. This may indicate that vanadium is naturally occurring in the soils within the area at concentrations above the SSV.

The maximum arsenic, lead and nickel concentrations recorded were encountered in the shallow topsoil (river terrace deposits) layer of TPB2 which is located in the north eastern corner in the vicinity of the former sewage works. There were no obvious visual signs recorded within the log

which would indicate the elevated results however, the contamination may be associated with previous operation of the former sewage works.

It is noted that there are a cluster of elevated arsenic concentrations within Zone D (outside the development area). These elevations were encountered within the natural soils and therefore similarly to vanadium this may indicate that arsenic is naturally occurring in this area in concentrations above the SSV.

4.2.2 Organics

The chemical results were assessed against the SSV for a residential with plant uptake land use (i.e. the most sensitive land use) and the determinands which were found to exceed the SSV are outlined below in Tables 4.2 – 4.4. These are illustrated on in Appendix C.

TPH (Total Petroleum Hydrocarbons) are hydrocarbons (hydrogen and carbon compounds) that are found in crude oil. This includes petroleum products, diesel range organics and mineral oils. PAH (Polycyclic Aromatic Hydrocarbon) compounds are also carbon and hydrogen compounds but are composed of multiple aromatic rings. These compounds are found in oil, coal and tar deposits and generally produced from the incomplete combustion of organic matter.

TPH

Table 4.2 Summary of TPH above the SSVs for a residential with plant uptake scenario

Determinand	SSV	Range of Concs above SSV (mg/kg)*	Number of Exceedances**	Location of Max Conc in Phase 2 application area ***
TPHC8-10	19	271 - 339	2	TPC19 / TPC24
TPHC10-12	93	770	1	TPC24A
TPH C12-16	140	541 – 1320 (260)	3 (1)	TPC16A (TPD87)
TPH C16-21 / C16-24	250	698 – 3000 (286)	6 (1)	TPC19 (TPD87)
TPH C21-35 / C24-40	890	923 – 2430 (1400)	8 (3)	TPC19 (TPC38)
m/p Xylene	42	43.3 (74.2)	1 (1)	TPC50B (TPC78A)

* concentration in brackets is the maximum concentration recorded outside the Phase 2 application area

** value in brackets is the number of exceedances outside the Phase 2 application area.

*** location in brackets is the location of the maximum concentration recorded outside the Phase 2 application area

PAH Compounds

Table 4.3 Summary of PAH above the SSVs for a residential with plant uptake scenario

Determinand	SSV	Range of Concs above SSV (mg/kg)*	Number of Exceedances**	Location of Max Conc in Phase 2 application area ***
Benzo(a)pyrene	0.83	1 – 14 (89.50)	22 (22)	TPB22 (TPB179B)
Benzo(a)anthrance	3.1	5.5 - 19 (79.9)	9 (13)	TPB22 (TPB179B)
Chrysene	6	6.5 -18 (85.2)	8 (9)	TPB22 (TPB179B)
Benzo(b)fluoranthene	5.6	6.6 - 23 (70.6)	6 (7)	TPB92 (TPB179B)

Determinand	SSV	Range of Concs above SSV (mg/kg)*	Number of Exceedances**	Location of Max Conc in Phase 2 application area ***
Benzo(k)fluoranthene	8.5	9.2 - 9.4 (65.9)	2 (5)	TPB22 (TPB179C2)
Indeno(123cd)pyrene	3.2	5.2 – 7.3 (52.8)	6 (14)	TPB92 (TPB179C2)
Dibenzo(ah)anthracene	0.76	1 – 1.9 (10.8)	6 (8)	TPB92 (TPB179B)
Naphthalene	1.5	2.36- 8.02 (8.6)	3 (3)	WSC3 (TPB179B)
Phenanthrene	92	(132.9 - 237.4)	(2)	Off site TPB179B
Benzo(ghi)perylene	44	(45.2 - 48.5)	(2)	Off site TPB179C2

* concentration in brackets is the maximum concentration recorded outside the Phase 2 application area

** value in brackets is the number of exceedances outside the Phase 2 application area.

*** location in brackets is the location of the maximum concentration recorded outside the Phase 2 application area

Volatile Compounds

Table 4.4 Summary of VOC above the SSVs for a residential with plant uptake scenario

Determinand	SSV	Range of Concs above SSV (mg/kg)*	Number of Exceedances**	Location of Max Conc in Phase 2 application area ***
124 Trimethylbenzene	0.35	0.89 – 8.44 (45.1)	5 (3)	WSC3 (TPC55)
112 Trichloroethane	6.2	14.3 (17.2)	1 (2)	WSC12 (TPC54)
1122 Tetrachloroethane	1.4	9.17 – 26 (114)	3 (2)	WSC12 (TPC54)
1112 Tetrachloroethane	0.9	58.2 (2.23)	1 (1)	WSC3 (TPC32)

* concentration in brackets is the maximum concentration recorded outside the Phase 2 application area

** value in brackets is the number of exceedances outside the Phase 2 application area.

The majority of organic contamination is located in Zones B and C. Zone C is the location of the fuel storage (including underground tanks) and where vehicle maintenance was undertaken. This is therefore the potential source of the organic contamination.

The TPH contamination encountered is generally from the heavier fractions such as C16 – 21 and C21 – 35. This would correspond with mineral oil / lube oil which is likely to have been used with regards to vehicle maintenance.

Benzo(a)pyrene was found to be elevated across Zones B and C with approximately half of the exceedances located within the proposed development area. The maximum concentrations of PAH compounds were found in either TPB22 or TPB92. TPB22 is located in the northern part of Zone B near to the former bomb storage area, whilst TPB92 is located near to the boundary with Zone C. On review of the logs for both locations, the samples were taken from the Made Ground strata (0.3m depth). In TPB22 the Made Ground comprised of gravel of brick, and concrete. No ash material was noted in either location.

It is noted that there are several exceedances of PAH compounds where located in the south eastern corner of Zone B which is outside the application area. These are associated with a Made Ground in the areas of the infilled gravel pits.

A C4SL has been published for Benzo(a)pyrene which is 5mg/kg for a residential with plant uptake scenario. For comparison, on review of the results for this site, 26 of the 44 exceedances had concentrations below this value.

In general Volatile Organic Compounds (VOC) contamination was below the limit of detection, however exceedances of some of the VOCs were detected in Zone C. These are localised around buildings.

4.2.3 Asbestos Screening

Soil samples from across the zones were analysed for asbestos fibres. In the following four locations fibres were detected (see Appendix C);

- TPB1C (0.4m) – Amosite (free fibres <0.1%);
- TPB1D (0.4m) – Crocidolite, Amosite, Chrysotile (Insulation and free fibres <0.1%);
- TPC77D (0.4-0.5m) - Chrysotile fibres (Bitumen <0.1%);
- WSC39 (0.2-0.6m) Chrysotile fibres (free fibres <0.1%);

The samples from TPB1C and TPB1D are within the proposed development area, whilst the other two sample are from locations outside of the main development area, but near to a proposed road within the Off- Site Infrastructure. On review of the logs, the samples from TPB1C and TPB1D were from the shallow Made Ground strata. No asbestos was recorded within the Made Ground. It is noted that an asbestos tile fragment is recorded in the Made Ground from TPB1B.

As asbestos fibres have been encountered it is likely that localised fibres may be present within soils across the application site.

4.2.4 Chemical Weapons

Ten soil samples from Zone B were analysed by BAE Systems for chemical weapon (S-Mustard) residues. All the results are recorded as below the limit of laboratory detection.

With regards to the S-Mustard analysis procedure, this is a two staged analysis. In the initial stage, 5 standards of different concentrations of H, Q and T forms of S-Mustard are analysed (these are control samples) along with the soil sample. Concentrations are detected within the standard (control) samples (as would be expected), however in all cases the soil sample concentrations are recorded as <1mg/kg i.e. below the limit of detection. Further analysis is undertaken in the second stage where individual compounds are identified via peaks on a chromatogram. In the 10 samples analysed 2 compounds (1,4-Thioxane and 1,4-Dithiane) are identified but the concentrations are recorded at less than the limit of laboratory detection (<0.5mg/kg).

These results indicate that chemical weapon residues and in particular S-Mustards are not present at detectable concentrations within the samples and therefore are not considered to be a concern with regards to human health.

4.2.5 Explosives

Soil samples from Zones B (10) and C (8) were analysed by BAE Systems for an explosive suite. All the results were below the limit of detection and therefore the risk from explosive residues do not warrant further consideration.

The presence of UXO on-site is known however and these hazards require mitigation. Please refer to section 4.2.7 below.

4.2.6 Radioactivity

Two soil samples (TPB83 0.15m / TPB83 0.35m) were tested for radioactivity by Health Protection Agency (HPA). TPB83 is located on the southern boundary (within Zone B) of the Phase 2 application area and was investigated as it was identified as a small burning pit. Sandstone flagstones were located beneath the turf covering the pit which contained ash, burnt dials and metal fragments. This pit was terminated and the flagstones put back in place to reduce the risk from radiological contamination. No remediation was undertaken in this area.

The samples were analysed for the presence of the most common gamma emitting radionuclides found in thorium 232 and uranium 238 decay series using a shielded high purity germanium detector linked to a multichannel analyser.

The conclusions from HPA indicated that the material at 0.15m may be subject to the requirements of the Ionising Radiation Regulations 1999 (IRR) and its use should be discussed with a Radiation Protection Adviser. This is due to a positive activity result with Actinium-228 at 0.2 +/- 0.1 Bq/g and Bismuth-214 at 3.1 +/- 0.6 Bq/g. The deeper sample is not subject to the requirements of the IRR due to a lower activity recorded.

It is understood that a geophysical survey for the site was undertaken which identified other potential burning grounds across the site. This information has not been available for review.

4.2.7 UXO

During the WSP ground investigations all excavations were assessed for unexploded ordnance. Trial pits were scanned using handheld magnetometers under the supervision of an Explosive Ordnance Disposal Engineer from Bactec International Ltd and boreholes / exploratory holes were cleared using Bactec downhole intrusive magnetometer rig.

Within Zone B, the following unexploded ordnance was encountered

- a 500lb “practice bomb” prior to excavation of trial pits in the northern part of the bomb storage area (northern part of Zone B) – this was excavated and deemed safe and taken away by RAF Explosive Ordnance Division for disposal
- a 500lb “live bomb” which was made safe by controlled explosion. On reinstatement of blast crater, two further 1000lb “live bombs” were identified which resulted in a second controlled explosion.

Due to the positive identification of live ordnance within the former bomb storage area, investigation on this part of the site was terminated until further survey work was undertaken by RAF.

The HCA has employed specialist consultancy Zetica to undertake further work which is detailed below.

Zetica has produced a SiteSafe UXO Risk Mitigation Plan for the whole of the Northstowe development.

Several potential sources of UXO hazard have been considered and there is the potential for ordnance to range in size from small arms ammunitions to large unexploded bombs (UXBs). Zetica’s study suggested that any anticipated hazards are likely to be at shallow depth, resulting from munitions disposal during World War II and post war training. Whilst the majority of

the site is considered to be a low hazard level, there are specific areas which are given a moderate or a high hazard level rating.

The main findings of this report are summarised as follows;

- There are no records of bombing or military activity on the Site during World War One (WWI).
- During World War Two (WWII), the Site was occupied by RAF Oakington, an operational bomber airfield.
- There are 12No. recorded air raids for RAF Oakington during WWII and more than 30No. High Explosive (HE) bombs fell on the Site in low intensity raids – all bombs were accounted for.
- For the geology of the Site, estimated average maximum bomb penetration depths vary between 2.5 metres (m) and 12.5m, depending on the exact nature of the underlying strata and weight of the bomb.
- In 1975, RAF Oakington was handed over to the Army as Oakington Barracks. Part of the Site was used as a dry training area.
- In 2005, 4No. British UXBs were discovered on the Site and disposed of by the RAF.
- Small arms ammunition, pyrotechnics and other training ordnance have been found on the Site during subsequent Explosive Ordnance Clearance (EOC) work.

Zetica's UXO Risk Mitigation Plan is included in Appendix D. The purpose of this report was to discharge part a) of Planning Condition 10 on the outline planning permission (S/0388/12/OL) in order for development to commence within the Phase 1 boundary but provides details of the potential risks across the whole site and provides options in order to mitigate them. Typical UXO risk mitigation methods are detailed in Table 4.5 below.

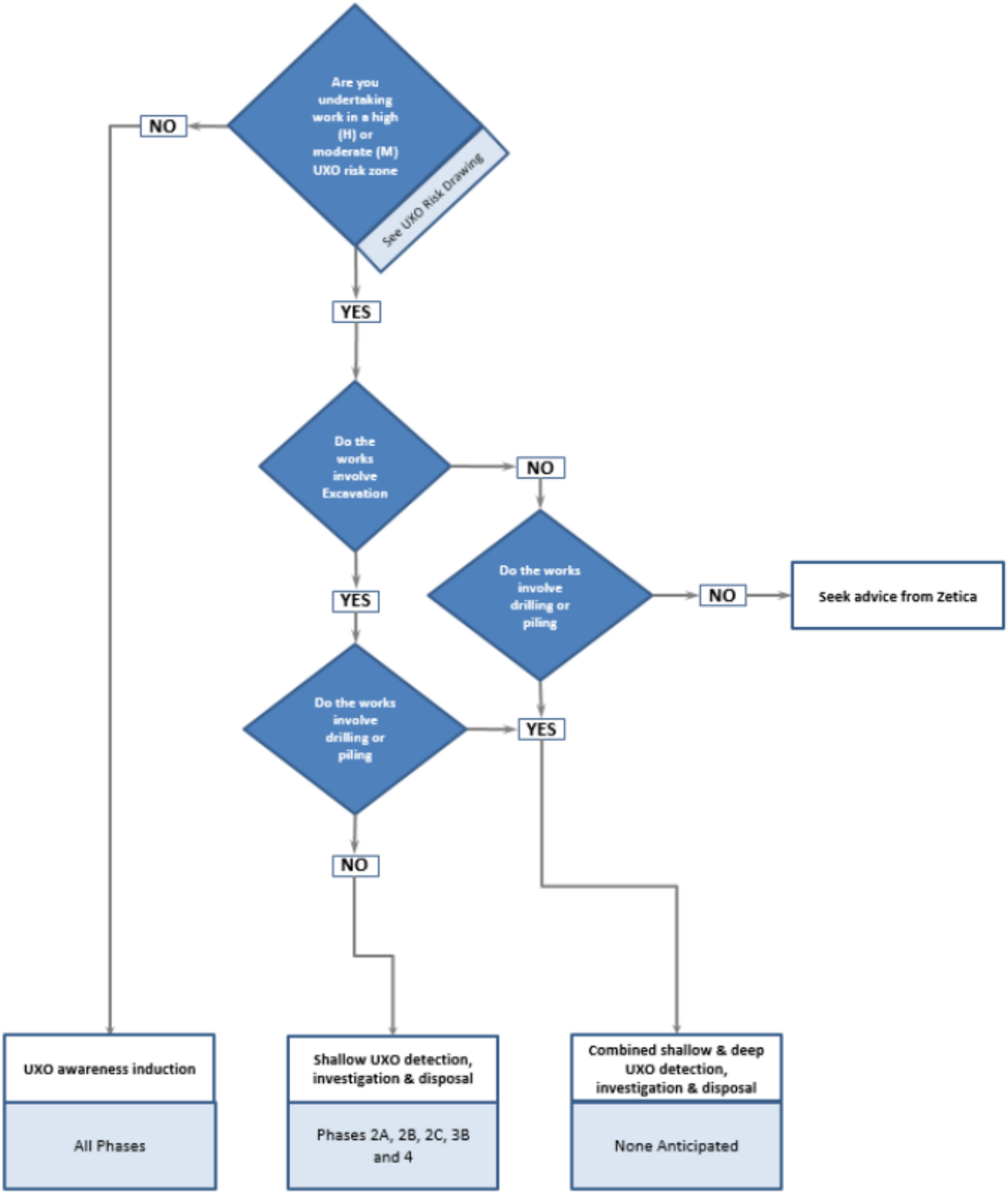
Table 4.5 Potential Risk Mitigation Methods

Potential UXO Hazard	Typical UXO Risk Mitigation Method
Shallow-buried UXBs	Non-intrusive magnetic survey, target investigation and EOD
Land service ammunition from disposal/Army training	Non-intrusive electromagnetic survey, target investigation and EOD
Small arms ammunition	Consideration of development layout, confidence scrape and application of cover solution, where appropriate.

UXO awareness inductions will be included as part of any standard site induction process throughout all Phases of the Northstowe development.

The flow chart provided below (Plan 5) shows the recommended approach to the risk mitigation plan for the anticipated UXO and site activities.

Plan 5 UXO Risk Mitigation Plan



5 Controlled Waters Assessment

5.1 Water Quality Standards (WQS)

To assess the groundwater in terms of its potential as a source of contamination, each contaminant concentration has 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).

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.

5.2 Groundwater Assessment

Groundwater samples from Zone A (BHA6, BHA7 and BHA10) and across Zones B and C have been compared to the relevant WQS. Generally the concentrations were below the water screening values with the majority of the results were below the limit of detection.

5.2.1 Inorganics

The following tables indicate where inorganic results have been encountered which are above the relevant DWS and EQS values. These are illustrated in Appendix E.

Table 5.1 Summary of Inorganics above the WQSs

Determinand	WQS (DWS/ EQS) ug/l	Range of Concs above WQS	Number of Exceedances	Location of Max Conc in Phase 2 application area
Copper	2000 / 10	13-46.9	25	BHA10
Nickel	20 / 20	23-180	10	BHD31
Boron	1000 / 2000	1380 - 1860	2	BHB1
Zinc	3000 / 75	87	1	BHD31
Chloride	250 mg/l	447-1150	2	BHA10

The above results indicates that generally inorganic determinands have concentrations below the appropriate WQS. With regards to Copper and Nickel, these determinands have stringent EQS values and whilst elevated values have been recorded in a number of monitoring wells, gross contamination is not indicated.

The exceedances are illustrated in Appendix E. This shows that the copper exceedances are spread across the proposed development site, whilst the majority of the nickel results are located in a cluster in the southern half of the site. The exploratory hole locations to the south are within natural soils and therefore it is likely that the nickel and zinc concentrations in the groundwater are naturally above the WQS.

Boron and Zinc are elevated against one of the WQS values in one sample location. Copper and Chloride are both elevated in BHA10 which is on the boundary of the Phase 2 development and is near to the bomb storage area.

5.2.2 Organics

The following tables indicates where organic results (TPH – total petroleum hydrocarbons, PAH – Polycyclic Aromatic Hydrocarbons, BTEX – Benzene, Toluene, Ethylbenzene and Xylene which are compounds found in petrol) have been encountered which are above the relevant DWS and EQS values. These are illustrated in Appendix E.

TPH / BTEX

Table 5.2 Summary of TPH above the WQS

Determinand	WQS (DWS/ EQS)	Range of Concs above WQS (mg/l)	Number of Exceedances	Location of Max Conc in Phase 2 application area
Ali C5-6	0.010	0.02-0.15	5	WWC21
Ali C6-8	0.010	0.05-3.9	5	WWC17#1 / WWC18
Ali C8-10	0.010	0.57-0.62	3	WWC17#1 / WWC18
Ali C10-12	0.010	0.03-1.2	4	WWC3
Ali C12-16	0.010	0.02-47	4	WWC3
Ali C16-21	0.010	0.02-3.9	4	WWC3
Ali C21-35	0.010	0.03-0.22	9	WWC23
Aro 6-7	0.010	0.038	1	WWC21
Aro C8-10	0.010	0.02-0.93	4	WWC17#1 / WWC18
Aro C10-12	0.010	0.05-1.8	4	WWC3
Aro C12-16	0.010	0.06-17	3	WWC3
Aro C16-21	0.010	3.2	1	WWC3
Aro C21-35	0.010	0.2-0.82	2	WWC3
C8-16	0.010	0.209-0.217	2	BHB18
C24-40	0.010	0.168-0.221	2	BHB18
Benzene	1 /10	1.6 – 83 (µg/l)	4	WWC17#1
m/p xylene	500 / 30	55 (µg/l)	1	WWC17#1

PAH Compounds

Table 5.3 Summary of PAH above the WQS

Determinand	WQS (DWS/ EQS)	Range of Concs above WQS (µg/l)	Number of Exceedances	Location of Max Conc in Phase 2 application area
Acenaphthene	10	120	1	WWC3
Benzo(a)anthrance	0.1	41	1	WWC3
Chyrsene	1	33	1	WWC3
Benzo(b)fluoranthene	0.1	30	1	WWC3
Naphthalene	10/2.4	250	1	WWC3
Phenanthrene	10	240	1	WWC3
Pyrene	10	120	1	WWC3
Fluoranthene	1	150	1	WWC3
Fluorene	10	74	1	WWC3
Anthracene	10	58	1	WWC3

Volatile Compounds

Determinand	WQS (DWS/ EQS)	Range of Concs above WQS (µg/l)	Number of Exceedances	Location of Max Conc in Phase 2 application area
Vinyl Chloride	0.5	220	1	WWC22#2
1,1 Dichloroethane	3	249	1	WWC22#2
Dibenzofuran	-	600		WWC3
1, 4 dichlorobenzene	300	2200	1	BHB56
Phenol	0.05/0.007 7 mg/l	0.14	1	WWC22#2

TPH contamination has been recorded in the groundwater across the site. As illustrated in Appendix E these are concentrated in Zone C. This would correspond with the soil contamination that was encountered mainly within this area. The drawing illustrates that aliphatic hydrocarbons are encountered in the majority of locations, with aromatic hydrocarbons only elevated in a number of monitoring wells. TPH exceedances have been encountered in the eastern part of the site in BHB13 and BHB18 which does not correspond with soil exceedances. Both these monitoring wells were in natural strata and the logs did not indicate any hydrocarbon contamination present.

With regards to several TPH fractions and PAH compounds, location WWC3 has recorded the maximum concentrations. This is located on the eastern boundary of Zone C and therefore may indicate groundwater migration of contamination in a north easterly direction. In the log for this location a hydrocarbon and solvent odour was noted between 0.2-4.0m within the Made Ground (to 1m depth) and River Terrace Deposit.

Dibenzofuran was recorded within the groundwater, however this is insoluble in water and therefore the concentrations are likely to be due to sediment in the sample rather than dissolved concentrations.

6 Ground Gas Assessment

6.1 Introduction

To establish the ground gas regime for the site, the ground gas monitoring undertaken by WSP has been reviewed. As the development is mainly taking place on Zones B and C, the data from these areas has been assessed. Monitoring was undertaken over 13 visits between February 2006 and October 2007. In Zone A, 3 monitoring wells are located within the Phase 2 area (BH6, 7 and 10) in Zone B 34 locations were monitored, with 41 locations in Zone C.

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.

6.2 Ground Gas Monitoring Results

Below is a summary of the range of ground gas monitoring results recorded during the monitoring rounds and full details can be found in the 2007 WSP Report for each zone.

Table 6.1 Summary of ground gas monitoring results

	Range of Results		
	Zone A	**Zone B**	**Zone C**
Methane (%v/v)	0.0-0.1	0.0-0.2 (BHB34)	0.0-**55.5** (WWC17(1))
Carbon Dioxide (%v/v)	0.0-7.8	0.0-7.0 (BHB50)	0.0-**10.8** (WWC17(1))
Oxygen (%v/v)	11.7-21.4	1.9-21.5 (PTM10)	0.1-21.6 (WWC3)
PID (ppm)	-	-	0 - 4.5 (WWC4)
Carbon Monoxide (ppm)	0-5	0 – 13 (WWB5)	0.0 - 6 (BHC23)
Hydrogen Sulphide(ppm)	0	0 – 12 (BHB34)	0-1 (WWC15(1) / WWC10)
Ground Gas Flow (l/h)	-0.8-**13 (BHA7)**	-6.7 – **6.4** (PTM10)	-3.7-3.2 (WWC22(1))
Atmospheric Pressure	997-1026	997-1028	993-1026

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

Methane concentrations are generally found to be low across the proposed development area, however in one location in Zone C WWC17, high concentrations (37.5-55.5% v/v) have been recorded. It is noted that this monitoring well was only monitored on 3 occasions and on each occasion the flow rate at this well was below detection of the monitor.

Within Zone C the next maximum result recorded during the monitoring rounds was 8.2% v/v which was in WWC3. This location recorded the maximum methane result in a number of monitoring rounds (range 1.5-8.2%v/v).

Likewise for carbon dioxide in Zone C the highest reading was from WWC17(1) with the next highest reading during the same visit at 4.9% v/v in WWC4. Generally WWC3 provided the maximum carbon dioxide readings in Zone C. The carbon dioxide readings across Zone B were generally below 5% v/v with only 2 maximum readings above this value.

On review of the logs for WWC17 and WWC3, there is no potential source for such high levels of ground gases. Made Ground is present in WWWC17 to a depth of 2.7m but comprises slightly sandy gravelly clay with gravel of brick and flint and in WWC3 Made Ground is to 1m depth and is gravelly sand with flint gravels.

It is however noted that in these locations (WWC17(1) and WWSC3) hydrocarbon odours are noted on the logs and detectable concentrations of hydrocarbons are recorded in the groundwater as discussed in Section 5. The hydrocarbon concentrations may have caused false readings on the gas monitor.

Flow readings are generally low with the majority of the readings below 1l/hr. The highest rate was recorded in Zone A on one occasion.

Low levels of carbon monoxide and hydrogen sulphide have been recorded on a number of occasions but in the majority of locations they were recorded below the detection limit of the monitor.

6.3 Hazardous Ground Gas Assessment

6.3.1 Carbon Dioxide and Methane

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. 6) 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 %)

Initially the GSVs for each Zone have been calculated using the maximum readings detected within each Zone and then to illustrate the worst case scenario across the whole site the GSV for the maximum readings taken from the site irrespective of Zone has been calculated. A summary of the GSVs are detailed in the table below along with the corresponding traffic light scenario.

Table 6.2 Summary of the calculated GSVs

Gas	GSV / Traffic Light			
	Zone A	Zone B	Zone C	Site Wide
Methane	0.013 / Green	0.0128 / Green	1.776 / Red	7.215 / Red
Carbon Dioxide	1.014 / Amber 1	0.448 / Green – Amber 1	0.345 / Amber 1 – Amber 2	1.404 / Amber 1 – Amber 2

The GSVs in the table above illustrate the different scenarios present across the proposed development site. In Zones A and B which is mainly open land a Green or Amber 1 scenario is appropriate based on the gas monitoring to date. However in Zone C where the highest readings were encountered a red scenario is appropriate for the methane and Amber 1 / Amber 2 for the

carbon dioxide readings. This is the same for the site wide scenario. It should be noted that this is not a wide spread issue and only concerns a few borehole locations.

For a Green scenario the risk is considered to be low and gas protection measures are not considered necessary. For Amber 1 / Amber 2 scenario gas protection measures are required in new properties such as a membrane and ventilated sub floor void. For a Red scenario, the CIRIA guidance states that standard residential housing would not normally be acceptable without further gas risk assessment and / or possible mitigation measures (i.e. remediation) to reduce the source of gas.

It is noted that the gas monitoring used for the above assessment was undertaken between 2006 and 2007. Further gas monitong is required to refine the above assessment and substantiate the findings.

7 Conceptual Model – Contaminant Linkages

7.1 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 E.

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.

7.2 Contaminant Sources

Based on the chemical data presented in the WSP Reports and the assessment against SSVs for a residential with plant uptake scenario the following determinands have been identified to be contaminants of concern;

Soils

- Inorganics – arsenic, vanadium, lead and nickel;
- Organics – benzo(a)pyrene and other PAH, TPH, Xylene, VOC;
- Ground Gases;
- Asbestos;
- Radiological;
- UXO (see Zetica's report);

Groundwater

- Inorganics – copper, boron, zinc and nickel
- TPH, PAH, Phenol, VOC

7.3 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. 7) 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 7.1 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.

7.4 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 and this has been illustrated on conceptual drawings which follow each table.

It should be noted that risks to construction workers have not been considered within the assessment below as 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 (2007) or any other relevant guidance.

Table 7.2 Summary of Contaminant Linkages – Residential with plant uptake scenario

CL No.	Contaminant Source	Sensitive Receptor	Pathway	Hazard (Severity)	Likelihood	Potential Risk	Comments
CL1	Inorganic contaminants (arsenic, lead, vanadium, nickel), PAH Compounds including benzo(a)pyrene (BaP), TPH, xylene and VOC in Made Ground and shallow Natural Soils	Human Health	Ingestion / Inhalation / Dermal Contact / Veg uptake	Chronic damage, carcinogenic compounds (**Medium to High**)	**Likely** Contaminant concentrations have been found to be elevated. For a residential scenario 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 such near surface soils if no remediation/mitigation is undertaken.	**Moderate to High**	Contamination has been encountered in the near surface soils. The level of remediation / mitigation required will depend on the overall design of the development but some basic cover protection is warranted, focused in soft landscaping areas.
CL2		Controlled Waters (Groundwater and Surface water)	Leaching and migration into water environment	Reduction of water quality, although unlikely to be a potable resource. (Low-**Medium**)	**Likely.** Exceedances of WQS were recorded in the groundwater analysis undertaken. This indicates that contaminants are available if infiltration occurs.	**Moderate**	Contaminants concentrations have been encountered in the groundwater especially with regards to TPH. It is unlikely that large scale remediation will be required, but localised water treatment within / around historic structures / service drains / tanks etc is likely.
CL3		Buildings / Services	Contact of contaminants with buildings and structures (excluding potable water supply pipes)	Damage to structures (**Mild**)	**Unlikely.** Identified contaminants are unlikely to cause significant damage to buildings. Contamination is not widespread across the site.	**Very Low**	None
CL4	Asbestos	Human Health	Inhalation of fibres	Chronic damage, carcinogenic compounds (**Medium**)	**Low to Likely.** Asbestos fibres have been detected in sample locations (only 4 though) within the 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.

CL No.	Contaminant Source	Sensitive Receptor	Pathway	Hazard (Severity)	Likelihood	Potential Risk	Comments
CL5	Radioactive Materials	Human Health	Contact with soils	Chronic damage (**Medium**)	**Likely.** Radioactive material was encountered in shallow soils in one location (TPB83) where a burning pit was encountered. It is therefore considered likely that contact could be made with this material (and other similar material if encountered) if the soil is disturbed in this area. Subject to RPA assessment.	**Moderate**	Migration / remedial action will be required prior to development to ensure the risk is mitigated. Consultation with Radiation Protection Adviser must be sought as scheme develops.
CL6	Ground Gases (methane and carbon dioxide - on-site source)	Human Health	Inhalation in confined spaces	Asphyxiation (**Severe**)	**Low to Likely (localised).** Concentrations of methane and carbon dioxide, occasionally very elevated, were recorded in areas across the site. Based on the current information, the risk to residential end users is considered to be low increasing to likely where elevated concentrations have been detected.	**Moderate to High**	Based on the ground gas monitoring data to date, ground gas precautionary measures (traffic light situation Green / to red) are likely to be required in proposed residential development which will mitigate the risk to receptors on site.
CL7		Buildings (on-site)	Accumulation in confined spaces	Explosion (**Severe**)	**Low to Likely (localised).** A maximum methane concentration of 55.5% v/v has been detected on site in one location, with much lower concentrations in other areas. Whilst the likelihood is generally considered to be low across the site, in localised areas this may increase to likely.	**Moderate to High**	Prior to development further ground gas monitoring (in line with CIRIA guidance) should be undertaken to refine ground gas regime.
CL8	Elevated inorganic contaminants (copper, nickel, boron, zinc) and TPH fractions (Aliphatic & Aromatic), PAH compounds, VOC	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.

8 Outline Remedial Strategy

Below is an outline of the potential remedial options that may be required with regards to the re-development of the site. Prior to development a detailed remedial strategy should be prepared and approved by the local authority.

The Phase 2 development site covers a large surface area and this should be utilised to the full when the detailed remedial strategy is prepared 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.

8.1 Investigations / Monitoring

Extensive investigations have been undertaken across the Phase 2 development area and the off-site Infrastructure area. However there are some areas which were not investigated previously due to access constraints. These are mainly the northern part of Zone C which was occupied by the Oakington Immigration Centre and the area around the bomb storage to the north of Zone B. These areas require investigation and risk assessment using current guidance prior to development to establish the land quality with regards to soils, groundwater and ground gases. If contamination is encountered which is considered to be unacceptable for the proposed development, remediation will be undertaken to ensure that the areas are suitable for use.

As detailed previously in this report, groundwater and gas monitoring was undertaken during the WSP investigations. Hyder has no reason to doubt the adequacy or methodology of this monitoring. However given the passing of time since this work was done in 2006/7, further monitoring will be needed as part of the detailed design process to better establish land gas and groundwater conditions. This should be undertaken in tandem with the above mentioned gap analysis investigation.

8.2 Contamination – Soils

8.2.1 Inorganic

Elevated inorganic contaminants (arsenic, vanadium, lead and nickel) were encountered within the proposed development zone. These were generally found to be in the shallow soils and therefore could pose an unacceptable risk to site end users.

Remedial measures will be undertaken in these areas to ensure that the risk to site end users is reduced to an acceptable level.

The remedial action undertaken will depend on the final design of the proposed development but is likely to take the form of the following;

- Removal of hotspot contamination and import of suitable “clean” material. These hotspots may be delineated by future gap analysis investigation or could be contained within historic structures such as those associated with the sewage works.
- Introduction of a cover layer system in areas of soft landscaping such as gardens / allotments and open spaces. The depth of cover is likely to be between 300-600mm depending on the location of the area. This should follow BRE 465 Guidance. Whether or not the cover system is required in all soft landscaped areas is subject to further gap analysis investigation.

It is noted that vanadium and arsenic were found to be above the SSV in natural soils and therefore these detereminands may naturally occur above this concentration in this area. This should be discussed with the Contaminated Land Officer to determine if higher SSV can be adopted for the development.

8.2.2 Organic

TPH / VOC / Tank Removal

TPH and localised VOC contamination has been encountered within the proposed development area. This was mainly within Zone C which is the location on the former fuel storage (including underground fuel storage tanks) and vehicle maintenance and therefore it is likely that these previous uses are the source of the contamination. It should be noted that whilst contamination was encountered, it was not found to be gross.

Remedial action will be undertaken to reduce the risk to site end users.

Prior to development all the underground fuel storage tanks will be removed or otherwise decommissioned and the surrounding soils will be validated to ensure that residual contamination is removed from site. This process is likely to remove much of the TPH contamination encountered. Other hotspot areas will be remediated by appropriate methods such as in-situ or ex-situ bioremediation depending on the level of contamination or by excavation and removal to a suitably licensed landfill site / treatment centre.

PAH

Benzo(a)pyrene and other PAH compounds have been encountered in shallow soils across the site and a contaminant linkage has been identified. The remedial action undertaken will depend on the final design of the proposed development but is likely to take the form of the following ;

- Removal of hotspot contamination and import of suitable “clean” material
- Introduction of a cover layer system in areas of soft landscaping such as gardens / allotments and open spaces. The depth of cover is likely to be between 300-600mm depending on the location of the area. This should follow BRE 465 Guidance. Whether or not the cover system is required in all soft landscaped areas is subject to further gap analysis investigation.

8.2.3 Asbestos

Asbestos fibres have been encountered within soils in two sample locations (TPB1C and TPB1D) within the proposed development area. These are within shallow soils (0.4m depth) and would pose an unacceptable risk to site end users. This area will be remediated / validated prior to development. This will involve the excavation of the area around TPB1 and the import of suitable “clean” material.

As asbestos fibres have been detected within the soils, it is possible that asbestos is present in areas not previously investigated. A Watching Brief (Section 8.7) approach will be adopted during the enabling works to deal with any asbestos encountered during this time.

8.3 Radiological Contamination

Radioactive material was encountered within the shallow ashy soils at TPB83 and a contaminant linkage has been identified. This area will be remediated to mitigate the risk to site end users. Other burning pits may be present on across the site and these will be investigated and remediated if necessary to reduce the risk to site end users.

Consultation with a Radiation Protection Adviser will be sought as part of the detailed design process prior to implementation of any remedial work to ensure the appropriate method of works is adopted.

8.4 Groundwater Contamination

Groundwater contamination has been encountered at the site and this will need to be reviewed when more monitoring and specific detailed risk assessment has been undertaken to inform the remedial strategy.

The source of the TPH contamination that has been encountered is likely to be associated with the fuel storage and therefore when the tanks are removed as detailed in 8.2.2 above it is likely that the source will be removed. This may include removal of local Non-Aqueous Phase Liquid (NAPL) sources.

Groundwater monitoring will be undertaken prior / during and after the tank removal to determine if the concentrations are reducing to appropriate levels. If any residual contamination remains, appropriate remediation methods will be adopted, the details of which will be determined at the detailed design stage, once Detailed Quantitative Risk Assessment (DQRA) has been completed.

With regards to the inorganic contamination encountered, it is considered unlikely that remediation will be required but this should be discussed with the Environment Agency.

8.5 Ground Gases

Ground gases have been detected on site and a contaminant linkage has been identified which will need to be addressed. Further monitoring will be undertaken to establish the current gas regime across the site. Based on the information to date, there is a range of gas regimes on site from Green to Red.

Gas protection measures in line with current guidance (CIRIA 665 / BS 8485) will be adopted within the detailed design of the buildings to ensure that the risk to site end users is mitigated. The design will be approved with the regulators (Local Authority – Building Control / Contaminated Land Officer) prior to implementation.

Currently a Red Scenario has been calculated for a small area of the site, if this remains the case after further up to date monitoring then mitigation measures such as remediation will be undertaken to reduce the gas regime to an acceptable level.

8.6 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 will be contacted prior to development to determine that the appropriate underground services are used within the development.

Current guidance such as UK Water Industry Research (WIR) (Ref 8) will be used to determine the appropriate drinking water pipes to be used across the development.

8.7 Watching Brief / Unexpected Contamination / UXO

During the site enabling works, a watching brief shall 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.

While asbestos has been encountered in one area during the works undertaken to date, the potential for asbestos to be present in other areas cannot be discounted. Therefore the watching brief should be extra vigilant in this respect.

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 will 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.

A method statement will be developed that will set out in detail how this unexpected contamination or material is to be dealt with to include a scheme of remedial measures and timescales for remediation.

Risks associated with UXO will be mitigated as per Zetica's specialist advice.

8.8 Verification

Throughout the remedial works, validation will be undertaken on any areas where material is removed and/or imported to ensure that the remediation requirements set out in the detailed remediation strategy have been undertaken.

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

Due diligence records, including 3D survey control of materials encountered, soil management including volumes, results of the Watching Brief and any testing, any further DQRA undertaken and outcomes of soil reuse and records of appropriate disposal:

- Records of re-use of materials and compliance with waste legislation where appropriate;
- Records of waste disposal, quantities, waste characterisation and receiving facilities;
- Record of the Watching Brief, findings and outcomes;
- Verification of hotspot removal and/or testing of soils following surface strip (if required);
- Details of any on-site soil or groundwater treatment;
- Results of further groundwater testing (and risk assessment as necessary);
- Records of the chemical analysis and conformance of clean imported topsoil;
- Verification of correct installation of gas protections measures including photographic evidence;
- Details of any remediation specifically of radiological protection purposes.

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

8.9 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. 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. 9). Whichever route is chosen soils must be proved demonstrated to be "suitable for use" in the area to be deposited and a Materials Management Plan (or method statement) should be produced during the design phase for the scheme.

During construction of the proposed development should the excess excavated material not be physically suitable for use as backfill or as other engineering fill within the site, the material would need to be disposed of to landfill. Further testing and separation of waste for off-site disposal will be undertaken during the excavation works to minimise any treatment requirements. The testing will enable the accurate classification of material to reduce wastes sent to non-hazardous and hazardous landfill. Inert waste would be the least expensive for disposal and the material could be more easily reused.

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

Under European Council Directive (91/689/EC), known as the Hazardous Waste Directive, a list of all wastes, hazardous or otherwise has been compiled known as the European Waste Catalogue (EWC, 1994, Commission Decision 94/3/EC). A revised EWC was released in 2002 under Commission Decision 2000/532/EC. This commission decision has been amended in turn by Commission Decisions 2001/118/EC, 2001/119/EC and 2001/573/EC. The EWC is a catalogue of all wastes, grouped according to generic industry, process or waste type. It differentiates between non-hazardous and hazardous.

Based on the EWC as published by the Environment Agency as 'Hazardous Waste: Interpretation of the definition and classification of hazardous waste, third edition v3, Technical Guidance WM2', (Ref 10), this source material (Made Ground and natural soils) is likely to be classified as EWC 2002 Code 17.05.03*; *soils and stones containing dangerous substances* or EWC 2002 Code 17.05.04; *soils and stones other than those mentioned in* 17.05.03*.

All threshold concentrations are laid out in the Environment Agency document 'Framework for the Classification of Contaminated Soils as Hazardous Waste, version 1, (Ref 11). Based on this framework, each contaminant is identified by the Table 3.2 of Annex VI of the CLP Regulation (1272/2008) (Ref 12) as having risk phrases.

Total soil contaminant concentrations are used to assess the presence of hazardous properties. For classification purposes, a reasonable worst case hazardous substance is assumed in line with Environment Agency guidance. For example, cadmium is assumed to be present as cadmium oxide or cadmium hydroxide rather than the less hazardous cadmium sulphate. The solubility and phase (vapour/solid) of the contaminant has also been taken into account in this assessment.

In order to determine the appropriate landfill site for disposal of the Made Ground, the results obtained from the testing undertaken during the excavation works and the proceeding investigations shall 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.

A Waste Strategy has been prepared for the proposed development and reference should be made to this documentation.

9 Conclusions and Recommendations

9.1 Conclusions

Extensive ground investigations have been undertaken across the proposed development site. Soil (Made Ground / natural soils) and groundwater samples from across the site have been analysed for a suite of inorganic and organic contaminants. The presence of radiological contaminants and UXO has also been investigated.

The analytical results have been assessed against current guidelines (SSVs / WQS) and whilst elevated concentrations have been recorded in some areas, the site is not considered to be grossly contaminated.

With regards to the soil results, 4 inorganic contaminants (arsenic, vanadium, lead and nickel) had concentrations above the SSV for a residential with plant uptake scenario. In the case of arsenic and vanadium these were high in natural soils and therefore may be naturally above the SSV 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 with indicates a low risk. TPH contamination was mainly located within Zone C which was previously used for fuel storage and vehicle maintenance.

A risk assessment has been undertaken and contaminant linkages identified.

- For human health contaminant linkages a 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 (CL6) from ground gases is 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 increasing the risk. The source of the gas is unknown, but may relate to hydrocarbon contamination found in the same area.
- Asbestos fibres have been detected in soils in 2 locations and therefore a moderate risk is presented which reduces to moderate / low in general areas (CL4) where asbestos has not been identified.
- Radioactive materials have been detected in shallow soils (CL5) in one specific area (burning pit) and a moderate risk is considered appropriate in this one area.
- The risk to controlled waters (CL2 / CL8) is considered to be moderate as groundwater testing has identified some elevated concentrations.
- The risk to proposed buildings (CL3) is considered to be low from the contamination encountered within the soils, however the risk from ground gases (CL7) is considered to be moderate increasing to high in areas where high gas concentrations have been recorded.

An Outline Remedial Strategy is detailed within Section 8. This provides a proposed scope of works that the remediation of the site will adopt. A detailed remedial strategy will be prepared once the detailed design of the proposed development is finalised and further investigation data is available.

9.2 Recommendations

The conclusions above provide a summary of the risks presented to the receptors for a residential with private gardens scenario, if the entire site was to be developed for this sensitive land use. However as the proposed development contains a mixture of residential, open space and

commercial land uses. It is recommended that once further investigation data is obtained at detailed design stage that detailed assessment is undertaken to establish the risks for the particular land use under consideration.

It is recommended that areas which were previously not investigated due to access constraints are investigated to determine the land quality and establish any remedial measures that need to be undertaken in these areas. Monitoring of ground gases and groundwater should be undertaken to establish the current regimes and if remediation is required.

Two of the main contaminants which were found to be above the SSV were Arsenic and Vanadium. The concentrations appear to be above SSV in natural soils and therefore may occur natural above the SSV concentrations. Bioaccessibility analysis could be undertaken on soil samples to determine the fraction of Arsenic / Vanadium that is available to receptors. The SSV assumes that 100% is available but this is generally not the case. If the bioaccessible fraction is known then the guideline can be re-calculated and a higher SSV adopted. Discussion with the regulators will be sought prior to undertaking such work to determine if this is acceptable and or if they accept higher SSV concentrations.

This report forms part of the engagement with the regulators (Environment Agency and local authority) to discuss the proposed development and the findings of the investigation. Discussions with the Environment Agency could be sought regarding the slightly elevated groundwater results and whether this causes any concerns. If an agreement in principle that no groundwater remediation was required, this would provide a degree of comfort to developers. Groundwater monitoring during development may be required to ensure that the development does not impact the water quality.

The report has been submitted to SCDC and their response is included in Appendix G. Further discussions with the Local Authority may include the high Arsenic / Benzo(a)pyrene concentrations detected. The Local Authority may have more information about background levels for these contaminants which can be used to determine if the concentration encountered are of concern and/or part of local background conditions.

10 References

1 WSP (2007) Interim Factual Report: Northstowe, Cambridgeshire Zone A

2 WSP (2007) Interim Factual Report: Northstowe, Cambridgeshire Zone B

3 WSP (2007) Interim Factual Report: Northstowe, Cambridgeshire Zone C

4 WSP (2007) Interim Factual Report: Northstowe, Cambridgeshire Zone D

5 Environment Agency (2009) Updated technical background to the CLEA model (SC05002/SR3)

6 CIRIA (2007) Assessing risks posed by hazardous ground gases to buildings (C665)

7 CIRIA (2001) Contaminated Land Risk Assessment – A Guide to Good Practice (C552)

8 UKWIR (2010) Guidance for the Selection of Water Supply pipes to be used in Brownfield Sites (10/WM/03/21)

9 CL:AIRE (2011) Definition of Waste: Development Industry Code of Practice

10 Environment Agency (2011) Hazardous Waste Interpretation of definition and classification of hazardous waste, Technical Guidance second edition v 2.3 WM2

11 Environment Agency (2004) Framework for Classification of Contaminated Soils as Hazardous Waste Version 1

12 European Regulation (EC) No 1272/2008 on Classification, Labelling and Packaging of Substances and Mixtures (CLP Regulation)