RPS

Ground Conditions Technical Report

Project Hydrus

AWE Plc

Quality Management

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Date:	28th June 2010	
Revision:	Rev3	
Project Number:	JER4214	
Document Reference:	JER4214R100618AG GCTR Rev3	
Document File Path:	\\Card-ph-01\projects\chepstow\AWE\JER4214 AWE (A) Hydrus DEEA\Reports\6. DEEA Chapter 7 - Ground Conditions\Rev3	

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ISO 14001 EMS 70824

FS 32940

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1 Introduction

1.1 Background

RPS Planning and Development (RPS) has been commissioned by AWE plc (AWE) to complete the environmental assessment required in support of the planning application for the Project Hydrus Development on AWE Aldermaston (AWE (A)). The Hydrus development includes a replacement hydrodynamics testing facility research and development building, a supporting building and associated electrical sub-station, situated on northern part of AWE(A) formerly the site of defence operations and development of associated components involving the use of explosive compounds.

The consideration of ground conditions on the Hydrus Application Site (the Application Site), including historical and future soil and groundwater contamination, forms an important part of the assessment. This document provides a description of all qualitative and quantitative technical assessments undertaken in support of the Ground Conditions chapter of the assessment. This document shall therefore form the principal appendix to the Ground Conditions chapter of the Defence Exempt Environmental Appraisal (DEEA) that presents the findings from the assessment process.

1.2 Key Objectives

This report shall review all relevant aspects of ground conditions upon the Application Site, using available historical data, past investigation reports, details of historical land-uses on the site and the results of more recent investigations on the site (*Ref 1 and Ref 2*). The Ground Conditions Technical Report (GCTR) shall include all qualitative and quantitative risk assessments for human health and controlled waters (i.e. groundwater and surface water) to identify any unacceptable risks from radiological, explosive, chemical or ground gas contamination for the proposed development. The results of the risk assessment shall be used to determine appropriate mitigation measures, where required.

This report has been prepared using guidance provided in CLR-11 (*Ref 3e*) and also 'Safegrounds - Best Practise Guidance for Site Characterisation' (*Ref 4)*. The key objectives of this report are as follows:

- Provide an assessment of the 'baseline' ground conditions present within the site;

- Based on the information provided determine the presence of any soil or groundwater contamination from explosives, radioactive materials, chemicals, asbestos or ground gas;
- Provide an assessment of the risks associated with any explosive, radiological, chemical, asbestos or ground gas contamination sources using current UK best practice;
- Determine the risk from live unexploded ordnance and whether remedial action is required to protect future site users;
- Complete a Conceptual Site Model to discuss residual risks (chemical, radiological and explosive determinants, and soil gas); and,
- Determine the need for mitigation measures and remediation.

1.3 Report Structure

The remainder of the report is structured as follows:

Chapter 2: *Regulatory Context;*

Chapter 3: *Site Setting;*

Chapter 4: *Baseline Conceptual Site Model (including pollutant linkages);*

Chapter 5: *Human Health Risk Assessment;*

Chapter 6: *Radiological Risk Assessment;*

Chapter 7: *Controlled Water Risk Assessment;*

Chapter 8: *Soil Gas Risk Assessment;*

Chapter 9: *Construction and Post-construction Assessment;*

Chapter 10: *Summary of Risks and Conclusions; and*

Chapter 11: *Recommendations (including mitigation measures and remediation requirements).*

2 Regulatory Context

2.1 Introduction

The type of contamination that may be present at the site can be split into two broad types, radiological and non radiological. Each of these types of contamination has different key pieces of legislation with which AWE plc must comply and the criteria applicable to both of these are used to assess the land quality at the site.

2.2 Non Radiological Contamination Legislation

2.2.1 Environmental Protection Act 1990 (Part IIA)

Implementation of Section 57 of the Environment Act 1995 added Part IIA into the Environmental Protection Act 1990. The application of this primary piece of legislation is via the Contaminated Land (England) Regulations 2006 (*Ref 5*).

Under Part IIA 'Contaminated Land' is defined as '

"any land which appears to the LOCAL AUTHORITY in whose area it is situated to be in such a condition, by reason of substances in, on or under the land, that -

"(a) SIGNIFICANT HARM is being caused or there is a SIGNIFICANT POSSIBILITY of such harm being caused; or

"(b) POLLUTION OF CONTROLLED WATERS is being, or is likely to be, caused".

In order to determine whether land is contaminated under Part IIA the concept of a 'Pollutant Linkage' is adopted. This means that a link between a contaminant and receptor by means of a pathway must exist. Consequently in order for a risk to be present at the site three components must exist:

1. Contaminant(s) must be present at concentrations capable of causing adverse environmental effects (Source);

2. A receptor (human, controlled water etc) must be present, or one which can be exposed to the site or migrating contaminants (Receptor); and

3. There must be an exposure pathway by which the receptor comes into contact with the environmental contaminant (Pollutant Linkage).

The source-pathway-receptor (SPR) approach is a useful means to generate a conceptual model, which can be used to identify critical pathways that a more detailed quantitative analysis may assess further if necessary. The first stage of the process was to determine the key contaminant(s) of concern (Source), followed by the most likely pathways that these contaminants would take in the environment and finally the potential receptors of concern.

2.2.2 Planning Policy Statement 23

As the site is to be redeveloped the proposed site use must be permitted by the Local Planning Authority. Planning Policy Statement 23 (PPS23) (*Ref 6*) provides guidance to the Local Planning Authority on ensuring that post development the site is suitable for use with respect to the presence of any land contamination.

PPS23 states that following development, the site should not be able to be 'determined' as 'contaminated land' under Part IIA of the Environmental Protection Act. The key principle of Planning Policy Statement 23 is that the opportunity should be taken to remediate contaminated land during development and PPS23 advocates the use of risk assessments to determine the need to undertake remediation.

Under the Town and Country Planning System the responsibility for providing information on whether a site is contaminated rests primarily with the developer. The Berkshire Contaminated Land Group, which comprises Local Authorities including West Berkshire, has produced a document entitled "The Berkshire Guide to Developing Potentially Contaminated Land" (*Ref 7*). The assessment of land contamination for the proposed development had been undertaken according to these guidelines.

2.2.3 The Water Framework Directive

The Water Framework Directive (WFD) consolidates a number of existing water-focused directives, and introduces new requirements on Members States. The objectives of the Water Framework Directive (WFD) are wide ranging across the fields of water use and management, and of water and ecosystem protection and restoration, and include:

1. Prevent deterioration and enhance status of aquatic ecosystems and associated wetlands;
2. Promote sustainable water use;
3. Reduce pollution from 'priority substances';

4. Prevent deterioration of status of groundwater bodies and progressively reduce groundwater pollution; and,

5. Contribute to mitigating the effects of floods and droughts.

The Water Framework Directive gives a new opportunity to plan for and deliver, through working with other interested parties, a better water environment. This applies to all surface freshwater bodies (including lakes, streams and rivers), groundwater, groundwater dependant ecosystems, estuaries and coastal waters out to one mile from low-water. It came into force in December 2000, and transposed into UK law by December 2003.

2.3 Radiological Contamination

2.3.1 Introduction

Under UK Law a specific definition of 'radioactively contaminated land' is outlined by the extension to Part IIA in August 2006 to include radioactivity. The Part IIA definition of radioactively contaminated land does not apply to nuclear licensed sites, as radioactively contaminated land on these sites is regulated by the Health and Safety Executive (HSE) under the Nuclear Installations Act 1965 (*Ref 8*). The HSE's role extends to establishing remediation criteria when sites are being de-licensed. It is important to note that the EA is responsible for authorising radioactive waste disposals from nuclear licensed sites.

The other key pieces of legislation that could apply to this site and the management of radioactive wastes are outlined below.

2.3.2 Nuclear Installations Act 1965 (as amended)

Under the Nuclear Installations Act 1965 (as amended) (NI Act) (*Ref 8*), no site may be used for the purposes of installing or operating nuclear facilities, unless a nuclear site licence has been granted by the HSE for that site. The Nuclear Safety Directorate (NSD), acting for HSE, sets out in conditions attached to the site licence the general safety requirements to deal with the risks on a nuclear site. The Nuclear Installations Inspectorate (NII) section of HSE is responsible for regulating nuclear site licences.

It is the NII's view that radioactively contaminated ground on a nuclear licensed site represents an accumulation of radioactive waste. Thus such material should be managed and dealt with by the site licensee. The licensee is required to control and contain radioactive waste, record locations and amounts and demonstrate that adequate safety arrangements are in place through a safety case. Further information on the management of radioactively contaminated land can be found in the NSD's Guidance for Inspectors on the Management of Radioactive Materials and Radioactive Waste on Nuclear Licensed Sites (*Ref 9*).

2.3.3 Radioactive Substances Act 1993 (RSA93)

This key piece of legislation controls the keeping and use of radioactive materials, and the accumulation and disposal of radioactive waste. The RSA93 (*Ref 10*) defines whether a material is radioactive as follows:

1. *Elements specified in Schedule 1 of Section 1 of the RSA93 which are present at specific activity levels greater than those listed in Table 2.1.*

Table 2.1. Schedule 1 Specified Elements and Their Limiting Specific Activities

Element	Solid (Bq/g)	Liquid (Bq/g)
Actinium	0.37	7.4×10^{-2}
Lead	0.74	3.7×10^{-3}
Polonium	0.37	2.59×10^{-2}
Protactinium	0.37	3.33×10^{-2}
Radium	0.37	3.7×10^{-4}
Thorium	2.59	3.7×10^{-2}
Uranium	11.1	0.74

2. *Any substances containing non-naturally occurring (man-made) radionuclides irrespective of its specific activity.*

Section 2 of the RSA specifies that 'radioactive waste' comprises waste which consists wholly or partly of:

(a) A substance or article which, if it were not waste, would be radioactive material, or

(b) A substance or article which has been contaminated in the course of the production, keeping or use of radioactive material, or by contact with or proximity to other waste falling within paragraph (a) (above) or this paragraph

2.3.4 The Radioactive Substances (SoLA) Exemption Order

Under the Substances of Low Activity (SoLA) Exemption Order (*Ref 11*), solid radioactive waste is 'exempt' from some of the provisions of the RSA 93 (Section 13(1), (3) and (4)) provided that it is substantially insoluble in water and has an activity that does not exceed 0.4 Bq/g.

The SoLA Exemption Order can be applied to naturally occurring radioelements (such as potassium) by subtracting the normal natural background level of a site from a measured sample concentration. The difference is then compared to the 0.4 Bq/g level.

For artificial radionuclides the SoLA Exemption Order level of 0.4 Bq/g is generally interpreted to be additional to the ubiquitous artificial background to account for low background levels of man made radionuclides such as fall out from nuclear weapon testing and Chernobyl.

2.3.5 The Radioactive Substances (PSRE etc.) Exemption Order (1962)

The Radioactive Substances (Phosphatic Substances, Rare Earths, etc.) Exemption Order (*Ref 12*) states that material that is radioactive solely because of the presence of one or more of the RSA 93 Schedule 1 elements and is substantially insoluble in water is unconditionally exempted from the provisions of the RSA 93 provided that the specific activity of each of the Schedule 1 elements present does not exceed 14.8 Bq/g.

2.3.6 Ionising Radiations Regulations 1999 (IRR1999)

The Ionising Radiations Regulations 1999 is the principal legislation relating to the protection of workers from exposure to ionising radiation (*Ref 13*). IRR99 sets out dose limits for exposure to radioactivity from working with ionising radiation for both radiation workers and the general public.

The average individual radiation dose in the UK is 2.6 mSv per year, mostly from natural and medical sources of radiation (2.2 and 0.36 mSv per year respectively).

2.4 Radiological Contamination Assessment Approach

2.4.1 Radioactivity Assessment in Soils

AWE have adopted the following approach of comparing soil sample measurements with limiting values given in the RSA 93 and the appropriate Exemption Orders as an indication of potential contamination. AWE considers background levels of gross alpha and beta in soils at AWE (A) to be 0.7 Bq/g alpha and 0.6 Bq/g beta (*Ref 14*).

- If only naturally occurring Schedule 1 radioelements are present, and the specific activity of the sample is below the Schedule 1 limit, the material is not considered to be radioactive.
- If only naturally occurring Schedule 1 radioelements are present, and the specific activity of the sample is above the Schedule 1 limit, but less than 14.8 Bq/g (or 4.9 Bq/g for radium and 7.4 Bq/g for thorium), then the material, although radioactive, is exempt from RSA 93. This material can then be disposed of as exempt waste and in accordance with other properties.
- For naturally occurring radioelements not listed in Schedule 1, if the specific activity of the sample, less the mean background specific activity (0.7 Bq/g), is below 0.4 Bq/g then the sample is not considered to be radioactive.

Given that AWE plc has adopted a soil background level of 0.7 Bq/g alpha and 0.6 Bq/g beta with respect to naturally occurring radioactivity at AWE (A), and taking into account the 0.4 Bq/g level given by the SoLA Exemption Order, a contamination “screening level” of 1.1 Bq/g alpha, 1.0 Bq/g beta and 1.7 Bq/g total activity (alpha+beta) is adopted.

Samples exhibiting gross alpha or gross beta activity above 1.1 Bq/g and 1.0 Bq/g respectively do not necessarily indicate radiological contamination, but that further assessment and analysis is required.

Typically, AWE analyse soil samples with elevated gross alpha and beta activity, using radiochemical analysis or gamma spectroscopy respectively. Additionally, based on historical uses in the areas of investigation, tritium analysis is undertaken and the activity compared against the SoLA Exemption Order activity of 0.40 Bq/g to assess whether the activities detected are indicative of exempt levels or radioactive levels in accordance with the regulations.

2.4.2 Radioactivity Assessment in Groundwater

AWE plc have adopted 'Threshold Levels' for gross alpha (40 Bq/m^3) and gross beta (500 Bq/m^3) in ground waters based on AWE's RSA93 arrangements for environmental monitoring for radioactivity within and around AWE. By way of comparison, the WHO Drinking Water Quality standard activity levels for gross alpha is 0.5 Bq/L (500 Bq/m^3) and gross beta is 1 Bq/L (1000 Bq/m^3), which are both higher and therefore less stringent than AWE 'Threshold Levels'.

Exceedances of the gross alpha (40 Bq/m^3) threshold triggers additional analysis for plutonium and uranium isotopes (Uranium-234, Uranium-235, Uranium-238, Plutonium-238, Plutonium-239 and Plutonium-240), while exceedances of the gross beta threshold (500 Bq/m^3) triggers additional gamma spectrometry.

Activity values for plutonium / uranium isotopes and tritium can then be compared to the criteria set out in Schedule 1 of the RSA93 where appropriate and also to the World Health Organisation (WHO) Drinking Water Quality (3rd Edition) Guideline Levels (*Ref 15*) which are summarised in *Table 2.2.*

These criteria are then used to gain a preliminary view of the order of magnitude of potential doses to individuals.

Table 2.2. WHO Drinking Water Quality Guideline Levels (3rd Edition)

Radionuclides	WHO Guideline Level
Gross Alpha	0.5 Bq/L (500 Bq/m^3)
Gross beta	1 Bq/L (1000 Bq/m^3)
Tritium (H-3)	10,000 Bq/L (10,000,000 Bq/m^3)
Uranium -234	10Bq/L (10,000 Bq/m^3)
Uranium-235	1 Bq/L (1,000 Bq/m^3)
Uranium-238	10 Bq/L (10,000 Bq/m^3)
Plutonium-238	1 Bq/L (1,000 Bq/m^3)
Plutonium-239	1 Bq/L (1,000 Bq/m^3)
Gross beta	1 Bq/L (1000 Bq/m3)

The Environment Agency is notified if:

- The plutonium alpha activity exceeds 10 Bq/m^3;

- The uranium alpha activity exceeds 50 Bq/m^3; and/or

- The tritium activity exceeds 50 kBq/m^3 at any of AWE's surface water discharge outfalls.

The EA regulates radioactive discharges to ensure that no member of the public receives an additional dose of more than 1mSv per year (*Ref 16*), which is considered As Low As Reasonably Practicable (ALARP), while the WHO radionuclide values in water are set such that a Reference Dose Level of 0.1 mSv per year would be achieved based on average consumption of water. Furthermore the UK Drinking Water Inspectorate uses a guideline level of 100 Bq/L for tritium, which although not mandatory, is recognised as an acceptable level for determining whether additional testing or remedial action is needed.

2.4.3 AWE Explosive Contamination Assessment Approach

There is currently no threshold explosive concentration in the UK for what constitutes an unacceptable amount of explosive residue within soils that could represent a risk of explosion. However, AWE has adopted a total explosives concentration of 0.1 % (or 1,000 mg/kg) as a threshold for determining whether decontamination/remediation would be required, on the basis that concentrations above 0.1% are considered to be Potential for Explosive Hazard (PFEH). Concentrations below 0.1% are regarded as Free from Explosive Hazard (FFEH), and highlighted in *Table 2.3*.

Table 2.3. Explosive Materials Threshold Concentrations

Total Explosive Concentration	Description	Remedial Action
>0.1 % (>1000 mg/kg)	Potential for Explosive Hazard (PFEH)	Further analysis/delineation required
<0.1 % (<1000 mg/kg)	Free From Explosive Hazard (FFEH)	No further action required

Note the above threshold levels have also been agreed with the HSE. Elevated levels of explosive residue (e.g. HMX, RDX, Nitrocellulose etc) identified in soils and groundwater are also assessed with respect to any toxicological risks posed to human health and risks to the aqueous environment. This is achieved through the adoption of guidance provided in CLR-11 (*Ref 3e*) as no UK prescribed acceptable 'threshold levels' exist for explosive compounds in soils or groundwater.

3 Environmental Site Setting

3.1 Introduction

This section provides a description of the history, geology, hydrogeology and hydrology of the Application Site and summarises historical investigation data and published data relevant to the Application Site and assessment process. This section provides a description of the baseline environmental conditions that shall underpin the technical assessments undertaken to determine the likely significance of impacts that may arise during the construction, operation and decommissioning phase of the development.

3.1.1 Data Sources

Historical Ground Investigations

Historical site investigations and associated monitoring infrastructure used to determine baseline conditions on the Application Site are summarised in *Table 3.1* and shown on *Drawing JER4214-006a.*

Table 3.1. Summary of Historical Sources of Site Investigations

Report	Date	Author	Report Type[1]	Site Investigation Locations Utilised[2]
Golder Associates. New HR Facility Ground Investigation Fieldwork Report. AWE Aldermaston.	2004	Golder Associates (UK) Ltd	I	BH0900-0912, BH0926-0929, TP0913-0925, TP0930-0935
SCRT 2: B Area North Exploratory Investigation Report. AWE Aldermaston.	2005	Golder Associates (UK) Ltd	I	BH0330-0333, BH0364, BH0396-0398
Land Quality Assessment Report. B Area North, AWE Aldermaston.	2007	BAE Systems	I	BAEBH1-3, BAETP1-5 plus numerous building footprint soil samples
Factual Report on Geotechnical Ground Investigation. AWE Aldermaston Hydrus.	2008	Golder Associates (UK) Ltd	F	CP1001-1003, R1001-1007, TP1001-1020, ENV001
Ground Investigation Interim Factual Report. Project Hydrus, AWE Aldermaston.	2009	RPS	F	BHHYD01-03, WSHYD-01-03
ESIIMS format ground investigation data received from AWE following request for information. Original reports not available for reference.	2009	AWE Database	-	04004, BH0095, BH0097, (ST13A, ST14), (CACE_TP3, 5-8), (EBH7, 8, 8A, 11, 11A)

Notes:

1. I denotes an interpretative report and F denotes factual report; and

2. This only includes ground investigation locations that contain sample information remaining at site following excavations as shown on *Drawing JER4214-006a*.

Other Data Sources

The following data sources were used to supplement our understanding of ground conditions on the Application Site:

- Envirocheck Data Sheet Report, AWE Aldermaston (*Ref 17*);
- British Geological Survey, 1:50,000, Sheet 268, Reading, Solid and Drift, 2000 and associated Geological Memoir (*Ref 18*);
- Ordnance Survey, 1:10,000, Sheet 44SW and 44NW, Berkshire; and
- Additional investigation reports (as referenced in text).

The Landmark Envirocheck Report for the AWE(A) Site is provided in *Appendix A*.

3.1.2 Site Description

The Application Site is situated adjacent to the northern boundary of AWE(A). AWE(A) is situated south of the Kennet Valley in Berkshire, approximately 15 km south-west of Reading, on a broad flat, wooded, east-west trending plateau at an elevation of approximately 100 mAOD. AWE(A) is bounded by the A340 to the west and south, Reading Road to the south, Red Lane to the east, and the grounds associated with Portland House and Aldermaston Court to the north.

The Application Site is defined by the red-line boundary of the planning application, as shown in *Drawing JER4214-001a*. The Application Site comprises the Project Hydrus Development Area (the Development Area) in the north-east, two pre-existing construction enclaves (i.e. the Central Area Construction Enclave (CACE) and West End Construction Enclave (WECE)) and various routes of access / egress. Further information relating to the proposed development can be found within *Chapter 1: Introduction* and *Chapter 5: Proposed Development* of the EA.

Development Area

Current land-use on the Development Area is dominated by rough grassland with occasional mature trees and some areas of demolition rubble. The entire Development Area is currently surrounded by chain link fencing.

To the south the land slopes downwards to a ditch which drains towards a 300mm diameter culvert which continues eastwards (*Ref 19)*. The AWE(A) site boundary is situated immediately north of the Development Area and passes in to woodland. Grassland is located to the south of the Development Area as well as other buildings associated with historical operations involving the use of explosive residues. The detonator building suite (B7A1 and B6D1) and three associated magazines (B9G3, B9G2, and B9G1) are located to the south-west of the Application Site. Woodland and grassed areas predominate to the west.

The Development Area contains all the principal structures associated with the proposed development and covers an area of approximately 6.5 hectares. The three main components of the Development Area is summarised below.

Permanent Features:

- Research and Development Building with eight lightning conductor towers;
- Support building in north-east corner;
- Electrical substation in west;
- Borehole housing (replacement chalk abstraction boreholes for AWE(A) Site);
- Sustainable Drainage System (SuDS) lagoon and associated swales;
- Associated security fencing, access roads and an operational vehicle waiting area.

More detailed information regarding the permanent structures associated with the Development Area can be found within *Chapter 5: Proposed Development* of the EA.

Temporary Construction Site and Associated Facilities

The temporary construction site within the Development Area shall be fenced and managed through the project Work Control Centre also located within the temporary construction site. The temporary construction site will include:

- Material lay-down areas; and
- Prefabrication areas and a refuelling area.
- Contractors Compound

Landscape Features (including Biodiversity Proposals)

These include measures to mitigate for the proposals and compliment the objectives of the site-wide Landscape Strategy that has been developed for AWE(A).

Construction Enclaves (CACE & WECE)

Ground conditions within CACE have been assessed as part of the High Explosives Fabrication Facility (HEFF) planning application which was granted planning permission from West Berkshire Council in February 2008 (Planning Reference: 07/02438/COMIND). Ground conditions within WECE have been assessed as part of the New Office Accommodation (NOA) planning application which was granted planning permission from West Berkshire Council in February 2007 (Planning Reference: 06/02326/COMIND). The Proposed Development does not include any changes to the existing use of the CACE and WECE, and therefore no additional potential impacts will be introduced. Consequently, these areas are not considered in this assessment, which principally focuses on the proposed Hydrus Development Site.

Temporary land uses (e.g. as construction support areas) are proposed in some parts of the Application Site, most notably within the CACE and WECE. The CACE and WACE were granted planning consent in February 2008 and 2007 respectively, as part of the HEFF and NOA planning applications during which assessment was made of the suitability of the ground conditions for the proposed development.. Given that the ground is unlikely to be disturbed in these areas during the construction phase of works, it is considered that the short-term risk posed to construction workers by any previously unidentified contamination will be managed through the application of CDM 2007 Regulations (Ref 7-35) and the adoption of Safe Systems of Work (SSoW). Consequently, no further assessment of ground conditions within the WECE and CACE areas have been undertaken as part of this appraisal.

3.1.3 Site History

During the 18th and 19th century, the Application Site formed part of Aldermaston Court estate (*Ref 20*). During the Second World War the site was developed into an airfield for training purposes and an arsenal storage area. The airfield was opened in the early 1940s and was used up until circa 1950 for training of paratroopers, construction of light aircraft, and temporarily as a civil airport. From approximately 1950 onwards the airfield was utilised by the Atomic Weapons Establishment (AWE).

Aerial photos supplied by AWE (1950, 1955, 1964, 1971, 1981, 1991, 1998, and 2003 - 2008) indicate that prior to the 1950s the site was largely undeveloped with mostly flat open and grassed areas interspersed with woodland. There are some areas of hard-standing, access roads and part of a runway aligned in a north south direction.

Between 1950 and 1955 a number of buildings were constructed within the Development Area in addition to access roadways and associated infrastructure. These structures include buildings B3A25, B3A26.1, B3A26.2, B3A27, B3A28, B3C7, B34.1, B35.1, B9D10, B9E10, B9C10, B9N10, and F26.5 the location of which are identified on *Drawing JER4214-002a*. The main uses of these buildings related to defence operations and development of associated components. This involved the use of explosive compounds. This development was supported by ancillary buildings housing compressors, a pump house, mess rooms, offices, workshops and garage.

The following potential contaminants of concern have been identified to have been utilised within buildings (*Ref 20* and *Ref 21*):

Buildings B3A25, B3A26, B3A28, B3C7, and B9C10

- High Explosives including PETN, HMX, RDX, TNT, TATB, HNS, potassium picrite.
- Solvents including acetone, butanone, normal butyl acetone, iso butyl methyl ketone.
- Plastics including polymers.

Building B9N10

- Hydrocarbons.

Building F26.5

- Potential historical ad hoc disposal of chemicals.

Between 2007 and 2008 demolition works were undertaken to clear the above buildings and surrounding blast bund material, leaving the Development Area flat and undeveloped (*Ref 20*).

Additional ground investigation and assessment work was undertaken as part of the BAE Land Quality Assessment to identify any risks posed at the site post building demolition / clearance. Stockpiles of crushed concrete at the north of the site were identified in a topographic survey undertaken in December 2007 (*Ref 20*) and a later survey topographic undertaken in November 2008 identified this material to be removed.

The BAE verification report states that 'the LQA concludes that there are no significant risks posed by contamination to any receptors in the site's proposed use as a commercial / industrial facility' (*Ref 20*).

No further re-profiling / removal of soils have occurred since the completion of BAE works on the Application Site. Material (crushed concrete) has been brought onto site to form roads and hard standing areas as part of the Water Supply Borehole project (see *Drawing JER4214-001a*).

3.1.4 Baseline Conditions

A variety of activities will be undertaken principally on the Development Area in preparation of the site for development as described in *Chapter 6: Construction Phase* of the EA. These minor enabling works generally include re-profiling and site and clearance and provide the 'baseline conditions' upon which the risk assessments will be based.

The baseline conditions for the Development Area include ground excavation and re-profiling works shown in *Drawing JER4214-004a* and *Drawing JER4214-005a.* These works are designed to 'tie in' with a general finish level of 100 mAOD and it estimated that 28,056 m^3 of material shall be excavated within the Development Area (See *Chapter 6: Construction Phase* of the EA). All excavated material will be subject to appropriate sampling and analysis in order to determine acceptable re-use and/or disposal. In this respect, all soil samples originating from material proposed to be excavated will be removed from our ground condition dataset when considering the potential risks to human health and groundwater posed by ground contamination in the proposed redevelopment, and discussed separately.

In addition, the baseline condition includes the demolition, clearance and validation work (i.e. environmental improvements) already undertaken on the Development Area, most notably:

- Sampling and characterisation of (now former) buildings (13No. including B3A25, B3A26.1, B3A26.2, B3A27, B3A28, B3C7, B34.1, B35.1, B9D10, B9E10, B9C10, B9N10, and F26.5), building contents, drainage sediment and soils.
- Removal of loose items / materials within buildings following appropriate sampling and cleaning operations. Items include furniture, miscellaneous plant, timber, plastics etc, waste oils, and old rags etc that may be potentially contaminated. The materials were incorporated into appropriate recycling / waste streams.

- Management of explosive plant, including their dismantling, cleaning and storage prior to removal for thermal proving.

- Additional decontamination works including grit blasting of internal buildings surfaces, removal of floor coverings, removal of asbestos containing materials, assessment and cleaning of drains, Data Quality Objective (DQO) sampling, and Data Quality Assessment (DQA), isolation/diversion of services, building demolition, removal of drains and services, removal of clean-aways, processing and deposition of demolition arisings.

- Land quality assessment (LQA) involving the excavation and sampling from 3 boreholes in the southern part of the site, 5 trial pits and of materials beneath former building footprints and trade waste drainage, and sampling of mound earth (earth ‘bunds’ surrounding demolished buildings) prior to its use as backfill.

3.2 Hydrology and Site Drainage

All surface water features in the vicinity of the Application Site are presented in *Drawing JER4214-003a.*

The AWE Aldermaston site is situated within the surface water catchment of the River Kennet. The northern parts of AWE Aldermaston, including the Application Site, generally drain northwards to the River Kennet. There are no surface water features present within the Application Site boundary. A review of 1:10,000 scale Ordnance Survey maps has identified the nearest surface water features to the Application Site to be:

- The Fish Pond and Stock Pond situated c. 200 m east of the Application Site boundary;

- Portland House Reservoir situated c. 330 m north of the Application Site; and

- Land drains and ponds situated more than 400 m west of the western site boundary.

Unnamed outlet channels emanate from each of the ponds and reservoirs identified above. These channel drain northwards, ultimately discharging to the drainage network associated with the River Kennet. Surface water drainage exists within the Development Area, the layout of surface drainage is shown on *Figure 6.1 (Chapter 6: Construction Phase).*

3.3 Geology

3.3.1 Introduction

The geology of the Application Site has been determined from the published geological information for the Reading Area (*Ref 18*) and a review of available geological logs within and adjacent to the Application Site. The location of the forty-three boreholes for which site specific geological information is available are shown in *Drawing JER4214-006a,* with associated geological logs provided in *Appendix B*. Monitoring boreholes are generally located within or adjacent to the Development Area, with an absence of borehole coverage on the access roads and CACE.

A summary of the local geological sequence for the AWE(A) site is presented in *Table 3.2* and the site-specific geology subsequently described.

Table 3.2. Geological Sequence underlying the Site

Unit / Formation	Description[1]	Likely Thickness[1] (m)
Top Soil	-	Ranges from absent to 0.4 m
Made Ground	See Report Text.	Ranges from absent to 1.9 m
Silchester Gravels (formerly Plateau Gravels)	Dense, orange-brown sand and gravel with variable sand, silt and clay matrix	Ranges from absent to 3.7 m
Bagshot Formation / Transition Zone	Orange-brown grading to dark-grey sand, fine to medium grained with silt and clay laminae	Ranges from 0.2 to greater than 17.1 m
London Clay Formation	Firm and stiff dark bluish and grey clay, variably silty, with beds of sand and silt and flint pebble seams; variably glauconitic and shelly	Base not intercepted (maximum thickness encountered – 66.7 m)
Lambeth Group	Comprises Harwich, Reading and Upnor Formations – typically sand and clay	Not penetrated
Upper Chalk	Soft white nodular chalk with flint seams	Not penetrated

1 Likely thickness & descriptions taken from geological logs for intrusive locations in *Drawing JER4214-006*a.

3.3.2 Topsoil

Topsoil was encountered in 70% of the forty-three boreholes advanced in the vicinity of the Development Area and is most common in the central and southern areas of the site. The land at the Development Area is rough grassland with occasional mature trees and some areas of demolition rubble and gravel.

3.3.3 Made Ground

Made Ground was found in 47% of the boreholes constructed across the Development Area. Made Ground encountered on the Development Area comprises a variable matrix of sand, gravel and clay mixed with brick fragments, flint, asphalt, concrete and tarmacadam. Made Ground is generally less than 1 m thick but exceeds 1.5 m in three boreholes with an average of 0.76 m where encountered.

3.3.4 Silchester Gravel

The Silchester Gravel is an unconsolidated sand and gravel deposit, typically clayey flint gravel on the Development Area. The Silchester Gravel is commonly includes an upper surface of gravely clay across the Aldermaston site, although this horizon is restricted to only five of forty-three boreholes on the Development Area, with a thickness of between 0.35 m – 0.6 m.

The remainder of the Silchester Gravel is typically sandy clayey gravel, with a thickness of between 1.5 m to 2.5 m on the Development Area. The Silchester Gravel attains a maximum thickness of 3.7 m in a single borehole (borehole R1007) situated towards the centre of the Development Area. The Silchester Gravel is reported to be absent in four boreholes (i.e. BH0364, BH0397, BH0928 and BH0928) where thickest sequence of Made Ground is encountered (i.e. 0.5 m to 1.9 m).

3.3.5 Bagshot Formation (Transitional Zone)

The Bagshot Formation has been encountered in all the boreholes drilled in the Development Area. The maximum thickness of Bagshot Formation encountered was 15.5 m in borehole BH0364 and the minimum thickness was 0.2 m in BHHYD-02. The Bagshot Formation has an average thickness of 2.1 m in boreholes which fully penetrate the formation. Borehole logs typically describe the Bagshot Formation as firm to stiff orange mottled grey gravelly sandy clay. The maximum combined thickness of the Bagshot Formation and Transitional Zone is greater than 19.5 m in borehole BH0364. The Bagshot Formation is described as damp/wet in 11 boreholes from 1.6 mbGL (in borehole (WSHYD-05).

Nineteen borehole logs describe a Transitional Zone which is found between the Bagshot Formation and the London Clay. The Transitional Zone is described as grey slightly sandy clay and is likely to represent the Claygate Member of the London Clay Formation (fine grained sand, silt and clay). The boundary between the Bagshot Formation and the London Clay is not a well defined point as the Bagshot Formation grades into the London Clay.

3.3.6 London Clay

London Clay underlies the surface deposits of the Silchester Gravel and Bagshot beds across the entire Aldermaston site. The London Clay underlying the Application Site is typically stiff bluish-grey clay with layers of sand and silt and is described as being wet or damp in five boreholes within the Development Area.

Sixty-three percent of the boreholes advanced in the Application Site penetrate the London Clay. A considerable thickness of London Clay is expected beneath the site and the maximum thickness demonstrated on the Development Area is 66.7 m (borehole R1006) although the base of the London Clay is not proven.

3.4 Hydrogeology

3.4.1 Hydrogeological Units and Groundwater Occurrence

The granular Silchester Gravel is classified by the Environment Agency as a minor aquifer unit (*Ref 22*), indicating that it cannot support large abstractions but may constitute a locally important water resource. The site is also characterised as having a high leaching potential, capable of transmitting modest quantities of water and supporting local supplies owing to the '*coarse textured or moderately shallow soils that readily transmit non-absorbed pollutants and liquid discharges but which have some ability to attenuate adsorbed pollutants because of their clay or organic contents*'.

The Bagshot Formation is also classified as a minor aquifer of intermediate leaching potential with '*a moderate ability to attenuate diffuse source pollutants*' but it is possible that a wide range of non-adsorbed diffuse source pollutants and liquid discharges could penetrate the layer and transmit pollutants. However, this formation is overlain by the Silchester Gravel minor aquifer across the site.

The London Clay is considered to be a non-aquifer, with very limited potential to transmit water. The London Clay is considered to represent the effective hydraulic base to the overlying minor aquifer. The Upper Chalk is classed as a major aquifer, and is of regional and national importance in terms of water supply.

3.4.2 Groundwater Levels and Flow

Groundwater has historically been identified in both the Silchester Gravels and Bagshot Formation (*Ref 24*). Furthermore, these aquifer units have been shown to have similar groundwater levels that respond quickly and in a similar manner suggesting a high degree of hydraulic continuity between both aquifer units. The two units are therefore considered to form a single aquifer unit, despite the hydraulic distinction between these units identified on geological logs for the Development Area (i.e. granular Silchester Gravels and the clay rich Bagshot Formation) (see *Appendix B*).

The low permeability London Clay constitutes the effective hydraulic base to the overlying minor aquifers, although the exact base of the aquifer is dependent on properties of Bagshot Formation that are transitional with the London Clay. The Silchester Gravel can be considered a shallow unconfined granular aquifer unit that has a high degree of hydraulic continuity with more granular, upper parts of the Bagshot Formation. This aquifer unit appears generally to be up to 5 m thick within the Development Area.

Over the wider AWE Aldermaston site groundwater flow in the shallow unconfined aquifer generally follows the subdued topography, diverging away from a groundwater high in the vicinity of the south-western corner of AWE Aldermaston site (*Ref 24*) and ultimately flowing towards the River Kennet and associated tributaries.

Groundwater level data, for the Silchester Gravel upper Bagshot Formation on the Development Area is provided in *Appendix C* and a contour plot for the shallow water table provided *Drawing JER4214-007a.* The predominant direction of groundwater flow in the shallow aquifer is to the east, with levels that decline from approximately 98.0 mAOD in the west to approximately 96.6 mAOD in the east. The water table is generally situated at a shallow depth below the ground surface of between 1.4 mbGL and 3.1 mbGL.

Groundwater flow occurs in the intergranular porosity of these unconsolidated sand and gravel deposits. The low permeability deposits of the London Clay (and Bagshot Formation where dominated by clay), constitute the hydraulic base to the overlying aquifer granular aquifer. Water levels have been obtained for a number of boreholes completed within the London Clay and are approximately 5 m lower than the groundwater level seen in the overlying shallow perched aquifer.

Transfer of water between the shallow perched aquifer and the underlying Chalk aquifer is considered negligible considering the presence of between 55 m and 100 m of intervening low permeability London Clay deposits.

3.4.3 Groundwater Recharge

The shallow unconfined aquifer will receive recharge from rainfall. The underlying Bagshot Formation/Transitional Zone will receive recharge via vertical flow from the Silchester Gravels. An estimate of the amount of natural recharge available was undertaken by Golders Associates Ltd in 2002 (*Ref 24*); it calculated that 188 mm/yr is available for recharge where there is no run-off and 145 mm/yr where run-off is accounted for within the calculations.

3.4.5 Aquifer Hydraulic Parameters

No laboratory or field permeability data is available for the Development Area. Hydraulic testing has previously been undertaken on the AWE(A) site by Golders Associates Ltd on the wider Aldermaston site (*Ref 25* after *Ref 24*) and is summarised in *Table 3.3.*

Table 3.3. Permeability of Principal Geological Units of AWE(A)

Geological Unit	Horizontal permeability (m/s)	Vertical permeability (m/s)
Silchester Gravel	10^{-5} to 10^{-6}	-
Claygate Member	10^{-5} to 10^{-6}	10^{-9}
London Clay (undifferentiated)	10^{-9} to 10^{-11}	10^{-11}

3.4.6 Groundwater Abstractions & Source Protection Zones

The minor aquifer formed by the Silchester Gravel and the Bagshot Formation have the potential to be a local source of groundwater supply. The confined Upper Chalk is classified as a major aquifer and provides a water supply regionally.

A total of twelve private and licensed groundwater abstraction sources were identified within 2 km of the AWE Aldermaston Site boundary on the Envirocheck Report for the AWE(A) site (see *Appendix A*). The details of these all abstractions are tabulated in *Appendix D.*

No abstraction sources are located immediately down gradient (i.e. east) of the Development Area. Furthermore, easterly flowing groundwater on the Development Areas flows into other parts of the AWE(A) site before reaching the surface water receptors of the Fish Ponds, approximately 200 m east of the Development Area boundary.

The AWE(A) Site is situated above a Zone 3 (Total Catchment) Source Protection Zone (SPZ) defined for an off site abstraction from the Chalk aquifer. As this SPZ is defined for the chalk aquifer it is considered hydraulically separated from surface activities and shallow groundwater on AWE(A) by the thick low permeability clay deposits of the London Clay.

A replacement water supply abstraction borehole has recently been constructed in the north-west of the Development Area by AWE (See *Drawing JER4214-001a*). This abstraction borehole penetrates through the London Clay into the confined Chalk aquifer at depth.

3.4.7 Groundwater Receptors

Surface water courses situated down gradient of the Development Area are the ultimate receptor for groundwater within the shallow aquifer underlying the Development Area. The nearest surface water bodies to the Development Area are Fish Pond and Stock Pond situated approximately 200 m east of the site boundary. The easterly direction of groundwater flow identified on the contour map presented in *Drawing JER4214-007a* confirms that these ponds are likely to be in hydraulic continuity with the shallow aquifer underlying the Application Site and therefore represent an important receptor to groundwater. The outlet channels from these surface water features flow northwards toward the River Kennet.

No other groundwater dependent features have been identified in the vicinity of the Application Site.

3.4.8 Groundwater Quality

Groundwater within the shallow unconfined aquifer underlying the Development Area is typically neutral in pH, only moderately mineralised although commonly containing some dissolved metals. The use of the shallow unconfined aquifer as a local source of water supply in the vicinity of the AWE(A) attest to its generally potable nature, although some contaminants are identified, generally occasionally, as a result of historical land-use practices on the site. Groundwater quality on the site is described in detail in *Section 7.2.1* and summarised in *Table 7.3* and *Table 7.4*.

4 Baseline Conceptual Site Model

4.1 Introduction

A Conceptual Site Model (CSM) has been produced for the Hydrus Development on the basis of the Environmental Site Setting presented in *Section 3*. The 'baseline' CSM is based on the existing ground conditions, geology, hydrogeology and hydrology and identifies key pollutant linkages currently associated with the site. The baseline CSM is presented in *Drawing JER4214-008a*, summarised along a west to east transect following the presumed groundwater flow direction.

A modified CSM is presented in *Section 9* for the construction and post-construction phase of the Hydrus Development. The modified CSM is based on the baseline CSM, but incorporates the key impacts that the proposed development is anticipated to have on physical site hydrogeology and pollutant linkages thereon.

4.2 Overview of the CSM

The Silchester Gravels and Bagshot Formation underlie the entire Application Site, beneath a veneer of Made Ground and top soil. The Silchester Gravel and more granular, upper horizons of the Bagshot Formation constitute a shallow, unconfined granular aquifer unit that is exploited for water supply in the local area. The unconfined aquifer is perched on low permeability horizons in the Bagshot Beds and the underlying London Clay. Although is basal elevation of the shallow unconfined aquifer underlying the Development Area is poorly constrained, it is generally thin and unlikely to be significantly greater than 5 m thick.

Groundwater is located at shallow depth, between 1.4 mbGL and 3.1 mbGL. Groundwater flows in the shallow unconfined aquifer is general in easterly direction, towards the Fish Pond situated approximately 200m down gradient (i.e. east) of the Development Area site boundary. Vertical flow through the London Clay to the underlying Chalk is negligible considering the thickness of this low permeability unit on the site (greater than 60 m).

In the absence of significant hard-standing across the Development Area, recharge to shallow aquifer is principally derived from surface precipitation. Lateral inflow onto the site, from up-gradient positions to the west is also an important source of groundwater on the site.

4.3 Pollutant (Source-Pathway-Receptor) Linkages

4.3.1 Introduction

In accordance with national guidance the risk assessment process is based on the principal of pollutant (source-pathway-receptor) linkages, as described in *Section 2.2*. All potential contaminant sources, pathways and linkages are described below and the pollutant linkages for the Application Site summarised in *Table 4.1*.

4.3.2 Sources

The following potential contamination sources have been identified from a review of historical reports and following baseline environmental characterisation of the site:

- Explosive residue, solvent, polymers contamination in soils and groundwater associated with historical operations within buildings (B3A25, B3A26, B3A28, B3C7, and B9C10, shown on *Drawing JER4214-002a*);
- Hydrocarbon contamination in soils and groundwater associated with previous operations within building B9N10, towards the centre of the Development Area (*Drawing JER4214-002a*);
- Potential chemical contamination associated with ad hoc disposal of chemicals associated with previous operations within building F26.5 in east of the Development Area.
- Asbestos in soils;
- Contaminants in the shallow groundwater aquifer associated with historical operations within buildings (including explosive residues, solvent, polymers, hydrocarbon and other chemical contamination);
- Toxic vapours generated by Volatile Organic Hydrocarbons (VOC); and,
- Radiological contamination in soil and groundwater associated with other AWE operations at the AWE (A) Site.

The risk assessments undertaken in subsequent sections will take into consideration the previous potential contamination sources identified based on the proposed development as commercial / industrial end use and in consideration of the site specific baseline conditions.

4.3.3 Pathways

Potential pathways have been identified for the purpose of risk assessments:

- Inhalation, dermal contact, and ingestion of soils and dust with radiological and non radiological contaminants by humans (including future site users, general public and construction workers);
- Direct (whole body) exposure to high energy beta and gamma radiation;
- Inhalation of volatile organic compounds;
- Explosion or asphyxiation as a result of the accumulation of soil / ground gases;
- Migration of leachable soil contaminants to groundwater;
- Discharges from surface water runoff; and
- Off-site migration of contamination through the shallow unconfined aquifer underlying the Application Site.

4.3.4 Receptors

In consideration of the proposed development the following potential site receptors have been identified that could be impacted by contamination.

Human Health

- AWE staff;
- AWE visitors and site users; and
- Construction staff; and

Controlled Waters

- Shallow groundwater and abstractions boreholes; and
- Surface waters dependant on groundwater, surface drainage or runoff.

4.3.5 Summary of Pollutant (SPR) Linkages

The pollutant (SPR) linkages identified on the site are summarised *Table 4.1*.

Table 4.1. Summary of Pollutant (SPR) Linkages

Source	Pathway	Receptor	Risk	Notes
Chemical contamination in soils relating to historical land use	Ingestion of soil / dust	Future site users (including AWE staff and visitors)	Low	Risks are low to negligible for site visitors due to far less time spent on site
Chemical contamination in soils relating to historical land use	Ingestion of soil / dust	Construction Workers (and ground workers involved in subsequent housekeeping)	Moderate to Low	Risks managed through SSoW / CDM 2007
Chemical contamination in soils relating to historical land use	Dermal Contact with soil / dust	Future site users (including AWE staff and visitors)	Low	Risks are low to negligible for site visitors due to far less time spent on site
Chemical contamination in soils relating to historical land use	Dermal Contact with soil / dust	Construction Workers (and ground workers involved in subsequent housekeeping)	Moderate to Low	Risks managed through SSoW / CDM 2007
Asbestos in soils	Disturbance and inhalation of asbestos fibres	Future Site Users (including AWE staff and visitors)	Low	Risks are low to negligible for site visitors due to far less time spent on site
Asbestos in soils	Inhalation of asbestos fibres	Construction Workers (and ground workers involved in subsequent housekeeping)	Moderate to Low	Previous investigations have identified asbestos on AWE (A) as a result of ad hoc tipping. Risks managed through SSoW / CDM 2007
Buried Unexploded Ordnance	Disturbance causing explosive risk	Construction Workers (and ground workers involved in subsequent housekeeping)	Low	Risks managed through SSoW / CDM 2007
Explosive residue contamination within soils	Ingestion / dermal contact	Future Site Users (including AWE staff and visitors)	Negligible	
Explosive residue contamination within soils	Ingestion / dermal contact	Construction Workers (and ground workers involved in subsequent housekeeping)	Low to Negligible	Risks managed through SSoW / CDM 2007

Table 4.1. Summary of Pollutant (SPR) Linkages (Continued)

Source	Pathway	Receptor	Risk	Notes
Explosive residues within soils	Disturbance causing explosive risk	Future Site Users (including AWE staff and visitors) and Construction Workers	Negligible	-
Radioactive contamination in soils	Inhalation / Ingestion / Dermal contact / Direct Exposure	Future Site Users (including AWE staff and visitors)	Negligible	-
		Construction Workers (and ground workers involved in subsequent housekeeping)	Negligible	Risks managed through SSoW / CDM 2007
Chemical contamination of soils relating to historical land use.	Shallow unconfined groundwater	Off-site groundwater and Fish Pond	Moderate	-
	Dermal contact or inhalation from disturbed soils	Construction Workers during development of the site	Moderate	Exposure during construction.
Chemical contamination (including explosive residue) and radiological contamination of shallow groundwater relating to historical land use.	Shallow unconfined groundwater	Off-site groundwater and Fish Pond	Moderate	-
	Dermal contact or inhalation of shallow unconfined groundwater	Construction Workers during development of the site	Moderate	Exposure possible if water table is intercepted during development.
Volatile Organic Carbons in Soil and/or Groundwater	Volatilisation and migration through unsaturated / soil zone	Site Users / Site Workers	Low	No obvious sources. Buildings demolished 1 or 2 years ago.

Table 4.1. Summary of Pollutant (SPR) Linkages (Continued)

Source	Pathway	Receptor	Risk	Notes
Soil Gas / Landfill Gas	Migration of gases through underlying soils and accumulation of gases within the proposed development causing explosive risk	Future Site Users (including AWE staff and visitors)	Low	Implementation of protection measures within development foundations in alignment with CIRIA guidance Report (Ref. 47) up to CS2
Soil Gas / Landfill Gas	Migration of gases through underlying soils and accumulation of gases within the proposed development causing risk of asphyxiation	Future Site Users (including AWE staff and visitors)	Low	Implementation of protection measures within development foundations in alignment with CIRIA guidance Report (Ref. 47) up to CS2
Soil Gas / Landfill Gas	Migration of gases through underlying soils and accumulation of gases within OFF SITE developments causing risk of explosion / asphyxiation	Future Site Users (including AWE staff and visitors)	Negligible	Limited proximity of development to other buildings and much of the surrounding land is soft landscaping allowing natural dissipation of any gases into the atmosphere
Previously unidentified contamination (including asbestos)	Ingestion / dermal contact/ Inhalation	Construction Workers (and ground workers involved in subsequent housekeeping)	Low	Risks managed through SSoW / CDM 2007
Previously unidentified ordnance	Explosive risk	Construction Workers (and ground workers involved in subsequent housekeeping)	Low to Negligible	Risks managed through SSoW / CDM 2007

4.4 Technical Assessments

To determine the risk posed by the pollutant linkages tentatively identified on the site, the following risk assessments have been undertaken and are summarised in the subsequent chapters:

- Human Health Risk Assessment (including explosives);
- Radiological Risk Assessment (including human health and groundwater);
- Controlled Water Risk Assessment;
- Gas Risk Assessment.

5 Human Health Risk Assessment

5.1 Introduction

5.1.1 Contaminated Land Risk Assessment Approach

Part IIA of the Environmental Protection Act (*Ref 5*) sets out the key requirements for establishing the significance of any harm to health and the principles of risk assessment associated with land contamination. The risks posed from land contamination are also a material consideration for Planning Authorities when developing structures or local plans and when considering applications for planning permission. Both Part IIA and the planning regime embrace the “suitable for use” approach. Part IIA is intended to compliment the planning regime in requiring action to be taken when unacceptable risks to health or the environment arise, taking into account the current use of the land and its environmental setting.

DEFRA and the Environment Agency have published technical guidance regarding the assessment of risks to health from soil contamination setting out basic principles, which the regulators would normally intend to use in the assessment and management of environmental risks and which are recommended for all public-domain risk assessments. They are intended to provide decision-makers, practitioners and the public with a consistent language and approach for environmental risk assessment and management.

At the time of writing, the assessment of risks to human health in the UK from the presence of soil contamination is in a transitory state. Until 2008, the Contaminated Land Report (CLR) series of documents CLR 7 to 11 (*Ref 3*) and CLEA UK software package (*Ref 26*) were utilised within the context of its intended use by DEFRA and the Environment Agency in providing relevant, appropriate, authoritative, and scientifically based information and advice on the assessment of risks arising from the presence of contamination in soils. In 2008, these documents (with the exception of CLR11) and CLEA UK were formally withdrawn by DEFRA and the EA as well as associated Soil Guideline Values (SGV) and TOX reports that formed the basis of human health risk assessment.

Updated guidance (*Ref 27* and *Ref 28*) as well as a new software package have been subsequently issued, but limited SGV and TOX data are available to enable risks to human health to be assessed using the new methodology.

In July 2009 LQM, in association with the CIEH, derived Generic Assessment Criteria (GAC) for an extensive range of contaminants based upon the new CLEA 1.04 model (*Ref 26*). These GAC cover most of the remaining common soil contaminants for which there are currently no SGV reports available.

5.1.2 Site Conceptualisation

The assessment has been undertaken within the context of planning application, and as for Part IIA, the first stage of risk assessment requires the development of a CSM to identify potential contamination sources, and critical pathways that could pose a risk to site receptors based on the development 'end use'.

The CSM must also consider whether sample analysis data from specific site areas should undergo assessment of risks posed from potential contamination separately from all other sample analysis data ('zoning'). This may be appropriate if it is known that an area of site may provide a different 'data set' of sample analysis data such as:

- through previous contamination incidents; or,
- differing *in-situ* environments (e.g. samples obtained from surface depths of less than 1m (or perhaps from Made Ground) compared to samples obtained from depths of 1m or greater (or perhaps from natural strata)).

5.2 RPS Risk Assessment Approach

RPS has used a 'tiered' risk assessment approach in alignment with guidance published by DEFRA and the Environment Agency. Science Reports SR2 and SR3 (*Ref 27* and *Ref 28*) provide technical and policy basis for the derivation of Soil Guideline Values (SGV), and establish the exposure parameters and health criteria values that are consistent with the UK approach to identifying appropriate assessment criteria. The dataset used in this assessment is provided in electronic form in *Appendix E*.

A number of contaminants such as barium, silver and tin have been excluded from the risk assessment process as it generally considered that they are of low toxicity to humans.

5.2.1 Tier 1 – Qualitative Risk Assessment

This stage qualitatively identifies each of the three components that are present on site with regards to the contamination Source-Pathway-Receptor (SPR) linkage, which forms the basis of the UK risk assessment approach as discussed in *Section 4.1*. Site redevelopment will be for a commercial / industrial end use the risk assessment has been based on this end use scenario.

5.2.2 Tier 2 – Comparison of the Data Using SGV and GAC

The Tier 2 risk assessment aims to identify contaminants of concern and their spatial distribution and requires generic benchmarks against which to compare the levels of soil contaminants. The exceedance of a benchmark suggests that a particular contaminant may pose an unacceptable risk to human health, and further risk assessment is required.

This requires the comparison of site soil contaminant concentrations with Soil Guideline Values (SGV) that have been published by the Environment Agency (*Ref 29*). Where no SGV is available for a particular contaminant, the soil concentrations are compared against the Generic Assessment Criteria (GAC) published by LQM/CIEH (*Ref 30*) that have been derived using the CLEA framework.

For those contaminants where no updated SGV have been issued or are not included within the LQM/CIEH document, site data is compared against old SGV and GAC that have been derived from the former CLEA (UK) model as a tentative screening tool only. This comparison provides the risk assessor with an indication as to whether a particular contaminant may or may not pose a risk to human health and whether additional assessment is required.

To enable a robust assessment of the data and in accordance with best practice methodology, where there is sufficient data (i.e. a data set consisting of 3 or more samples) a maximum value test has been undertaken to identify any statistical outliers that are not representative of typical conditions at the site. Any identified outliers are considered independently of the remaining dataset as they potentially represent a separate population. A mean value test has also been undertaken for soils that will be in the top 1.00m following redevelopment to identify the 'average' conditions at the site. The mean value test calculates a parameter called the 95% Upper Confidence Limit (95% UCL) which statistically represents a concentration which any further samples would be expected to be below with a 95% level of confidence. The use of the 95% UCL reflects the best practice guidance outlined in CLR11 *(Ref 3)*.

Where SGV are exceeded or where screening against GAC indicate a potential risk to human health, there needs to be consideration for undertaking further more detailed human health risk assessment including utilising more site specific information when formulating risk threshold criteria (such as contaminant toxicological characteristics, migration mechanisms and exposure pathways). An exceedance of the derived risk threshold criteria may suggest that remediation is required to mitigate risks posed to human health.

5.3 Tier 1 – Qualitative Risk Assessment

The human health risks have been assessed based on a long-term exposure to contamination as per a proposed industrial / commercial development involving attendance by staff and site visitors. The principal exposure pathways are described in *Table 4.1* and include:

- Ingestion of soil and dust;
- Dermal contact with soil and dust;
- Inhalation of outdoor air from soil volatilisation; and
- Inhalation of indoor air from soil volatilisation.

5.4 Tier 2 – Generic Risk Assessment

Based on the proposed development and associated exposure pathways, the site has been zoned for assessment into 2 areas as follows:

- The Development Area; and,
- The central area construction enclave (CACE).

This section provides a comparison of soil analysis data from previous ground investigations undertaken within the Development Area against the appropriate SGV and GAC to assess if there is an unacceptable risk to the health of future site occupants in the proposed development and/or to construction workers involved in redevelopment activities. Management of risks from land contamination within the CACE will be discussed separately in *Section 5.5*.

The proposed development activities will involve excavation of soils to varying depths across the Development Area, and their removal as waste as outlined on *Drawing JER4214-004a*. As such, the human health risk assessment has concentrated upon identifying contamination that will remain *in situ* following redevelopment activities that will potentially represent a significant risk to future site occupants. The potential risks posed to construction workers from the waste soils removed, and any potential required mitigation measures are discussed within *Section 5.6*.

Soil data from the Development Area has been further split into two groups based upon the considered risk of exposure to future site occupants:

- Soil samples that will be in the top 1.00 mbGL following redevelopment; and,
- Soil samples that will be at depths greater than 1.00mbGL following redevelopment.

Drawing JER4214-005a outlines final redevelopment levels (mAOD) for the Development Area.

Contaminants within the top 1.00 mbGL based on proposed finish levels (*Drawing JER4214-005a*) are considered to have the potential to represent an unacceptable risk to future site occupants, especially within the top 0.60 mbGL ('the soil mixing zone' (*Ref 31*)) where migration of contamination to the surface over time by natural mechanisms is likely. It is considered that non-volatile contamination buried at a depth of greater than 1.00mbGL is unlikely to represent a significant risk to human health so long as it remains undisturbed. Volatile contaminants (such as hydrocarbons and mercury) in soils deeper than 1.00 mbGL have the potential to migrate vertically to the surface, and thus have the potential to represent a risk to future site occupants.

To identify any contamination at depths greater than 1.00mbGL that has the potential to represent a risk to human health (either due to migration of volatile contamination to the surface or through future ground disturbance), maximum concentrations of determinands from depths greater than 1.00 mbGL will be compared directly against risk threshold criteria.

The followings sections provide a summary of the data assessment undertaken for all key chemical contaminants.

5.4.1 Inorganic Contaminants in Soil within the Development Area

Soils at Depths Less than 1.00 mbGL following Development

Table 5.1 provides a summary of the inorganic analysis undertaken upon soil samples that will remain at depths less than 1.00 mbGL following the proposed site redevelopment.

Table 5.1. Inorganic Analysis of Soils that will be at Depths Less than 1.00 mbGL Following Redevelopment

Determinand	No. of Samples >LOD/ No. of Samples Tested	Concentration Range (mg/kg)				SGV / GAC [1, 5] (mg/kg)	Is 95% UCL Greater than SGV / GAC?	No. of Outliers	Concentration (mg/kg) & Location of Outliers[5]
		Min	Max	Location of Max[5]	95% UCL[3]				
Arsenic	14/22	<1	14	TP1008 @ 0.50mbGL	8.32	640 [1]	N	3	11 - R1003 @ 0.50mbGL 12 – BH0333 @ 0.00mbGL 14 – TP1008 @0.50mbGL
Beryllium	2/19	<0.3	0.4	BAETP4 @ 0.30mbGL	-	420[4]	-	0	0
Cadmium	0/22	<0.3	<1	N/A	-	230 [1]	N	0	0
Chromium	19/22	<3	30	TP1001 @ 0.50mbGL	15.46	30,400 [4]	N	0	0
Lead	21/22	<3.5	38	BAEBH2 @ 0.20mbGL	18.76	750 [2]	N	2	38 – BAEBH2 @ 0.20mbGL 26 – TP0914 @ 0.10mbGL
Mercury	0/22	<0.1	<1	N/A	-	3600 [1]	N	0	0
Nickel	17/22	<0.9	8.2	CP1003 @ 0.50mbGL	5.46	1800 [1]	N	0	0
Selenium	2/22	<0.3	2	TP0914 @ 0.10mbGL	-	13,000 [1]	N	0	0
Vanadium	18	2.2	41	R1003 @ 0.50mbGL	22.06	3160[4]	-	0	0
Zinc	21/22	2.6	386.1	WSHYD-05 @ 0.35-0.70mbGL	111.55	665,000[4]	-	2	386.1 - WSHYD-05 @ 0.35-0.70mbGL 54 - TP0914 @ 0.10mbGL

Notes: Value in **bold** exceeds the derived screening criteria.

1. SGV provided by The Environmental Agency's recent publication Science Report SC050021 (*Ref 29*).
2. Historical SGV (*Ref 32*).
3. Calculation is based on the arithmetic mean. The methodologies used to derive the SGV for lead utilise the geometric rather than the arithmetic mean. This methodology uses the logged data. All 95th percentile values include outlier sample analysis results.
4. LQM GAC for HHRA (*Ref 30*).
5. Sample depths correspond to depth prior to redevelopment.

For all the determinands analysed the 95% UCL was identified to be below the SGV/GAC which indicates that typical levels of inorganic determinands that are to remain in the top 1.00 mbGL following redevelopment do not represent a significant risk to future site occupants.

As outlined in *Table 5.1*, statistical outliers have been identified for arsenic (3 total), lead (2 total) and zinc (2 total). In each instance, the concentrations detected are significantly below the respective SGV/GAC and are therefore not considered to represent a significant risk to future site occupants.

Soils at Depths Greater than 1.00mbGL Following Redevelopment

Table 5.2 provides a summary of the inorganic analysis undertaken upon soil samples that will remain at depths greater than 1.00 mbGL following the proposed site redevelopment.

Table 5.2. Inorganic Analysis of Soils that will be at Depths Greater than 1.00 mbGL Following Redevelopment

Determinand	No. of Samples >LOD/ No. of Samples Tested	Concentration Range (mg/kg)			SGV / GAC [1, 3] (mg/kg)	No. of Samples >SGV (Sample ID)
		Min	Max	Location of Max		
Arsenic	58/87	<1	117	BAEBH3 @ 2.40mbGL	640 [1]	0
Barium	47/51	<6	49	ENV001 @ 1.20mbGL	Not Toxic	-
Beryllium	19/52	<0.3	2.5	BAEBH3 @ 2.40mbGL	420	0
Boron	22/87	<0.3	3	BAETP5 @ 2.80mbGL	192,000	-
Cadmium	7/87	<0.1	2	BH0903 @ 5.00mbGL	230 [1]	0
Chromium	80/87	<1	60	BH0912 @ 3.00mbGL	30,400 [3]	0
Copper	70/87	<1	58	CP1002 @ 3.50mbGL	71,700	-
Lead	83/87	<1	37	BAEBH3 @ 2.40mbGL	750 [2]	0
Mercury	1/87	<0.05	0.1	BAEBH3 @ 2.40mbGL	3600 [1]	0
Nickel	80/87	<0.9	77	BH0903 @ 5.00mbGL	1800 [1]	0
Selenium	17/87	<0.3	2	TP0913 & TP0923 @ 1.00mbGL	13,000 [2]	0
Vanadium	51/51	1.8	98	CP1003 @ 2.20mbGL	3160	0
Zinc	85/87	<2.5	267	BH0903 @ 5.00mbGL	665,000	-

Notes: Value in bold exceeds the derived screening criteria.

1. SGV provided by The Environment Agency's recent publication Science Report SC050021 (*Ref 29*)
2. Historical SGV (*Ref 32*)
3. LQM GAC HHRA (*Ref 30*)

None of the samples analysed from depths greater than 1.00 mbGL exhibited concentrations of inorganic determinands in excess of the respective SGV/GAC. This indicates that concentrations of determinands in soils that will be at depths greater than 1.00 mbGL following redevelopment do not represent a significant risk to future site users, even if they become disturbed in the future.

5.4.2 Total Petroleum Hydrocarbons and BTEX in Soils within the Development Area

Soils at Depths Less than 1.00 mbGL following Development

Table 5.3 provides a summary of the banded TPH and BTEX analysis undertaken upon soils that will remain at depths less than 1.00 mbGL following redevelopment. The majority of samples were found to exhibit concentrations below the laboratory Limit of Detect (LOD). As such, comparison against SGV/GAC has been undertaken on a sample by sample basis.

Table 5.3. TPH and BTEX Analysis of Soils that will be at Depths Less than 1.00 mbGL Following Redevelopment

Determinand	No. of Samples >LOD/ No. of Samples Tested	Concentration Range (mg/kg)			SGV / GAC [1, 2] (mg/kg)	Is Max Value Greater than SGV / GAC?
		Min	Max	Location of Max		
Aliphatics >C5 - C6	0/16	<0.01		-	3400 [2]	N/A
Aliphatics >C6 - C8	0/16	<0.01		-	8300 [2]	N/A
Aliphatics >C8 - C10	0/19	<0.01		-	2100 [2]	N/A
Aliphatics >C10 - C12	0/19	<0.01		-	10,000 [2]	N/A
Aliphatics >C12 - C16	0/19	<0.01		-	61,000 [2]	N/A
Aliphatics >C16 - C21	0/19	<0.01		-	1,600,000 [2]	N/A
Aliphatics >C21 - C35	0/19	<0.01		-	1,600,000 [2]	N/A
Aromatics >C6 – C7	0/16	<0.01		-	28,000 [2]	N/A
Aromatics >C7 - C8	0/16	<0.01		-	59,000 [2]	N/A
Aromatics >C8 - C10	0/19	<0.01		-	3700 [2]	N/A
Aromatics >C10 - C12	0/19	<0.01		-	17,000 [2]	N/A
Aromatics >C12 - C16	1/19	<0.01	6.6	TP1008 @ 0.50mbGL	36,000 [2]	N
Aromatics >C16 - C21	4/19	<0.01	36.0	TP1008 @ 0.50mbGL	28,000 [2]	N
Aromatics >C21 - C35	7/19	<0.01	220	TP1008 @ 0.50mbGL	28,000 [2]	N

Notes:

1. SGV provided by The Environment Agency's recent publication Science Report SC050021 (*Ref 29*).
2. LQM GAC HHRA (*Ref 30*) including conservative assumptions of 1% soil organic matter (SOM) content.

Table 5.3. TPH and BTEX Analysis of Soils that will be at Depths Less than 1.00 mbGL Following Redevelopment (Continued)

Determinand	No. of Samples >LOD/ No. of Samples Tested	Concentration Range (mg/kg)			SGV / GAC [1, 2] (mg/kg)	Is Max Value Greater than SGV / GAC?
		Min	Max	Location of Max		
Benzene	0/37	<0.02		-	95 [1]	N/A
Toluene	0/37	<0.10		-	4400 [1]	N/A
Ethylbenzene	0/37	<0.10		-	2800 [1]	N/A
m/p/o xylene	0/37	<0.10		-	2600 [1]	N/A

Notes:

1. SGV provided by The Environment Agency's recent publication Science Report SC050021 (*Ref 29*).

2. LQM GAC HHRA (*Ref 30*) including conservative assumptions of 1% soil organic matter (SOM) content.

The maximum concentrations of TPH and BTEX did not exceed the respective GAC/SGV screening criteria. This indicates that levels of TPH and BTEX that will remain in the top 1.00 mbGL following redevelopment do not represent a significant risk to future site occupants.

Soils at Depths Greater than 1.00mbGL Following Redevelopment

Table 5.4 provides a summary of the banded TPH and BTEX analysis undertaken upon soils that will remain at depths greater than 1.00 mbGL following redevelopment.

Table 5.4. TPH and BTEX Analysis of Soils that will be at Depths Greater than 1.00 mbGL Following Redevelopment

Determinand	No. of Samples >LOD/ No. of Samples Tested	Concentration Range (mg/kg)			SGV / GAC [1, 2] (mg/kg)	No. of Samples >SGV (Sample ID)
		Min	Max	Location of Max		
Aliphatics >C6 - C8	0/48	<0.01		-	3400 [2]	0
Aliphatics >C8 - C10	0/48	<0.01		-	8300 [2]	0
Aliphatics >C10 - C12	0/49	<0.01		-	2100 [2]	0
Aliphatics >C12 - C16	2/49	<0.01	39.0	39.0 (R1005 @ 3.50mbGL)	10,000 [2]	0
Aliphatics >C16 - C21	2/49	<0.01	6.66	6.66 (BHHYD-01 @ 14.00mbGL)	61,000 [2]	0
Aliphatics >C21 - C35	3/49	<0.01	47.7	47.7 (BHHYD-01 @ 14.00mbGL)	1,600,000 [2]	0
Aromatics >C6 – C7	0/48	<0.01		-	28,000 [2]	0
Aromatics >C7 - C8	0/48	<0.01		-	59,000 [2]	0
Aromatics >C8 - C10	0/48	<0.01		-	3700 [2]	0
Aromatics >C10 - C12	0/49	<0.01		-	17,000 [2]	0
Aromatics >C12 - C16	1/49	<0.01	0.99	0.99 (CP1003 @ 1.50mbGL)	36,000 [2]	0
Aromatics >C16 - C21	2/49	<0.01 – 0.99	0.99	0.99 (ENV001 @ 1.20mbGL)	28,000 [2]	0
Aromatics >C21 - C35	3/49	<0.01 – 15.5	15.5	15.5 (BHHYD-01 @ 14.00mbGL)	28,000 [2]	0
Benzene	0/105	<0.02		-	95 [1]	0
Toluene	0/105	<0.10		-	4400 [1]	0
Ethylbenzene	0/105	<0.10		-	2800 [1]	0
m/p/o xylene	0/105	<0.10		-	2600 [1]	0

Notes:

1. SGV provided by The Environment Agency's recent publication Science Report SC050021 (*Ref 29*).
2. LQM GAC HHRA (*Ref 30*) including conservative assumptions of 1% soil organic matter (SOM) content.

The maximum concentrations of TPH and BTEX did not exceed the respective GAC/SGV screening criteria. This indicates that levels of TPH and BTEX that will remain at depths greater than 1.00 mbGL following redevelopment pose a negligible risk to future site occupants.

5.4.3 Polycyclic Aromatic Hydrocarbons in Soils within the Development Area

Soils at Depths Less than 1.00mbGL Following Redevelopment

Table 5.5 provides a summary of the PAH analysis undertaken upon soil samples that will remain at depths less than 1.00 mbGL following redevelopment.

Table 5.5. PAH Analysis of Soils that will be at Depths Less than 1.00 mbGL Following Redevelopment

Determinand	No. of Samples >LOD/ No. of Samples Tested	Concentration Range (mg/kg)				GAC(1) (mg/kg)	Is 95% UCLGre ater than GAC?	No. of Outliers (Sample ID)	Concentration (mg/kg) & Location of Outliers
		Min	Max	Location of Max	95% UCL				
Acenaphthene	3/24	<0.1	7.79	(TP0914 @ 0.10mbGL)	2.04	85,000	No	1	7.79 (TP0914 @ 0.10mbGL)
Acenaphthylene	2/24	<0.1	44.44	(TP0914 @ 0.10mbGL)	10.20	84,000	No	1	44.44 (TP0914 @ 0.10mbGL)
Anthracene	4/24	<0.1	68.03	(TP0914 @ 0.10mbGL)	15.54	530,000	No	1	68.03 (TP0914 @ 0.10mbGL)
Benzo(a) anthracene	7/24	<0.1	54.44	(TP0914 @ 0.10mbGL)	12.65	90	No	1	54.44 (TP0914 @ 0.10mbGL)
Benzo(a) pyrene	7/24	<0.1	41.77	(TP0914 @ 0.10mbGL)	9.82	14	No	1	**41.77 (TP0914 @ 0.10mbGL)**
Benzo(b) fluoranthene	7/24	<0.1	61.18	(TP0914 @ 0.10mbGL)	14.15	100	No	1	61.18 (TP0914 @ 0.10mbGL)
Benzo(ghi) perylene	5/24	<0.1	14.50	(TP0914 @ 0.10mbGL)	3.94	650	No	1	14.50 (TP0914 @ 0.10mbGL)
Benzo(k) fluoranthene	6/24	<0.1	24.22	(TP0914 @ 0.10mbGL)	5.77	140	No	1	24.22 (TP0914 @ 0.10mbGL)
Chrysene	7/24	<0.1	46.84	(TP0914 @ 0.10mbGL)	10.94	140	No	1	46.84 (TP0914 @ 0.10mbGL)
Dibenzo(a,h) anthracene	3/24	<0.1	4.57	(TP0914 @ 0.10mbGL)	1.81	13	No	1	4.57 (TP0914 @ 0.10mbGL)
Indeno(1,2,3-c,d) pyrene	5/24	<0.1	13.73	(TP0914 @ 0.10mbGL)	3.75	60	No	1	13.73 (TP0914 @ 0.10mbGL)
Fluoranthene	8/24	<0.1	128.37	(TP0914 @ 0.10mbGL)	29.46	23,000	No	1	128.37 (TP0914 @ 0.10mbGL)
Fluorene	3/24	<0.1	41.01	(TP0914 @ 0.10mbGL)	9.43	64,000	No	1	41.01 (TP0914 @ 0.10mbGL)
Naphthalene	2/42	<0.1	23.63	(TP0914 @ 0.10mbGL)	3.21	200	No	1	23.63 (TP0914 @ 0.10mbGL)
Phenanthrene	7/24	<0.1	100.96	(TP0914 @ 0.10mbGL)	22.96	22,000	No	1	100.96 (TP0914 @ 0.10mbGL)
Pyrene	7/24	<0.1	98.65	(TP0914 @ 0.10mbGL)	22.70	54,000	No	1	98.65 (TP0914 @ 0.10mbGL)

Notes:

Outliers highlighted in **bold** indicate exceedances of the relevant GAC / SGV.

1. LQM GAC HHRA (*Ref 30*) including conservative assumptions of 1% soil organic matter (SOM) content.

The 95% Upper Confidence Limit (UCL) for each of the individual PAH did not exceed the respective GAC screening criteria. This indicates that typical levels of PAH that will remain in the top 1.00 mbGL following redevelopment do not represent a significant risk to future site occupants.

Sample TP0914 @ 0.10 mbGL (which was identified as a statistical outlier for all of the individual PAH) demonstrated a benzo(a)pyrene concentration (41.77 mg/kg) in excess of the RPS GAC of 14 mg/kg. The ground conditions identified in the borehole log do not identify any potential contamination source (e.g. tarmac, coal), that may be responsible for the detected elevated levels of PAH at this location. Based on the absence of elevated levels of PAH in adjacent ground investigation locations in this part of the site, it is considered that the benzo(a)pyrene contamination detected at Trial Pit TP0914 is likely to be isolated.

It should be noted that since this assessment was undertaken, the red line boundary has changed and Trial Pit TP0914 now lies outside of the proposed Development Area. Consequently, the identified benzo(a)pyrene contamination is not considered to represent a significant risk to human health in the proposed development It is considered, however, that independently of this EA, AWE may nonetheless want to investigate the levels of benzo(a)pyrene contamination at this location to assess the risk posed to site occupants and controlled water and ensure its appropriate management.

Soils at Depths Greater than 1.00mbGL Following Redevelopment

Table 5.6 provides a summary of the PAH analysis undertaken upon soil samples that will remain at depths greater than 1.00 mbGL following redevelopment.

Table 5.6. PAH Analysis of Soils that will be at Depths Greater than 1.00 mbGL Following Redevelopment.

Determinand	No. of Samples >LOD/ No. of Samples Tested	Concentration Range (mg/kg)			GAC [1] (mg/kg)	No. of Samples >GAC (Sample ID)
		Min	Max	Location of Max		
Acenaphthene	29/92	<0.1	2.436	TP0916 @ 1.00mbGL	85,000	0
Acenaphthylene	29/92	<0.1	4.495	TP0917 @ 2.00mbGL	84,000	0
Anthracene	29/92	<0.1	6.417	TP0916 @ 1.00mbGL	530,000	0
Benzo(a)pyrene	29/92	<0.1	11.590	TP0916 @ 1.00mbGL	14	0
Benzo(a)anthracene	30/92	<0.1	14.538	TP0916 @ 1.00mbGL	90	0
Benzo(b)fluoranthene	29/92	<0.1	11.018	TP0916 @ 1.00mbGL	100	0
Benzo(k)fluoranthene	29/92	<0.1	4.960	TP0916 @ 1.00mbGL	140	0
Benzo(ghi)perylene	29/92	<0.1	7.415	TP0916 @ 1.00mbGL	650	0
Chrysene	29/92	<0.1	13.331	TP0916 @ 1.00mbGL	140	0
Dibenzo(a,h)anthracene	26/92	<0.1	2.067	TP0916 @ 1.00mbGL	13	0
Indeno(1,2,3-c,d)pyrene	29/92	<0.1	7.771	TP0916 @ 1.00mbGL	60	0
Fluoranthene	31/92	<0.1	20.306	TP0916 @ 1.00mbGL	23,000	0
Fluorene	29/92	<0.1	3.759	TP0916 @ 1.00mbGL	64,000	0
Naphthalene	29/148	<0.1	3.487	TP0917 @ 2.00mbGL	200	0
Pyrene	31/92	<0.1	19.297	TP0916 @ 1.00mbGL	54,000	0
Phenanthrene	30/92	<0.1	22.834	TP0916 @ 1.00mbGL	22,000	0

Notes:

1. LQM GAC HHRA (*Ref 30*) including conservative assumptions of 1% soil organic matter (SOM) content.

None of the samples exceeded the GAC screening criteria for any of the PAH. This indicates that levels of PAH that will remain at depths greater than 1.00 mbGL following redevelopment pose a negligible risk to human health.

5.4.4 Asbestos

No asbestos analysis has been undertaken upon soils that will remain in-situ within the Development Area following redevelopment. Due to known historical tipping activities at AWE(A) and the identification of asbestos in shallow soils elsewhere at the AWE(A) site, the presence of asbestos within shallow soils cannot be discounted. As such, the potential remains for asbestos to be present in areas that have not been subject to investigation, which should be accounted for in the *Remediation Statement*.

5.4.5 Summary of Tier 2 Generic Risk Assessment

For all determinands analysed, the 95% UCL was found to be at concentrations below the respective SGV/GAC which suggests that average ground conditions within the Development Area do not represent a significant risk to the health of future site users. All outliers identified within the red line boundary of the Development Area were identified at concentrations which did not exceed their respective SGV/GAC and are therefore not considered significant and do not represent a significant risk to the health of future site users.

5.5 Assessment of Soils within the CACE Area

As discussed in *Section 3.1.2* the main consideration in the assessment of risks posed by contaminated soils in the CACE Area is the risk posed to construction workers (i.e. shorter term 'acute' risks). Based on the assessment work undertaken and mitigation measures proposed within the HEFF ES *Section 3.1.2* (*sub section Central Area Construction Enclave (CACE)*) it is considered that adequate protection measures are in place to minimise any potential risks posed to construction workers from soil contamination within the CACE Area during construction phase activities.

As an additional level of assurance, results of soil chemical analysis data for the CACE Area have been screened against SGV/GAC to identify whether any gross contamination has previously been identified that requires consideration in regard to the risks posed to construction workers. Although the mentioned SGV/GAC have been derived based on long term (i.e. chronic) exposure to contamination, this will provide an indication of whether any gross contamination is present that requires further consideration.

A single sample from within the top 1.00 mbGL within the CACE Area has been subject to analysis for potential chemical contamination. Sample CACE_TP5 @ 0.20-0.30 mbGL has been subject to analysis for metals (As, Ba, Be, B, Cd, Cr, Cu, Pb, Hg, Ni, Se, V and Zn), TPH (aliphatic/aromatic split and carbon banding), and BTEX. The majority of determinands were detected below the analysis minimum limit of detection (LOD), and where in excess of the LOD were significantly below the respective SGV/GAC.

As such, the risk posed to construction workers from chemical contamination of soils within the CACE Area is considered to be low, especially when considering that it is not intended to excavate the soils in this area of the site.

5.6 Summary of Risk posed from Soils Proposed to be Excavated

The analysis data collected from samples located in areas proposed to be excavated (as shown in *Drawing JER4214-004a* and *Section 3.1.4)* during site redevelopment, should be used in conjunction with appropriate and representative sampling and analysis to ensure that any soils identified for re-use at the site are of an appropriate quality (and do not pose an unacceptable risk to future site users), or if waste disposal is preferred that the materials are appropriately characterised to support disposal.

To identify any levels of contamination that could potentially pose an unacceptable risk to future site users (and therefore place a restriction upon the re-use of the material on site), maximum concentrations of determinands have been screened against SGV/GAC. This will also enable identification of any levels of contamination that represent a potentially significant risk to construction workers who will come into contact with the soils during site redevelopment.

Soil analysis results for determinands for which there are appropriate SGV/GAC for comparison have been included in this assessment, and are summarised in *Table 5.7* to *Table 5.9.*

Table 5.7. Inorganic Analysis Results for Soils that will be Excavated during Redevelopment

Determinand	No. of Samples >LOD/ No. of Samples Tested	Concentration Range (mg/kg)			SGV / GAC (1, 3) (mg/kg)	No. of Samples >SGV (Sample ID)
		Min	Max	Location of Max		
Arsenic	85/104	<1	77	CP1001 @ 2.70mbGL	640 (1)	0
Barium	55/55	13	290	TP1013 @ 0.20mbGL	Not Toxic	-
Beryllium	22/81	<0.3	2	B3C7SLABSE @ 0.00mbGL	420	0
Boron	86/105	<0.3	2	BH0910 @ 0.00mbGL, BH0911 @ 0.00mbGL & BH0927 @ 0.00mbGL	192,000	0
Cadmium	2/104	<0.3	1.3	CP1001 @ 2.70mbGL	230 (1)	0
Chromium	102/104	<4.5	104	BH0905 @ 0.00mbGL	30,400 (3)	0
Copper	79/105	<2	35	TP1017 @ 0.30mbGL	71,700	0
Lead	98/104	<1	63	BAETP5 @ 0.20mbGL	750 (2)	0
Mercury	7/105	<0.1	2.1	BAEBH1 @ 0.10mbGL	3600 (1)	0
Nickel	86/105	<0.9	18	B3C7SLABNE @ 0.00mbGL & BH0905 @ 0.00mbGL	1800 (1)	0
Selenium	21/105	<0.3	2	11 Sample Locations	13,000 (2)	0
Vanadium	56/56	3	160	CP1001 @ 2.70mbGL	3160	0
Zinc	96/105	<1	58	B3C7SLAB4 @ 0.00mbGL & TP0933 @ 0.10mbGL	665,000	0

Notes: Value in **bold** exceeds the SGV / GAC.

1. SGV provided by The Environment Agency's recent publication Science Report SC050021 (*Ref 29*).

2. Historical SGV (*Ref 32*).

3. LQM GAC HHRA (*Ref 30*).

Table 5.8. TPH and BTEX Analysis Results for Soils that will be Excavated during Redevelopment

Determinand	No. of Samples >LOD/ No. of Samples Tested	Concentration Range (mg/kg)			SGV / GAC (1, 2) (mg/kg)	No. of Samples >SGV (Sample ID)
		Min	Max	Location of Max		
Aliphatics >C6 - C8	0/63	<0.01 (3)		-	3400 (2)	0
Aliphatics >C8 - C10	0/72	<0.01 (3)		-	8300 (2)	0
Aliphatics >C10 - C12	1/72	<0.01	2.4	B9C10SLAB @ 0.00mbGL	2100 (2)	0
Aliphatics >C12 - C16	5/72	<0.01	7.4	R1004 @ 3.50mbGL	10,000 (2)	0
Aliphatics >C16 - C21	14/72	<0.01	22	B3C7SLAB2 @ 0.00mbGL	61,000 (2)	0
Aliphatics >C21 - C35	22/72	<0.01	105	B3C7SLAB2 @ 0.00mbGL	1,600,000 (2)	0
Aromatics >C6 – C7	0/63	<0.01 (3)		-	28,000 (2)	0
Aromatics >C7 - C8	0/63	<0.01 (3)		-	59,000 (2)	0
Aromatics >C8 - C10	0/72	<0.01 (3)		-	3700 (2)	0
Aromatics >C10 - C12	1/72	<0.01	2.6	B9C10SLAB @ 0.00mbGL	17,000 (2)	0
Aromatics >C12 - C16	14/72	<0.01	29	TP1013 @ 0.20mbGL	36,000 (2)	0
Aromatics >C16 - C21	23/72	<0.01	170	TP1009 @ 0.10mbGL	28,000 (2)	0
Aromatics >C21 - C35	39/72	<0.01	950	TP1009 @ 0.10mbGL	28,000 (2)	0
Benzene	0/148	<0.01 (3)		-	95 (1)	0
Toluene	2/148	<0.02	0.005	BH0911 @ 0.00mbGL	4400 (1)	0
Ethylbenzene	1/148	<0.1	0.005	BH0911 @ 0.00mbGL	2800 (1)	0
m/p/o xylene	2/148	<0.1	0.019	BH0911 @ 0.00mbGL	2600 (1)	0

Notes:

1. SGV provided by The Environment Agency's recent publication Science Report SC050021 (*Ref 29*);
2. LQM GAC HHRA (*Ref 30*) including conservative assumptions of 1% soil organic matter (SOM) content;
3. No results identified above laboratory equipment limit of detection (LOD).

Table 5.9. PAH Analysis Results for Soils that will be Excavated during Redevelopment

Determinand	No. of Samples >LOD/ No. of Samples Tested	Concentration Range (mg/kg)			GAC [1] (mg/kg)	No. of Samples >GAC (Sample ID)
		Min	Max	Location of Max		
Acenaphthene	43/120	<0.1	8.72	BH0901 @ 2.00mbGL	85,000	0
Acenaphthylene	42/120	<0.1	41.09	BH0901 @ 2.00mbGL	84,000	0
Anthracene	51/120	<0.1	60.93	BH0901 @ 2.00mbGL	530,000	0
Benzo(a)pyrene	**67/120**	**<0.1**	**44.64**	**BH0901 @ 2.00mbGL**	**14**	**1**
Benzo(a)anthracene	69/120	<0.1	56.57	BH0901 @ 2.00mbGL	90	0
Benzo(b)fluoranthene	66/120	<0.1	64.14	BH0901 @ 2.00mbGL	100	0
Benzo(k)fluoranthene	64/120	<0.1	25.74	BH0901 @ 2.00mbGL	140	0
Benzo(ghi)perylene	58/120	<0.1	15.15	BH0901 @ 2.00mbGL	650	0
Chrysene	67/120	<0.1	52.25	BH0901 @ 2.00mbGL	140	0
Dibenzo(a,h)anthracene	45/120	<0.1	4.12	BH0901 @ 2.00mbGL	13	0
Indeno(1,2,3-c,d)pyrene	59/120	<0.1	14.08	BH0901 @ 2.00mbGL	60	0
Fluoranthene	72/120	<0.1	128.96	BH0901 @ 2.00mbGL	23,000	0
Fluorene	43/120	<0.1	42.64	BH0901 @ 2.00mbGL	64,000	0
Naphthalene	45/196	<0.1	16.63	BH0901 @ 2.00mbGL	200	0
Pyrene	71/120	<0.1	101.98	BH0901 @ 2.00mbGL	54,000	0
Phenanthrene	67/120	<0.1	92.19	BH0901 @ 2.00mbGL	22,000	0

Notes:

Value in **bold** exceeds the SGV / GAC.

1. LQM GAC HHRA (Ref 30) including conservative assumptions of 1% soil organic matter (SOM) content.

Only one SGV/GAC exceedance has been identified for soils that will be excavated during redevelopment; BH0901 @ 2mbGL, which displayed a benzo(a)pyrene concentration of 44.64mg/kg which exceeded the GAC of 14 mg/kg. The remaining data set did not identify any significantly elevated levels of benzo(a)pyrene which would indicate that the identified contamination is isolated and not widespread.

The elevated benzo(a)pyrene concentration detected in soils at location BH901 represents a potential risk to future site users if it is subject to re-use at the site during redevelopment, and therefore during redevelopment it should be delineated and stockpiled separately from other soils and subject to appropriate waste characterisation and disposal. The levels of benzo(a)pyrene detected are not considered to represent a significant risk to construction workers due to the low timeframes for exposure, however, the remaining risk should be managed through implementation of an appropriate Safe System of Work.

Six samples of material that are to be excavated during redevelopment (Samples BHHYD-01 0 – 0.4mbGL, BHHYD-02 0 – 0.4mbGL, BHHYD-03 0 – 0.3mbGL, WSHYD-04 0 – 0.3mbGL, WSYHD-05 0 – 0.45mbGL, WSYHD-06 0 – 0.4mbGL) were subject to asbestos screen analysis and the results did not identify any bulk fibres that would suggest the presence of asbestos contamination.

Based on the available information the risk posed to construction workers from contamination levels in soils that will be excavated during redevelopment are considered to be low, provided that appropriate Safe Systems of Work (SSoW) are implemented to minimise the potential for exposure. This is usually dealt with through adherence to CDM Regulations 2007 (*Ref 33*), implementation of safe working practices (as outlined in the SSoW) and the use of suitable personal protective equipment (and potentially respiratory protective equipment). A watching brief for asbestos should be maintained through excavation activities, which is detailed in the *Remediation Statement*.

5.7 Summary of Explosive Risk

Historical activities at the AWE site, involving the processing of explosive compounds, may have resulted in contamination of soils. Therefore, assessment of the concentrations of explosives present within soils in the Development Area is required in order to identify any risks posed to site receptors and to establish the need for any remediation.

Explosive Residues in Soils

Soil samples collected during previous investigations in the Development Area have been scheduled for a suite of explosive analysis which has included picric acid, picrite, HMX, RDX, EGDN, Tetryl, NG, TNT, HNS, PETN, 2,4-DNT, 2,6-DNT and NC.

Sampling locations originated from:

- RPS 2009 site investigation (*Table 3.1*) including BHHYD-01-03, WSHYD-04–06;
- BAE site investigation (*Table 3.1*) which included 48 soil samples collected from soils beneath former building footprints on site and associated drainage and 7 composite samples from blast bund material surrounding the former buildings (which was used for void infill once building and footprints were removed).

Explosives analysis of soil samples (thirteen) that will remain on site following redevlopment has identified 3 detections above the analysis LOD:

- F26.5 SLAB S3 1.5m, 8.8mg/kg HMX;
- F26.5 SLAB S5 1.5m, 1.4mg/kg HMX; and,
- F26.5 SLAB S6 B/SUMP 3.0m, 4.8 mg/kg HMX.

No elevated concentrations above the AWE explosives threshold of 0.1% (or 1000 mg/kg) have been identified and therefore the material is considered to be 'Free from Explosive Hazard' (FFEH) (*Table 2.3*). No data is available for these locations at greater depth, however, based on the low concentrations detected it is considered unlikely that any significant levels of explosives contamination are present at greater depth that represent a significant risk to future site users.

The identified exceedances of HMX within samples have been compared to RPS' GAC of 110,000 mg/kg (to assess the toxicological risk it poses to human health). All results fall significantly (up to six magnitudes) below the threshold value and therefore it is considered that there is a negligible risk to human health posed from explosive residues within soil at the site.

Thirty-six samples of soils proposed to be excavated (*Section 3.1.4*) have been subject to analysis for explosive residues. Only one sample detected the presence of explosives in excess of the analysis LOD; 4.5mg/kg HMX within sample B3A28SLABSW. At this concentration the sample would be considered 'Free from Explosive Hazard' (FFEH) and to represent a negligible risk to human health.

Based on the sample data set we would consider that the risks posed to construction workers from explosive residues in soil are low, however appropriate safe systems of work (SSoW) should be implemented to minimise any potential risks posed to construction workers becoming exposed to previously unidentified contamination. This is usually managed through adherence to CDM Regulations 2007 (*Ref 33*) which should also include an awareness of site staff of the types of contamination that could potentially be encountered at the site management systems to deal with previously unidentified contamination.

Although no ordnance has been discovered during previous site investigations within the Development Area, its presence cannot be discounted due to AWE (A) previous historical uses as an airfield. As such, provision should be made to account for the potential for encountering ordnance in the redevelopment plan for the site, and the associated Safe System of Work documentation.

6 Radiological Risk Assessment

6.1 Introduction

An assessment of the risks posed from radiological sources in soil and groundwater was carried out by reviewing radiochemical analytical data from samples that had been collected during several different site investigations within and surrounding the site. The dataset used for the radiological risk assessment is provided in electronic format in *Appendix E*.

6.2 AWE (A) Radiological Contamination Assessment Approach

6.2.1 General Assessment Approach

For the purpose of this assessment site-specific radiological data has been separated for the following areas of the Application Site (*Drawing JER4214-001a*):

- The Development Area; and,
- The Central Area Construction Enclave (CACE) Area.

For the Development Area, the long term (chronic) risks posed to human health based on the proposed redevelopment, potential risks posed from soils proposed to be excavated and potential risks posed to construction workers involved in the redevelopment require consideration.

Where sufficient sample numbers allow (sample data set greater than 3), the 95th percentile Upper Confidence Limit (95% UCL or US95) of the mean measured concentration for the data set will be compared against the risk based threshold levels. Additionally, any statistical outliers have been identified and are separately assessed. Where sample numbers are less than 3, risk based thresholds will be compared against the maximum activity values identified.

For the CACE area the main concern is the short-term risks posed to construction workers during the project construction phase. The separation of the data in this respect has been undertaken, to enable independent consideration of the risks posed in these different areas.

Any samples which are located within proposed excavation areas (*Drawing JER4214-004a, Section 3.1.2*) will be removed from the data set and assessed separately in terms of risks posed from material re-use / considerations for off site disposal of materials.

6.2.2 Summary of Source-Pathway-Receptor Linkages

When assessing the risk posed by the identified contamination, consideration of the potential pathways by which exposure to receptors can occur requires consideration. The main receptors requiring consideration are:

- Future site occupants (including AWE Staff and visitors);
- Construction Workers; and
- Surface water and Groundwater.

The major pathways for exposure to radioactive soil contamination include;

- Inhalation of contaminated soil and dust;
- Ingestion of contaminated soil and dust;
- Direct exposure; and
- Dermal contact.

The main exposure pathways for alpha activity will be via inhalation and/or ingestion of contaminated soil as alpha radiation is easily shielded by material and only travels a few centimetres in air. In this respect, if contamination is buried then the likelihood of exposure via these pathways is very low to future site occupants

The main exposure pathways for beta activity are via inhalation and ingestion pathways, although higher energy beta activity will also result in direct exposure and dermal pathways becoming increasingly important. As such, buried contamination can still give rise to a measureable beta dose. The penetration of beta activity in soil is still quite low, and depending upon the nature and magnitude of contamination, beta activity buried at a depth of >0.50 mbGL is unlikely to result in significant dose due to direct exposure.

Gamma radiation operates through the same pathways as alpha and beta (i.e. inhalation, ingestion, direct exposure etc) but the direct exposure represents a significant exposure mechanism. Depending upon the nature and magnitude of the contamination present, even soils buried at shallow depth can provide significant direct exposure.

Contaminants, if present within the top 1.00 mbGL based on proposed finish levels (*Drawing JER4214-005a*) are considered to have the potential to represent an unacceptable risk to future site occupants, especially within the top 0.60 mbGL ('the soil mixing zone' (*Ref 31*)) where migration of contamination to the surface over time by natural mechanisms is likely.

Future site users are less likely to become exposed to contamination buried at depths greater than 1.00 mbGL (by dermal contact, inhalation and ingestion pathways) and therefore pose a lower risk to human health. However, elevated levels of gamma-emitting radionuclides if present at depths greater than 1.00 mbGL can still give rise to a significant dose rate at ground level which requires consideration. As a conservative approach, soil samples greater than 1.00 m depth have been screened against radiological risk based threshold levels to identify any contaminants that potentially represent a significant risk to human health.

6.2.3 Risk Assessment Threshold Levels

Gross Alpha and Beta Assessment

Gross alpha and gross beta analyses are screening tools used to identify gross levels of activity in samples, and therefore depending upon the specific nature of the contributing radionuclides does not provide an assessment of the 'level of risk' posed. However, the analysis is useful as it indicates (when compared against known background levels) the magnitude of any contamination present.

This takes into account AWE's consideration that background gross alpha and beta is 0.70 Bq/g and 0.60 Bq/g respectively when assessing soil samples (as per *Section 2.4.1*). When assessing gross alpha and gross beta activity in groundwater, RPS have again adhered to AWE's Threshold Limits which are 40 Bq/m^3 and 500 Bq/m^3 respectively, and also the WHO Drinking Water Standards of 500 Bq/m^3 and 1000 Bq/m^3 for gross alpha and gross beta activity respectively (see *Section 2.3.7*).

Anthropogenic and Naturally Occurring Radionuclides

To assess the risks posed by radiological contaminants in soil, activity levels for specific radionuclides will be compared against the International Atomic Energy Authority (IAEA) exclusion, exemption and clearance criterion (herein referred to as 'IAEA Criteria') outlined in the Safety Guide No. RS-G-1.7 (*Ref 34*) as a conservative basis for the assessment of risk. The IAEA criteria are identified by the HSE as appropriate for delicensing, and are based upon demonstrating achievement of a residual risk of death of one in a million per year. Any exceedances of the IAEA criteria do not necessarily indicate a significant risk for the proposed end use, but will help to identify any levels of contamination that may require more detailed risk assessment.

Analysis Suites

All samples (soil and groundwater) have been subject to a minimum of gross alpha/beta analysis, and selected samples have been subject to gamma spectrometry based on the level of gross alpha / gross beta activity identified. In accordance with AWE procedure, samples exhibiting gross alpha activity in excess of 1.10 Bq/g (background + SoLA) are scheduled for radiochemistry analysis to include Pu and U radionuclides. Samples exhibiting gross beta activity in excess of 1.00 Bq/g (background + SoLA) are scheduled for gamma spectrometry. Samples exhibiting both gross alpha and gross beta threshold exceedances are scheduled for radiochemistry analysis. Background activity levels for gross alpha and gross beta at AWE (A) and AWE (B) have been identified as 0.7 and 0.60 Bq/g respectively (*Ref 35*), and SoLA activity levels of 0.40 Bq/g.

The gamma spectrometry suite undertaken includes radionuclides that may be present as a results of contamination due to historical and current operations (anthropogenic / man made sources), and also radionuclides that may be present due to their occurrence in natural strata / geology (NORM, or natural sources). This includes:

- Anthropogenic: Co-60, Cs-137, U-235, Am-241;
- NORM: K-40, Ra-226, Th-234.

The suite of radiochemistry analysis includes plutonium radionuclides (Pu-238, Pu-239/240) and uranium radionuclides (U-234, U-235, and U-238).

There is no historical evidence for the use of tritium in the Development Area, however other historical operations at AWE(A) have included the use of tritium, and it has been identified within soils at other areas of AWE(A) and consequently is a potential contaminant of interest.

6.3 Radioactivity in Soils within the Development Area

6.3.1 Soils to Remain at Depths Less than 1.00mbGL Post Redevelopment

Gross Alpha and Beta Analysis

A summary of available gross alpha and gross beta activity or soils that will remain within the top 1.0 mbGL following redevelopment is shown in *Table 6.1.*

Table 6.1. Gross Alpha and Beta Activity for Soils that will be at Depths Less than 1.00 mbGL Following Redevelopment

Determinand	No. of Samples Tested	Activity Range (Bq/g)			Location and Depth (mbGL) of Maximum Concentration	No. of Outliers	AWE Threshold (Bq/g)
		Min	Max	95% UCL [1]			
Gross Alpha	7	0.39	0.83	0.66	WSHYD-05 @ 0.70mbGL	0	1.1
Gross Beta	7	0.37	1.0	0.78	WSHYD-05 @ 0.70mbGL	0	1.0

Note:

1. Based on 95% upper confidence limit, which excludes outliers.
2. Values in **bold** exceed the SGV / GAC.

None of the samples analysed from the top 1.00 mbGL exceeded the AWE threshold criteria for gross alpha or gross beta activity. Furthermore, the 95% UCL for both gross alpha and gross beta activity is significantly below the AWE threshold which indicates that average gross alpha and beta activity at the site is consistent with the natural range of background levels. Sample WSHYD-05 at 0.70mbGL identified a gross beta activity equivalent to the AWE gross beta threshold of 1.00 Bq/g and was subsequently scheduled for gamma spectrometry analysis.

Gamma Spectrometry Analysis

Soil sample WSHYD-05 at 0.70mbGL underwent gamma spectrometry analysis which identified the following activities which have been compared against the IAEA criteria, as shown in *Table 6.2*.

Table 6.2. Gamma Spectrometry for Soil (Sample WSHYD-05 0.7m)

Determinand	Activity (Bq/g)	IAEA Criterion (Bq/g)	IAEA Criterion Exceeded?
Am-241[1]	<LOD (0.005)	0.1	No
Co-60[(1)]	<LOD (0.007)	0.1	No
Cs-137[(1)]	<LOD (0.006)	0.1	No
K-40[(2)]	0.630	10	No
Ra-226[(2)]	0.110	1	No
Th-234[(2)]	<LOD (0.039)	1	No
U-235[(2)]	0.006	1	No

Note:

1. Radionuclides of artificial origin;
2. Radionuclides of natural origin.

Only Naturally Occurring Radioactive Materials (NORM) radionuclides were identified above the analysis LOD. No individual exceedances of the IAEA criterion were identified and therefore the risks posed to human health are not considered to be significant.

6.3.2 Soils to Remain at Depths Greater than 1.0 mbGL Post Redevelopment

A summary of available gross alpha and gross beta analysis data for soils that will remain at depths greater than 1.00mbGL following redevelopment is shown in *Table 6.3.*

Table 6.3. Gross Alpha and Beta Activity in Soils (>1.0 mbGL Post Development)

Determinand	Activity Range (Bq/g)			Location and Depth (mbGL) of Max Concentration	No. of Outliers	No. of Samples Tested	AWE Threshold
	Min	Max	95% UCL[(1)]				
Gross Alpha	0.31	**1.12**	0.80	TP0930 @ 1.00mbGL	1	67	1.1
Gross Beta	0.39	**2.16**	0.83	BHHYD-02 @ 6.00mbGL	1	67	1.0

Note:

3. Based on 95% upper confidence limit, which excludes outliers.
4. Values in **bold** exceed the SGV / GAC.

Gross Alpha Exceedances

The 95% UCL for the gross alpha activity dataset is marginally above the AWE threshold of 1.1 Bq/g. However, only two out of the sixty-seven samples analysed exceeded the AWE threshold criteria for gross alpha activity, including;

- A marginal exceedance of 1.12 Bq/g from sample TP0930 at 1.00mbG; and

- An outlier (2.16 Bq/g from sample WSHYD-06 at 3.0 mbGL) which is more than twice the AWE threshold criteria.

No further analysis results are present for the outlier WSHYD-06 at 3.00 mbGL, or sample TP0930 at 1.00 mbGL. Both of these samples originated from natural ground strata (Bagshot Formation and Silchester Gravels respectively) and in the absence of significant levels of activity at shallower depth are considered to be due to local variation of naturally occurring radioactivity, rather than contamination. Also, due to the limited mechanism for exposure to alpha activity at this depth these exceedances are not considered significant in terms of radiological risk.

Radiochemistry analysis was undertaken on a sample from TP0923 at 1.00 mbGL (although no accompanying gross alpha activity result is available), the results of which are discussed in *Table 6.4*.

Gross Beta Exceedances

The 95% UCL for the gross beta dataset is below the AWE threshold and therefore it can be concluded that average conditions across the site are consistent with background levels. Four out of the sixty-seven samples subject to analysis marginally exceeded the AWE threshold criteria for gross beta activity of 1.00 Bq/g. These were at locations BH0928 at 10.00mbGL (1.08 Bq/g), BH0929 at 5.00 mbGL (1.18 Bq/g), and BHHYD-02 at 6.00mbGL (1.19 Bq/g) respectively) and one outlier from sample BH0926 at 5.00mbGL with activity of 1.36 Bq/g. Further gamma spectrometry analysis was undertaken on three out of the four samples which were identified as a gross beta threshold exceedance (outlier BH0926 at 5.00mbGL, BH0929 at 5.00mbGL and BHHYD-02 at 6.00mbGL), the results of which are presented in *Table 6.5*

No further analysis was scheduled for sample BH0928 at 10.00 mbGL, however this sample originated from natural strata (London Clay) and the activity detected are likely to be due to natural variation in the presence of NORM radionuclides than due to contamination.

Gamma Spectrometry and Radiochemical Analysis

In accordance with AWE protocol for samples with gross alpha and beta activity exceeding AWE threshold screening levels, sample TP0923 @ 1.00mbGL underwent additional radiochemistry analysis and samples BH0926 @ 5.00mbGL, BH0929 @ 5.00mbGL, and BHHYD-02 @ 6.11m underwent gamma spectrometry. The results are summarised in *Table 6.4* and *Table 6.5* and compared against the IAEA Clearance and Exemption criterion.

Table 6.4. Radiochemistry Analysis Results for Soils to Remain at Depths Greater than 1.00 mbGL following Redevelopment

Sample	Geological Strata	Determinand	Activity (Bq/g)	IAEA Criterion (Bq/g)	IAEA Criteiron Exceeded
TP0923 @ 1.00mbGL	Silchester Gravels	Pu-238[1]	<LOD (0.00082)	0.1	No
		Pu-239-240[1]	<LOD (0.00089)	0.1	No
		U-234[2]	0.00827	1	No
		U-235[2]	<LOD (0.00053)	1	No
		U-238[2]	0.00581	1	No

Note:

1. Radionuclides of artificial origin;
2. Radionuclides of natural origin.

Table 6.5. Gamma Spectrometry Analysis Results for Soils to Remain at Depths Greater than 1.00 mbGL following Redevelopment

Sample	Geological Strata	Determinand	Activity (Bq/g)	IAEA Criterion (Bq/g)	IAEA Criteiron Exceeded
BH0926 @ 5.00mbGL[3]	Bagshot Formation	Am-241[1]	<LOD (0.009)	0.1	No
		Co-60 [1]	<LOD (0.013)	0.1	No
		Cs-137 [1]	<LOD (0.011)	0.1	No
		K-40[2]	0.952	10	No
		Ra-226[2]	<LOD (0.173)	1	No
		U-235[2]	<LOD (0.010)	1	No
		U-238[2]	<LOD (0.091)	1	No
BH0929 @ 5.00mbGL	Bagshot Formation	Am-241[1]	<LOD (0.009)	0.1	No
		Co-60 [1]	<LOD (0.013)	0.1	No
		Cs-137[1]	<LOD (0.011)	0.1	No
		K-40[2]	0.819	10	No
		Ra-226[2]	<LOD (0.172)	1	No
		U-235[2]	<LOD (0.010)	1	No
		U-238[2]	<LOD (0.086)	1	No
BHHYD-02 @ 6.00mbGL	London Clay	Am-241[1]	<LOD (0.006)	0.1	No
		Co-60 [1]	<LOD (0.007)	0.1	No
		Cs-137[1]	<LOD (0.007)	0.1	No
		K-40[2]	0.799	10	No
		Ra-226[2]	0.154	1	No
		Th-234[2]	0.061	1	No
		U-235[2]	0.009	1	No

Note:

1. Radionuclides of artificial origin;
2. Radionuclides of natural origin;
3. Sample Identified as an Outlier.

No plutonium radionuclides were detected at activities above the analysis LOD which is significantly below the IAEA criteria. All samples which underwent gamma spectrometry exhibited activity of anthropogenic radionuclides below the analysis LOD which again is significantly below the IAEA criteria. The gamma spectrometry also identified levels of NORM radionuclides to be significantly below the IAEA criterion. In conclusion, despite the samples exhibiting gross beta activity in excess of the AWE threshold (with the exception of TP0923 @ 1.00 mbGL), the further analysis undertaken has demonstrated that the activities of individual radionuclides present are not considered to represent a significant risk to human health. This is further reinforced by the fact that the samples are at depths greater than 1.00 mbGL and therefore the soils are unlikely to be encountered by future site occupants in the proposed end use.

Tritium

No tritium analysis has to date been undertaken upon soils within the Development Area that are to remain in-situ following redevelopment. As outlined in *Section 6.5*, a number of samples collected from soil that is to be excavated during redevelopment have been subject to analysis for tritium with a maximum activity of 0.65 ± 0.02 Bq/g detected. Although the activity detected is indicative of 'radioactive' in accordance with current legislation (the Radioactive Substances Act 1993 (RSA93) *(Ref 48)* and the SoLA Exemption Order *(Ref 49)*) the level of risk to human health posed by the activity detected is considered to be very low.

To illustrate the level of risk posed by the identified tritium, the maximum detected activity of 0.65 Bq/g is over 100 times lower than the IAEA Clearance and Exemption criterion *(Ref 34)* for tritium of 100 Bq/g. The HSE Delicensing Criterion *(Ref 50)* identifies that if the IAEA Clearance and Exemption criterion are met, then delicensing for unrestricted future use should be satisfied (equating to an annual dose of 10 μSv). Clearly, the IAEA levels are designed to be appropriately conservative, and demonstrate that the levels of tritium detected in shallow soils in the Development Area are of little significance in a human health risk context.

As no historical use of tritium in the Development Area is known, the most likely source of the identified tritium is from air-borne discharge, and as such would be expected to be concentrated in shallow soils. As the activities detected in shallow soils are low and of very low significance in a risk context, it is considered to be highly unlikely for deeper soils to exhibit tritium activity that represents a significant risk to human health.

6.4 Radioactivity in Soils within the CACE Area

As discussed in *Section 3.1.2* and *Section 5.5* the main consideration in the assessment of risks posed by contaminated soils in the CACE Area is the risk posed to construction workers (i.e. shorter term 'acute' risks). There is no soil radiological assessment data available from within the CACE area for assessment, however there is no known historical use of radioactive materials in the CACE area.

It is considered that adequate protection measures are in place to minimise any potential risks posed to construction workers from soil contamination during construction phase activities based on the information contained within the HEFF ES chapter *(Section 3.1.2* (*sub section Central Area Construction Enclave (CACE)* and based on *Section 5.5* comments*).*

The CACE Area is predominantly underlain by hardstanding creating a barrier between receptors and the underlying ground conditions, which is not proposed to be disturbed, and therefore considering also the short timeframes for exposure of the construction workers, it is considered the risk posed to construction workers is low provided that appropriate Safe Systems of Work (SSoW) are implemented. This is usually dealt with through adherence to CDM Regulations 2007 (*Ref 36*).

6.5 Summary of Risks posed From Soils proposed to be Excavated

To identify any gross contamination that is indicative of radioactive waste for disposal purposes or could potentially represent a significant risk to construction workers, radiological soil analysis data relating to these soils have been directly screened against AWE threshold values, as summarised in *Table 6.4*.

The data includes tritium analysis results for an additional 39 samples collected by AWE to provide additional coverage across the entire Development Area where soils are to be excavated for disposal or re-use during redevelopment. The decision to collect additional samples was made by AWE to facilitate a rigorous radioactive waste assessment following the detection of tritium at levels in excess of the SoLA Exemption Order Level of 0.40 Bq/g at location BHHYD-01 at 0.00 mbGL.

Table 6.4. Assessment of Radiological Soil Analysis for Excavated Soils

Determinand	Activity Range (Bq/g)			Location and Depth (mbGL) of Max Concentration	Number of Outliers	No. of Samples Tested	AWE Threshold
	Min	Max	95% UCL[1]				
Gross Alpha	0.38	**1.17**	**0.67**	TP0923 @ 0.00mbGL	2	46	1.1
Gross Beta	0.39	0.85	0.53	BH0912 @ 0.00mbGL	1	46	1.0
Tritium	<0.01	0.65	0.056	BHHYD-01 @ 0.00mbGL	1	43	0.4 / 100[2]

Note:

1. Based on 95% upper confidence limit, which excludes outliers.
2. SoLA Limit / IAEA Criterion.

Review of the gross alpha, gross beta and tritium analysis data identified the following;

- One marginal gross alpha exceedance was identified in soil sample TP0923 0.00 mbGL (1.17Bq/g) in excess of the AWE gross alpha threshold value of 1.10 Bq/g.
- No exceedances of the gross beta activity threshold were identified in any samples.
- One marginal exceedance of the SoLA Exemption Order level of 0.40 Bq/g was identified in sample BHHYD-01 at 0.00 mbGL due to tritium (0.65 Bq/g) which was also identified to be an outlier.
- All other samples exhibited tritium activity below the SoLA exemption order level, with less than half of samples analysed (20) detecting activity in excess of the analysis minimum detection limit. Even when including the identified outlier, a 95% UCL for the tritium dataset of 0.11 Bq/g is significantly below the SoLA Exemption Order Level of 0.40 Bq/g..

There is no additional analysis data for sample TP0923 to identify whether the detected elevated gross alpha activity originated from natural or anthropogenic sources. The investigation borehole log does not provide a detailed description of the soil, but also does not indicate a potential source for the elevated activity. There is no known historical use of radioactive materials in the Development Area, and as the gross alpha activity identified at this location is only a marginal exceedance above the AWE Threshold value of 1.10 Bq/g it is considered unlikely to be due to radiological contamination, but rather due locally elevated levels of naturally occurring radioactivity in the soil. The activity detected is not considered to pose a significant risk to construction workers during the site redevelopment.

The tritium activity detected in samples collected from soil that is to be excavated during redevelopment is significantly below the IAEA clearance and exemption criterion of 100 Bq/g and is therefore not considered to represent a significant risk to construction workers.

As there is no known historical use of tritium in the Development Area, the activity of 0.65 Bq/g at location BHHYD-01 was unexpected. As the subsequent further collection and analysis of 39 shallow soils across the Hydrus Development Area has not detected tritium activity in excess of the SoLA Exemption Order level of 0.40 Bq/g (maximum 0.12 Bq/g) it is considered that the outlier result is anomalous.

The 95% UCL for the tritium dataset (including the outlier from location BHHYD-001) of 0.11 Bq/g is significantly below the SoLA Exemption Order level of 0.40 Bq/g. As such it is considered that shallow soils that will be excavated during demolition should be classified as clean/exempt for waste disposal purposes.

It is anticipated that excavated soils will be subject to either re-use on site (where appropriate) or waste disposal, and soils should be subject to an appropriate suite of analysis (including radiological determinands) on a volume basis to inform and support appropriate waste management activities.

6.6 Radioactivity in Groundwater

6.6.1 Introduction

The following section assesses the risks from radiological contaminants identified in the groundwater samples collected from various site investigations at the site and also the various repeat rounds of monitoring.

6.6.2 Summary of Radiochemical Analytical Results

The radiochemical analytical data from the following boreholes has been reviewed:

- 26 groundwater samples from Boreholes BH900 – 902, BH909, BH911, BH912, BH926 – 928 from Golder Associates Report (2004) as per *Table 3.1*. Most boreholes are present within the Development Area however Borehole BH0398 is located south of the Development Area red line boundary but has been include due to its close proximity to the site.

- 14 samples from Round 1 of RPS Report (2009) as per *Table 3.1*. Round 2 results are pending at the time of authorship of this report. Most boreholes are located within the Development Area however borehole EBH8A in located to the south west of the Development Area red line boundary.

- 1 sample from Borehole 04004 (ESIIMS data) dated 1997.

Samples were analysed for gross alpha / beta and tritium activity. A summary of the range of activities found is given in *Table 6.5.*

Table 6.5. Gross Alpha, Gross Beta and Tritium Analyses in Groundwater

Determinand	Total Number of Analyses	AWE Notification Level (Bq/m^3)	Number >AWE Notification Level	Activity Range (Bq/m^3)
Gross Alpha	40	40	12	<LOD (10) – 470
Gross Beta	40	500	1	<LOD (35) – 1569
Tritium	40	10,000,000[1]	0	<LOD (5310) – 21,880

Note:

1. WHO Drinking Water Guidelines (Ref 15).

Twelve samples demonstrated gross alpha activity in excess of the AWE Notification Level. The analytical uncertainty of the gross alpha analysis was often in excess of 40% which in a number of cases makes it difficult to identify whether the AWE gross alpha notification level was actually exceeded.

Only 1 sample exceeded the gross beta notification level of 500 Bq/m^3 (BH0909, 1569 Bq/m^3) which also demonstrated a gross alpha activity of 160 Bq/m^3. All samples exhibited tritium activity well below the WHO DWG of 10,000,000 Bq/m^3.

Twelve groundwater samples were also submitted for radiochemistry analysis during previous investigations. A summary of the activity ranges for the additional radiochemical analysis is provided in *Table 6.6*.

Table 6.6. Summary of Radiochemistry Analysis of Groundwater

Determinand	Number of Analyses	WHO DWS (Bq/m^3)	Number >WHO DWS	Activity Range (Bq/m^3)
U-234	12	10,000	0	62.9 – 360
U-235	12	1000	0	<LOD (1.04) – 10
U-238	12	10,000	0	9.91 - 250
Pu-238	12	1,000	0	<LOD (0.4 – 1.6)
Pu-239/40	12	1,000	0	<LOD (0.41 – 1.6)

One sample (Borehole 04004) underwent gamma spectrometry analysis and no anthropogenic radionuclides were detected in the sample at activities exceeding the laboratory LOD.

6.6.3 Radiochemical Gross Alpha / Beta Data Assessment for Groundwater

Results of groundwater gross alpha and gross beta data from the boreholes within the Hydrus site boundary, depicted in *Drawing JER4212-005a,* are summarised in *Table 6.7.*

Table 6.7. Radiological Activity within Groundwater Samples.

Determinant	Activity Range (Bq/m^3)			Location and Depth (mbGL) of Max Concentration	No. of Samples Tested	No. of outliers	AWE Notification Level (Bq/m^3)
	Min	Max	95% UCL(1)				
Gross Alpha	2.88	**470**	**106.85**	BHHYD-01	40	1	40
Gross Beta	60.0	**1560.0**	356.92	BH0909	40	1	500

Note:

1. Based on 95% upper confidence limit, which excludes outliers.
2. Values in **bold** denotes exceedances.

Twelve out of forty samples tested exceeded AWE Notification Level for gross alpha activity. The maximum alpha activity was found in borehole BHHYD-01 at 470 Bq/m^3 (identified as an outlier) which is over 10 times the AWE notification level. No samples were identified as exceeding WHO Drinking Water Quality standard activity levels for gross alpha activity of 500 Bq/m^3. The 95% UCL for gross alpha activity is in excess of the AWE notification level which suggests that average groundwater conditions at the site are elevated.

Only one out of the forty samples tested exceeded the AWE notification level for gross beta activity of 500Bq/m^3, with the exceedance observed in Borehole BH0909 at 1560 Bq/m^3 (identified as an outlier). This maximum activity level also exceeds the WHO drinking water guideline for gross beta activity of 1000 Bq/m^3. The 95% UCL for the dataset (including the gross beta outlier) is significantly below the AWE Notification level and therefore average gross beta activity in groundwater at the site are not considered to represent a significant risk. This gross beta activity outlier for location BH0909 was scheduled for additional radiochemistry analysis.

6.6.4 Radiochemistry Analysis Results

Eleven of the twelve samples which were identified as gross alpha activity exceedances above the AWE Threshold Value (including the identifier outlier) underwent additional radiochemistry analysis. One additional sample which exhibited gross alpha activity below the AWE notification level was also scheduled for further analysis. The activities of plutonium isotopes were all identified to be below the analysis LOD for all the samples analysed and significantly below WHO DWG activity levels.

Uranium activity can be due to anthropogenic or natural sources, but the ratio of the uranium isotopes detected will indicate whether the emission source is natural or artificial. The samples with the highest uranium-234 and uranium-238 activities were found in the same samples which had the highest gross alpha activity, Borehole BHHYD-01. The uranium isotopes, for the samples analysed (including gross beta outlier sample BH0909), were typically consistent with natural environmental levels with a U-234:U-238 ratio of approximately 1 and therefore the gross beta activity exceedances identified are considered to be due to regionally enhanced NORM rather than contamination. The highest uranium-234 and uranium-238 activities were several orders of magnitude lower than the WHO Drinking Water Guidelines of 10,000 Bq/m^3 and therefore not considered to represent a significant risk to future site occupants.

Although one sample (BH0900) represented an exceedance over the AWE threshold activity level and was not scheduled for further analysis to identify whether it was due to natural or anthropogenic sources, the additional analysis information available (including 3 other samples taken from the same borehole, Borehole BH0900) suggests that elevated alpha activities are likely to originate from natural sources and are not considered to be representative of contamination.

Comparison has been made against the AWE notification and WHO DWG thresholds to assess the level of risk posed to future site users, however in reality it is highly unlikely that future site occupants and construction workers will come into contact with groundwater let alone use it as a drinking water supply, and consequently the risk posed by the levels of activity detected is considered to be low.

6.6.5 Assessment of Groundwater Tritium Analysis

A total of 40 samples were analysed for tritium, of which 13 samples identified activity in of less than LOD (ranging from <5310 - <9390Bq/m^3). Fifteen out of the remaining samples displayed negative results ranging from -0.4 to -4.55Bq/$m^{3.}$ The remaining data set displayed a maximum measurable activity level was 21,880 Bq/m^3 from sample BH0909 with no other analytical results for tritium at the same location available. A second highest activity level of 8960Bq/m^3 was identified within sample BH0912 in which two other tritium analysis results are present both of which are at activity levels a magnitude lower (960 and 890Bq/m^3).

All activity levels are considerably lower than the UK Drinking Water Inspectorate Guideline of 100,000 Bq/m^3 and the WHO Drinking Water Guideline (3rd Edition) of 10,000,000 Bq/m^3 and therefore not considered to represent a significant risk to human health. The activity levels identified are also in keeping with activity levels typically found within groundwater at other areas of AWE (A).

6.7 Summary of Radioactivity found in Soils and Groundwater

Soils exhibiting gross alpha activity and gross beta activity above the AWE threshold screening levels were identified as originating from natural ground materials, such as clay and gravels. Samples which were submitted for further radiochemical and gamma spectrometry analysis, including outliers, displayed activity levels indicative of radionuclides representative of Naturally Occurring Radioactive Materials (NORM) at background levels rather than due to sources of contamination from site operations. Levels of tritium identified in soils that are to be removed during redevelopment have been found to be low and at levels that are not considered to represent a significant risk to human health. Based on the likely source of the low levels of tritium identified being due to airborne discharge from elsewhere on the AWE site the most elevated activity is expected to be at the ground surface, as such tritium levels in the soils at depths that will remain at the site are not considered to be significant in a risk context.. It is considered that no significant risk to future site occupants is posed from radioactivity in soil at the site.

No radioactivity data is available for soils within the CACE area, however in light of the short timescales for exposure, and the presence of widespread hard standing surface covering that will provide a barrier, it is considered that risks posed to construction workers are low; however, appropriate SSoW should be implemented during future groundworks to provide protection against unknown contamination.

No levels of radioactivity representing a significant risk to construction workers has been identified in soils proposed to be excavated. No significantly elevated levels of radioactivity in groundwater that could pose a risk to human health were identified during the data assessment. The levels of gross alpha and beta activity identified in groundwater are considered to be representative of typical background levels.

7 Controlled Water Risk Assessment

7.1 Introduction

7.1.1 Approach

The controlled waters risk assessment has focussed on the Development Area within the Application Site. Groundwater quality data has been obtained for thirty-seven groundwater monitoring points installed within or adjacent to the Development Area, the location of which is shown in *Drawings JER4214-010a(i) a to JER4214-010a(iv)*. These installations were constructed in six phases of intrusive works undertaken on the Aldermaston site as summarised in *Table 7.1.*

Table 7.1. Summary of Groundwater Monitoring Installations

Study	Date	Monitoring Infrastructure	Reference
Golder Associates (UK) Ltd. New HR Facility Ground Investigation Fieldwork Report. AWE Aldermaston.	2004	BH0900-0912, BH0926-0928	*Ref 37*
Golder Associates (UK) Ltd. SCRT 2: B Area North Exploratory Investigation Report. AWE Aldermaston.	2005	BH0330-0333, BH0364, BH0396-0398	*Ref 38*
BAE Systems. Land Quality Assessment Report. B Area North, AWE Aldermaston.	2007	BAEBH1-3	*Ref 20*
Atkins. Factual Report on Geotechnical Ground Investigation. AWE Aldermaston Hydrus.	2008	CP1001-1003, R1002-1003	*Ref 25*
RPS. Ground Investigation Interim Factual Report. Project Hydrus, AWE Aldermaston.	2009	BHHYD01-03, WSHYD04-06	*Ref 1*
ESIIMS format ground investigation data received from AWE following request for information. Original reports not available for reference.	2009	04004, ST13A, ST14, EBH7, EBH8, EBH8A	*Ref 39*

The groundwater quality dataset used in this assessment is provided in electronic form in *Appendix E*. This dataset has been obtained from AWE's own in-house data management system (ESIIMS) and augmented by manual data entry from hard copy laboratory receipts appended to monitoring reports associated with studies not included within the ESIIMS database. The source of each data entry is clearly identified in *Appendix E*.

Groundwater monitoring data is available for all years between 2000 and 2009 inclusive, except 2008. The frequency of monitoring rounds and analytical suite used varies each year, although data is now available for approximately 250 organic and inorganic substances within groundwater. Parameters measured in groundwater include:

- Volatile Organic Compounds (VOC);
- Semi-Volatile Organic Compounds (sVOC);
- BTEX Hydrocarbons (i.e. Benzene, Toluene, Ethylbenzene and Xylenes);
- Polycyclic Aromatic Hydrocarbons (PAH);
- Petroleum Hydrocarbons (including Diesel Range Organics (DRO), Gasoline Range Organics (GRO) and Petroleum Range Organics (PRO), as well as banded aliphatic and aromatic hydrocarbons);
- Total Phenols and Phenol;
- Metals and metalloids (including hazardous and non hazardous);
- Polychlorinated Biphenyls (PCBs);
- Various Inorganic Substances; and
- Various other parameters including pH, Biological Oxygen Demand, Chemical Oxygen Demand and , Electrical Conductivity (EC).

When pollution of groundwater has occurred the risk from the pollutants are assessed on a site-specific basis using risk assessment tools in line with current best practice (e.g. *Ref 3e* and *Ref 40*). In line with this guidance, the following approach has been used to evaluate groundwater quality:

- The entire groundwater quality dataset has been screened against relevant Assessment Criteria (AC) to identify principal Contaminants of Concern (COC) in groundwater;
- The spatial distribution and temporal variation of concentrations of the COC identified in groundwater have been reviewed to determine whether their occurrence is likely to represent an issue for groundwater quality on and down-gradient of the Application Site, hence determine which COC, if any, require further quantitative risk assessment with regards to controlled waters;

- Historical soil contamination data and historical land-use has been reviewed to determine whether any link can be made between COC identified in groundwater and soil contamination observed on the Application Site.
- A Quantified Risk Assessment (QRA) for controlled waters is undertaken where deemed necessary.

Data has only been used where a sample location and sample date is available.

7.1.2 Visual and Olfactory Evidence of Contamination

Visual and olfactory evidence of groundwater contamination was obtained from the geological logs for the Development Area and is summarised in *Table 7.2*.

Table 7.2. Visual and Olfactory Evidence of Contamination

Borehole ID	Borehole Location	Visual and Olfactory Evidence of Contamination
WSHYD-05	Centre of Site. In vicinity of footprint of former structures.	Slight organic odour within clays from 0.45-0.7 mbGL.
CP1002	Centre of Site. In vicinity of footprint of former structures.	Local brown staining on surfaces between 5.0-7.6 mbGL
CP1003	West of Site	Below 5.5 mbGL rare brown staining on fissures
R1003	North. In vicinity of footprint of former structures	Local brown staining on surfaces between 4.5-5.0 mbGL
R1006	Centre of Site. In vicinity of footprint of former structures.	Local brown staining on surfaces between 4.9-7.45 mbGL

Only five of the thirty-seven boreholes present on the site show any visual and olfactory evidence of contamination. These five are generally located in the vicinity of former buildings present on the Application Site.

7.2 Groundwater (Tier 1) Screening Assessment

7.2.1 Introduction

The groundwater screening assessment involves the comparison of tabulated analytical results for groundwater samples taken on the Development Area with published Assessment Criteria (AC) in accordance with published guidance (*Ref 40*). This assessment determines compliance or non-compliance with respect to those standards. The water quality standards used within this assessment are as follows:

- Revised UK Drinking Water Standards (DWS) (Water Supply (Water Quality) Regulations (2000)) are used for the evaluation of potential human health risks associated with the ingestion of either groundwater or surface water (*Ref 41*); and
- Environmental Quality Standards (EQS) (*Ref 42*) for the assessment of water quality with respect to impact upon freshwater in surface water courses.

As the shallow unconfined groundwater contained principally in the Silchester Gravel constitutes a Minor Aquifer the Revised Drinking Water Standards (Water Supply (Water Quality) Regulations 2000) (*Ref 41*) have been used for the purpose of screening where available, although no groundwater abstraction sources are located down-gradient of the Application Site.

The ultimate receptor of groundwater beneath the Development Area is likely to be the ponds situated down gradient (i.e. East) of the site boundary. Freshwater Environmental Quality Standards (EQS) for surface waters have also been used as AC. An EQS must not be exceeded in any watercourse in England and Wales and reflect a concentration of specific substances that is protective of aquatic life, usually invertebrates or fish.

The EQS for many List II metals (as defined by the Groundwater Regulations, 1998) is dependent on the hardness of the water body. The 50 mg/l to 100 mg/l 'alkalinity band' has been used to derive EQS for this assessment. The use of the 50 mg/l – 100 mg/l 'alkalinity band' is consistent with the 'average' alkalinity for larger data sets pertaining to other proximal Development Areas on the AWE Aldermaston site (most notably the NOA Development Area). Alkalinity data for groundwater on the Hydrus Application Site is limited, an alkalinity of between 28 mg/l and 150 mg/l is observed in eight analyses with an average of 80 mg/l (See *Appendix D*).

The result of the groundwater quality screening assessment is summarised in *Table 7.3* and *Table 7.4* and described below.

7.2.2 Organic Contaminants

A summary of the screening assessment for organic contaminants that occur in groundwater at concentrations above the Method Detection Limit (MDL) is presented in *Table 7.3*. The entire screened dataset, including parameters identified in groundwater at concentrations below the MDL, is provided in *Appendix F*.

Table 7.3. Screening Assessment of Organic Substances in Groundwater

Determinand	Type	Total Number of Analyses	Analyses Above Detection Limit (No.)	Analyses Above Detection Limit (%)	Concentration Range (µg/l)	Mean Concentration (µg/l)	Assessment Criterion (AC)	Value (µg/l)	No. Analyses Above AC	Mean Conc. Above AC
Petroleum Range Organics (PRO) (C4-C10)	TPH	56	7	12.5%	11-132	38.1	DWS	10	7	Yes
Gasoline Range Organics (GRO) (C10-C12)	TPH	44	1	2.3%	360 - 727	-	DWS	10	1	Yes
Diesel Range Organics (DRO) (C10-C40)	TPH	85	13	15.3%	74 – 864	297	DWS	10	13	Yes
Aromatics (>EC21-EC35)	TPH	32	7	21.9%	10 - 52	23.4	DWS	10	6	Yes
Aliphatics (>C12-C16)	TPH	32	1	3.1%	28	-	DWS	10	1	-
Aliphatics (>C16-C21)	TPH	32	10	31.3%	10 - 71	30.1	DWS	10	8	Yes
Aliphatics (>C21-C35)	TPH	32	20	62.5%	15 - 728	171	DWS	10	20	Yes
Toluene	BTEX	199	1	0.5%	39	-	DWS	10	1	-
o-Xylene	BTEX	170	3	1.8%	14 - 27	19	DWS	10	3	Yes
Total Phenol	Phenol	17	4	23.5%	10 - 10	10	DWS	0.5	4	Yes
Phenol	Phenol	95	0	-	-	-	-	-	-	-
Trichloroethene	VOC	93	3	3.2%	3 - 4	3.33	DWS	10	0	No
1,1,1-Trichloroethane	VOC	90	1	1.1%	1500	-	EQS	100	1	-
1,2-Dichlorobenzene	VOC	151	1	0.7%	3	-	WHO	1000	0	-
Tetrachloroethene	VOC	89	1	1.1%	3	-	DWS	10	0	-
Thiocyanate	Misc	36	1	2.8%	60	-	-	No AC	-	-

Table 7.3. Screening Assessment of Organic Substances in Groundwater (Continued)

Determinand	Type	Total Number of Analyses	Analyses Above Detection Limit (No.)	Analyses Above Detection Limit (%)	Concentration Range (µg/l)	Mean Concentration (µg/l)	Assessment Criterion (AC)	Value (µg/l)	No. Analyses Above AC	Mean Conc. Above AC
Total Polyaromatic Hydrocarbons	PAH	49	27	55.1%	0.066 - 2000	102	DWS	0.1	26	Yes
Di-sec-octyl phthalate	PAH	56	11	19.6%	1 - 4	2.09	DWS	0.1	11	Yes
Fluoranthene	PAH	104	8	7.7%	0.01 - 0.25	0.101	DWS	0.1	4	Yes
Diethyl phthalate	PAH	59	4	6.8%	1 - 2	1.50	DWS	0.1	4	Yes
Phenanthrene	PAH	104	12	11.5%	0.02 - 2.275	0.252	DWS	0.1	4	Yes
Pyrene	PAH	104	10	9.6%	0.01 - 0.238	0.075	DWS	0.1	3	No
Di-n-butylphthalate	PAH	59	3	5.1%	1 - 3	1.67	DWS	0.1	3	Yes
Naphthalene	PAH	196	13	6.6%	0.03 - 17	1.54	EQS	10	1	Yes
Anthracene	PAH	104	10	9.6%	0.016 - 0.501	0.079	DWS	0.1	1	No
Acenaphthene	PAH	104	11	10.6%	0.02 - 0.063	0.035	DWS	0.1	0	No
Benzo(a)pyrene	PAH	104	1	1.0%	0.247	-	DWS	0.01	1	-
Benzo(a)anthracene	PAH	104	4	3.8%	0.044 - 0.142	0.077	DWS	0.1	1	No
Chrysene	PAH	104	5	4.8%	0.019 - 0.149	0.049	DWS	0.1	1	No
Fluorene	PAH	104	11	10.6%	0.01 - 0.061	0.028	DWS	0.1	0	No
Acenaphthylene	PAH	104	3	2.9%	0.01 - 0.048	0.023	DWS	0.1	0	No
Benzo(b)fluoranthene	PAH	104	1	1.0%	0.268	-	DWS	0.1	1	-
Benzo(ghi)perylene	PAH	104	1	1.0%	0.292	-	DWS	0.1	1	-
Benzo(k)fluoranthene	PAH	104	1	1.0%	0.196	-	DWS	0.1	1	-
Dibenzo(ah)anthracene	PAH	104	1	1.0%	0.048	-	DWS	0.1	0	-
Indeno(1,2,3,cd)pyrene	PAH	104	1	1.0%	0.161	-	DWS	0.1	1	-

7.2.3 Organic Contaminants

No pesticides or PCBs have been identified in groundwater.

Volatile Organic Compounds (VOC)

Only four VOC have been identified in groundwater, namely Trichloroethene (TCE), 1,1,1-Trichloroethane (TCA), Tetrachloroethene (PCE) and 1,2-Dichlorobenzene. VOC have only been identified in between 1 and 3 analyses out of a total approximately 100 analyses. All four VOC occur at low concentration, approaching the MDL. The EQS for TCE is exceeded on the single occasion it was observed in groundwater. No other AC were exceeded.

VOC are not considered to be Contaminant of Concern (COC) in groundwater.

Phenols

Total phenols were observed in groundwater at a concentration of 10 µg/l in four of the seventeen analyses undertaken. A concentration of 10 µg/l is greater than the UK DWS for phenol (of 0.5 µg/l), however phenol has not been identified in groundwater despite 95 analyses being undertaken on the Development Area. Phenols are not considered to be a COC in groundwater.

BTEX Hydrocarbons

Toluene and o-xylene are the only BTEX hydrocarbons identified in groundwater at concentrations that exceed the MDL. However, both toluene and o-xylene occur at low concentration in less than 1 or 3 occasions out of 199 or 170 analyses respectively. BTEX hydrocarbons are not considered to be a COC in groundwater.

Petroleum Hydrocarbons

A wide variety of analytical approaches has been used to detect the presence of petroleum hydrocarbons in groundwater. These include:

- Total Petroleum Hydrocarbon Criteria Working Group (TPH CWG) (C5-35) Aliphatic/Aromatic Split (with CWG banding) - 32 analyses;
- Petroleum Range Organics (PRO) (C4-C10) – 56 analyses;
- Gasoline Range Organics (GRO) (C10-C12) – 44 analyses; and
- Diesel Range Organics (DRO) (C10-C40) – 85 analyses.

Petroleum hydrocarbons have been identified in groundwater samples from the Application Site. DRO is most commonly identified hydrocarbon, being present at concentrations above the MDL in 13 of the 85 analyses undertaken (c. 15%), with a mean and maximum concentration of 0.3 mg/l and 0.9 mg/l respectively. The TPH CWG analyses indicate that DRO in groundwater is dominated by longer chain aliphatics (>C21-C35), with limited occurrence of short chain hydrocarbons and/or aromatic hydrocarbons. Where petroleum hydrocarbons are identified above the MDL, they also exceed the UK DWS for Oils/hydrocarbons of 0.01 mg/l (i.e. 10 µg/l).

Petroleum hydrocarbons and in particular DRO is considered to be a COC in groundwater requiring further assessment. Although the dominance of longer chain aliphatics (>C21-C35) is considered indicative of hydrocarbons of comparatively low mobility.

Polycyclic Aromatic Hydrocarbons (PAH)

The concentration PAH in groundwater (Totals and speciated) has been screened against the UK DWS of 0.1 µg/l. The UK DWS for PAH is based on the sum of four specific PAH historically associated with contamination of water supplies, namely benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene, indeno(1,2,3-cd)pyrene, and can only be considered a general indictor of risk for other PAH. In light of this PAH specific assessment criteria have been used where available (i.e. Benzo(a)pyrene (BaP) and naphthalene).

Total PAH have been identified at concentrations above the detection limit in 55% of the forty-nine analyses undertaken with concentrations ranging from 0.07 µg/l to 2000 µg/l. The maximum concentration of 2000 µg/l is considered anomalous in light of the following observations:

- Other analyses for this borehole indicate Total PAH concentration below the MDL and of 0.58 µg/l;
- All speciated PAH measured on the same monitoring round occur at below the MDL; and
- The second highest TPH measured on the Application Site is only 250 µg/l.

Total PAH exceed the UK DWS of 0.1 µg/l on twenty-six of the twenty-seven analyses that exceed the MDL.

In addition to total PAHs, analysis for speciated PAH is also routinely undertaken for groundwater. However, in contrast with results for Total PAHs, most individual PAH species occur infrequently or are absent from groundwater. Many speciated PAH were identified in groundwater occur on a single occasion and are often associated with a single sample taken from borehole ST14 in 2006. This monitoring borehole is however characterised by concentrations below the detection limit in the four preceding monitoring rounds available for this borehole.

Di-sec-octyl phthalate, pyrene, phenanthrene, naphthalene, anthracene, acenaphthene, fluorene and fluoranthene have been identified at concentrations above the MDL in approximately 10% of all analyses undertaken (c. 104). However, the applied UK DWS of 0.1 µg/l is only exceed on three occasions (or less) for di-sec-octyl phthalate, fluoranthene, diethyl phthalate, phenanthrene, pyrene and di-n-utylphthalate out of a total of approximately 104 analyses.

Although total PAH are seen at concentrations above the MDL, this is not reflected in the concentrations of individual PAH species which are more routinely monitored in groundwater. This cause of the discrepancy between the total PAH concentrations and speciated PAH concentrations is unclear, but may relate to the use of Flame Ionisation Detection (FID) to measure total PAH concentrations. Despite this observation PAH are considered to be a COC in groundwater requiring further consideration.

7.2.4 Inorganic Contaminants

A wide variety of inorganic parameters have been identified in groundwater. A summary of the screening assessment for inorganic contaminants that occur in groundwater at concentrations above the Method Detection Limit (MDL) is presented in *Table 7.4*. The entire screened dataset, including parameters not identified in groundwater at concentrations above the MDL, is provided in *Appendix F*.

Table 7.4. Screening Assessment of Inorganic Substances in Groundwater

Determinand	Type	Total Number of Analyses	Analyses Above Detection Limit (No.)	Analyses Above Detection Limit (%)	Concentration Range (µg/l)	Mean Concentration (µg/l)	Assessment Criterion (AC)	Value (µg/l)	No. Analyses Above AC	Mean Conc. Above AC
Cadmium	Haz	129	10	7.8%	0.1 - 8.4	1.60	DWS	5	2	No
Mercury	Haz	121	9	7.4%	0.05 - 0.1	0.063	DWS / EQS	1	0	No
Arsenic	Non haz	129	35	27.1%	1 - 27	3.17	DWS	10	2	No
Barium	Non haz	69	68	98.6%	10 - 60	29.1	DWS	1000	0	No
Boron	Non haz	129	52	40.3%	10 - 181	44.3	DWS	1000	0	No
Chromium	Non haz	129	85	65.9%	1 - 121	4.32	DWS	50	1	No
Copper	Non haz	129	65	50.4%	1 - 34	3.7	DWS	2000	0	No
Lead	Non haz	129	6	4.7%	1 - 3	1.50	DWS	25	0	No
Nickel	Non haz	129	120	93.0%	1-160	9	DWS	20	8	No
Selenium	Non haz	117	40	34.2%	1 - 12	2.38	DWS	10	1	No
Vanadium	Non haz	44	26	59.1%	1 - 5	2.54	EQS	20	0	No
Zinc	Non haz	128	102	79.7%	3 - 180	22.7	DWS	5000	0	No
Alkalinity	Misc	8	8	100.0%	10 - 150 mg/l	80.25 mg/l	-	No Ac	-	-
Ammoniacal nitrogen as N	Misc	44	9	20.5%	200 - 1900	778	DWS	500	4	Yes
Ammoniacal nitrogen as NH4-N	Misc	56	31	55.4%	200 - 7900	968	DWS	500	16	Yes
Biochemical Oxygen Demand	Misc	32	25	78.1%	1000 - 48000	10640	-	No AC	-	-

Table 7.4. Screening Assessment of Inorganic Substances in Groundwater (Continued)

Determinand	Type	Total Number of Analyses	Analyses Above Detection Limit (No.)	Analyses Above Detection Limit (%)	Concentration Range (mg/l)	Mean Concentration (mg/l)	Assessment Criterion (AC)	Value (mg/l)	No. Analyses Above AC	Mean Conc. Above AC
Calcium	Misc	7	7	100.0%	12.97 – 38.4	27.05	DWS	250	0	No
Chemical Oxygen Demand	Misc	54	42	77.8%	11 - 2455	289.7	-	No AC	-	-
Chloride	Misc	55	55	100.0%	12 - 71	29.3	DWS	250	0	No
Dissolved Oxygen	Misc	10	10	100.0%	3.1 – 8.4	6.91	-	No AC	-	-
Electrical Conductivity	Misc	29	29	100.0%	0.199 – 0.353	0.288	-	No AC	-	-
Iron	Metal	20	17	85.0%	0.010 – 0.787	0.147	DWS	0.2	2	No
Magnesium	Metal	8	8	100.0%	1.74 – 7.74	5.32	DWS	5	0	No
Manganese	Metal	8	8	100.0%	0.004 – 0.124	0.0423	DWS	0.05	2	No
Nitrate (as N)	Misc	26	19	73.1%	0.3 – 1.7	0.558	DWS	11.3	0	No
pH	Misc	132	132	100.0%	4.6 - 8.59	7.28	7.28	No AC	-	-
Potassium	Metal	7	7	100.0%	1.6 – 3.6	2.514	DWS	12	0	No
Sodium	Metal	7	7	100.0%	16.5 – 47.5	31.4	DWS	200	0	No
Solvent Extractable Matter	Misc	9	7	77.8%	1 - 3	1.571	-	No AC	-	-
Sulphate	Misc	88	87	98.9%	4 - 4696	78.93	DWS	250	1	No
Sulphide	Misc	7	7	16.3%	30 - 140	57.1	DWS	0.25	7	Yes
Total Dissolved Solids	Misc	7	7	100.0%	101 - 175	146.3	-	No AC	-	-
Total Organic Carbon	Misc	34	34	100.0%	1.0 - 53	5.5	-	No AC	-	-
Total Oxidised Nitrogen	Misc	7	4	57.1%	1.3 – 5.9	3.6	DWS	11.3	0	No
Total Sulphur	Misc	25	25	100.0%	4 - 165	298.8	-	No AC	-	-
Total Suspended Solids	Misc	7	7	100.0%	20 - 517	143.4	-	No AC	-	-

Hazardous (former List I) and Non Hazardous (former List II) Metals

A wide variety of hazardous and non hazardous metals and metalloids are routinely measured in groundwater (generally more than 100 analyses). Nickel, zinc, chromium, barium and copper are routinely observed in groundwater, being identified in more than 50% of samples analysed. The concentration of all hazardous and non hazardous metals are typically low, with their respective AC rarely exceeded and average concentrations below the relevant AC. Occasional failures are observed at some boreholes, however continuously elevated concentrations are not generally observed.

Nickel is the only metal for which the UK DWS is exceeded on more than two occasions. The 8 occasions the UK DWS for nickel is exceeded represents less than 7% of all analyses, however the majority of exceedances are observed in two boreholes namely BH0398 and BH0364. Both boreholes are located off site in a lateral and down-gradient position to the Development Area.

List I and List II metals are not therefore considered to be COC in groundwater.

Major Cations

A variety of major cations have been monitored in groundwater, including calcium, iron, magnesium, manganese, potassium and sodium. Few failures with respect to the AC for these cations are observed and they are not therefore considered to represent COC in groundwater.

Ammoniacal Nitrogen

Ammoniacal nitrogen is commonly observed in groundwater on the site and occurs frequently at concentrations above the UK DWS for this parameter. This parameter is considered to represent a COC in groundwater requiring further consideration.

Major Anions

A variety of major anions are monitored in groundwater. These include chloride, nitrate (as N), Total Oxidised Nitrogen and sulphate. Major anions rarely occur at concentrations above their respective AC and are not considered to represent COC in groundwater.

Other Parameters

Sulphide has been identified in groundwater routinely at concentrations above the UK DWS. A number of observations regarding this parameter can be made:

- Sulphide routinely identified across the AWE(A) site at elevated concentrations,
- Elevated sulphide concentrations are observed in off site and up gradient locations relative to the Development Area;
- There is no site-specific source for sulphide identified in the Development Area.

Elevated sulphide concentrations are considered an artefact of baseline water quality for the aquifer and sulphide is not therefore considered a COC requiring further assessment.

Most other parameters have no AC defined or occur at concentrations below their respective AC.

7.3 Principal Contaminants of Concern

On the basis of the groundwater screening assessment presented in *Section 7.2* the principal Contaminants of Concern (COC) requiring further evaluation are considered to be:

- Diesel Range Organic (DRO) Hydrocarbons – specifically Aliphatics ($>C_{21}$-C_{35});
- Polycyclic Aromatic Hydrocarbons (PAH); and
- Ammoniacal nitrogen.

Nickel is not considered a COC as repeated occurrences at concentrations above the UK DWS are only observed in boreholes situated outside of the Application Site boundary and in lateral or down-gradient positions relative to the groundwater flow field on the site.

The distribution and temporal variability of each of the COCs is described below to determine whether further Quantified Risk Assessment (QRA) is required for these parameters. Soil contamination data is also screened to assess whether any link between contamination in the soil and contaminants observed in groundwater can be identified.

7.3.1 Petroleum Hydrocarbons

Diesel Range Organic Hydrocarbons

The screening assessment presented in *Section 7.2* demonstrates that the concentration of DRO (C_{10}–C_{40}) in groundwater exceeds its assessment criteria on thirteen occasions (*Table 7.3*). The distribution of maximum DRO concentrations observed in all monitoring rounds on the Development Area is shown in *Drawing*

JER4214-0105ia. Ten of the eighteen boreholes across the site have never detected DRO at concentrations above the MDL. Non-detects are seen across the site, but are most commonly associated with boreholes in the central area near the footprint of former buildings on the Application Site.

DRO concentrations range from the detection limit to a maximum concentration of 0.595 mg/l in borehole BH0909. Elevated concentrations occur infrequently and are widely distributed across the Application Site. The highest concentrations of DRO are seen in the southern and western areas of the Application Site, although no well defined source areas of contamination are apparent.

Aliphatic Hydrocarbon

The nature of DRO contamination in groundwater is further examined by the review of banded aromatic and aliphatic hydrocarbons dataset. The spatial distribution of banded aliphatic and aromatic hydrocarbons identified in groundwater is shown in *Drawing JER4214-010iia* and *Drawing JER4214-010iiia* respectively.

The groundwater screening presented in *Section 7.2* demonstrates that long chain aliphatic hydrocarbons (HCs) (C_{21}–C_{35}) dominate the petroleum hydrocarbons identified in groundwater. The maximum concentrations of aliphatic (C_{21}–C_{35}) hydrocarbons observed in groundwater are shown in *Drawing JER4214-010iia*, with a maximum concentration of 0.728 mg/l in borehole BAEBH1. Elevated concentrations are generally observed in the centre of the site, but have little correlation with the footprint of former buildings. Elevated concentrations of aliphatic (C_{21}–C_{35}) are also observed in the two boreholes situated closest to the down-gradient site boundary, namely WSHYD-06 and BHHYD-03, with concentrations of 0.34 mg/l and 0.26 mg/l respectively.

The data presented in *Drawing JER4214-010iia* also demonstrates that lighter aliphatic hydrocarbons (i.e. C_{16}–C_{21}) are rarely present in groundwater (having exceeded the AC eight times) and occur at low concentrations where present.

The distribution of aliphatic hydrocarbons in soils on the Development Area is shown in *Drawing JER4214-011ia*. The principal observations from this drawing include:

- Infrequent occurrence of aliphatic hydrocarbons in soils;
- Low concentration of aliphatic hydrocarbons in soils where present (less than 150 mg/kg); and
- Elevated soil concentrations associated with footprint of former buildings on the site.

There is little correlation between the location of elevated concentrations of aliphatic (C_{21}–C_{35}) hydrocarbons in soil and that observed in groundwater. Furthermore, no significant source areas of aliphatic (C_{21}–C_{35}) hydrocarbons are apparent in soils.

Aromatic Hydrocarbons

The distribution of maximum aromatic (C_{21}–C_{35}) hydrocarbon concentrations in groundwater are shown in *Drawing JER4214-010iia*. Aromatic HCs (C_{21}–C_{35}) hydrocarbons are generally absent from groundwater, with a maximum concentration of 0.052 mg/l observed in borehole BHHYD-02. Furthermore, aromatic HCs (C_{16}–C_{21}) have never been detected in groundwater. No further quantitative risk assessment is considered necessary with respect to aromatic hydrocarbons in groundwater.

The distribution of aromatic hydrocarbons in groundwater contrasts with their distribution in soil as shown in *Drawing JER4214-011ia*. From *Drawing JER4214-011ia* the following observations can be made*:*

- Aromatic hydrocarbons in soils are dominated by heavier fractions (i.e. EC_{21} – EC_{35});
- The concentration of aromatic HCs (EC_{21} – EC_{35}) range from below the MDL to a maximum of 1,000 mg/kg;
- Elevated concentrations of aromatic hydrocarbons in soils are observed in the central area of the site (including the footprint of former buildings) and the north-east corner of the site.

The source of the soil contamination identified in the north-east corner of the site is unclear. *Table 7.5* shows the maximum concentration of aromatic HCs (EC_{21} – EC_{35}) measured in each trial pit in the north-east area. All samples with elevated aromatic HCs (EC_{21} – EC_{35}) were from a shallow depth of 0.2 mbGL.

Table 7.5. Concentration of aromatic C21-C35 in Trial Pits.

Trial Pit ID	Concentration in Soil (mg/kg @ 0.2 mbGL)
TP1012	180
TP1013	750
TP1014	900
TP1015	20
TP1016	400

The geological logs shows that the samples taken from 0.2 mbGL were from a dark brown organic silty gravelly sand (described on three of the five trial pit logs as Made Ground). The depth of Made Ground in the trial pits ranges from 0.28 m (in trial pit TP 1014) to 0.35 m (in trial pit TP1016). Additional samples were taken from each of the above trail pits at a depth of between 2.5 mbGL - 3.0 mbGL and demonstrated concentrations below the MDL for aromatic HCs (EC_{21} – EC_{35}).

Borehole BH0364 is located approximately 50 m down-gradient of this part of the site. Monitoring at this borehole has only been undertaken for PRO C_4-C_{10} and PRO C_{10}-C_{12}, although neither has ever been detected in BH0364. It is not therefore possible to know if any of the heavier fractions are present in groundwater.

Additional quantitative risk assessment shall be undertaken in an attempt to determine soil remedial targets for aromatic (EC_{21} – EC_{35}) to protect groundwater quality (i.e. controlled waters) at the site boundary considering:

- The proximity north-eastern source area of aromatic (EC_{21} – EC_{35}) contamination of shallow soils to the down gradient site boundary; and
- The absence of appropriate monitoring data for the down-gradient groundwater borehole.

7.3.2 Polycyclic Aromatic Hydrocarbons (PAH)

Total PAH

PAH have been analysed by a variety of methods since 2001, with total PAH having been measured each year since 2001, except for 2008. Temporal trends in the concentration or total PAH could not be determined as there is limited time series data available for boreholes within the Application Site. The most recent data for total PAH is for March 2009 and includes data for six recently installed boreholes, namely BHHYD-01, BHHYD-02, BHHYD-03, WSHYD-04, WSHYD-05 and WSHYD-06. However, speciated PAH were not measured during this round.

The long-term maximum historical concentration of total PAHs for all boreholes on the site is shown in *Drawing JER4214-005iiia*. Highest concentrations appear to occur in the centre of the site and towards the northern site boundary (lateral to groundwater flow). The maximum recorded total TPH concentration is 2 mg/l and was recorded in borehole BH0330 in August 2004. However, this is result is not considered representative of the BH0330, where total PAH concentrations measured in the preceding and subsequent monitoring round were below the MDL and 0.00058 mg/l respectively. Apart from BH0330, the highest recorded concentrations are seen in three of new boreholes installed in the centre of the site (WSHYD-04, WSHYD-05 and WSHYD-06), with a concentration range of 0.13 mg/l to 0.25 mg/l.

Boreholes situated in an up-gradient location relative to the groundwater flow field (in on-site and off-site locations) indicate the presence of total PAH at concentrations above the MDL, but at lower concentrations than seen within the Development Area (e.g. EBH7, ST13A and ST14). The remainder of the boreholes on the Development Area show relatively low concentrations of total PAH, with non-detects recorded for most other monitoring rounds.

The concentration and distribution of total PAH in soils is shown in *Drawing JER4214-006iiia*. Soil concentrations above the MDL occur infrequently in soils. Where concentrations above the MDL are identified they are typically low (less than 100 mg/kg) and generally associated with the footprint of former buildings within the Application Area. No link between soil contamination and total PAH in groundwater is evident.

It is conspicuous that the elevated concentrations measured for total PAH greatly exceed the maximum concentration record for each speciated PAH (see *Table 7.3*). This discrepancy may relate to the analytical method used to measure total PAH concentrations (i.e. Flame Ionisation Detection (FID)). For this reason the more extensive dataset for speciated PAH has been studied to determine the nature and likely significance of PAH contamination in groundwater.

Speciated PAH

The screening assessment presented in *Section 7.2* has identified the following PAH with concentrations that exceed the AC on more than one occasion: Di-sec-octyl phthalate; fluoranthene; diethyl phthalate; phenanthrene; pyrene; and di-n-butylphthalate. The occurrence of each of these PAH is summarised below.

Di-sec-octyl-phthalate

Di-sec-octyl-phthalate is most widely used as a general purpose plasticiser for the manufacture of flexible plastics (especially polyvinyl chloride). Di-sec-octyl-phthalate has been monitored in eight boreholes within or adjacent to the Application Site. Di-sec-octyl-phthalate has been identified in eleven out of fifty-six groundwater samples analysed and its occurrence in groundwater is summarised *Table 7.6*.

Table 7.6. Occurrence of Di-sec-octyl-phthalate in Groundwater

Borehole In Which AC is Exceeded	Position in Groundwater Flow Field	Total Number of Analyses	Method Detection Limit (µg/l)	Number of Analyses Above MDL	Number Analyses Above AC	Maximum Concentration (µg/l)
BH0331	Centre of Site	4	1	1	1	2
BH0332	Centre of Site	6	1	2	1	4
BH0900	Centre of Site	3	1	1	1	1
BH0901	Centre of Site	2	1	1	1	2
BH0902	Centre of Site	3	1	2	1	2
BH0909	Southern / Central	3	1	1	1	2
BH0927	Northern / Central	3	1	2	2	3
BH0928	Northern / Central	3	1	1	1	2

Di-sec-octyl-phthalate is generally restricted to boreholes in the centre of the site and is absent from ten boreholes on the site, including all boreholes in off-site locations. Where di-sec-octyl-phthalate is observed at concentrations above the MDL it occurs occasionally and at low concentration, with a maximum concentration of 4 µg/l recorded in a single sample out of six from BH0332. Di-sec-octyl-phthalate is not considered a COC requiring further assessment.

Fluoranthene

The occurrence of fluoranthene in groundwater is summarised *Table 7.7*.

Table 7.7. Occurrence of Fluoranthene in Groundwater

Borehole In Which AC is Exceeded	Position in Groundwater Flow Field	Total Number of Analyses	Method Detection Limit (µg/l)	Number of Analyses Above MDL	Number Analyses Above AC	Maximum Concentration (µg/l)
EBH7	Up-gradient, Off-site	2	0.01	1	1	0.109
EBH8	Up-gradient, Site Boundary	3	0.01	2	1	0.181
EBH8A	Up-gradient, Site Boundary	3	0.01	2	1	0.194
ST14	Up-gradient, Site Boundary	5	0.01	1	1	0.25

The occurrence of fluoranthene at concentrations above the MDL is restricted to boreholes in an up-gradient position and generally in off site locations. The MDL is only occasionally exceeded in individual boreholes, with concentrations only marginally above the AC for total PAH. Fluoranthene is not therefore considered to be a COC requiring further quantitative risk assessment.

Diethyl phthalate

The occurrence of diethyl phthalate in groundwater is summarised *Table 7.8.*

Table 7.8. Occurrence of Diethyl phthalate in Groundwater

Borehole In Which AC is Exceeded	Position in Groundwater Flow Field	Total Number of Analyses	Method Detection Limit (µg/l)	Number of Analyses Above MDL	Number Analyses Above AC	Maximum Concentration (µg/l)
BH0332	Centre of Site	6	1	1	1	2
BH0900	Centre of Site	3	1	1	1	2
BH0901	Centre of Site	2	1	1	1	1
BH0909	Southern / Central	3	1	1	1	1

Diethyl phthalate is observed in frequently at concentrations above the MDL in individual boreholes, with a maximum concentration of 1 µg/l to 2 µg/l. Diethyl phthalate is not therefore considered to be a COC requiring further quantitative risk assessment.

Phenanthrene

The occurrence of phenanthrene in groundwater is summarised *Table 7.9.*

Table 7.9. Occurrence of Phenanthrene in Groundwater

Borehole In Which AC is Exceeded	Position in Groundwater Flow Field	Total Number of Analyses	Method Detection Limit (µg/l)	Number of Analyses Above MDL	Number Analyses Above AC	Maximum Concentration (µg/l)
EBH7	Up-gradient, Off-site	2	0.01	2	1	0.142
EBH8	Up-gradient, Site Boundary	3	0.01	2	1	0.205
EBH8A	Up-gradient, Site Boundary	3	0.01	2	2	2.2

The occurrence of phenanthrene at concentrations above the MDL is restricted to boreholes in an up-gradient with respect to the groundwater flow field and generally in an off-site position. The AC is occasionally exceeded in boreholes EBH7 and EHB8 but at low concentrations. The AC is exceeded in two of the three occasions it has been measured at borehole EBH8A. The occurrence of phenanthrene in borehole EBH8A is not considered to require additional assessment considering:

- Low concentrations observed in this borehole;
- Position of borehole EBH8A on the up-gradient site boundary.

Pyrene

The occurrence of pyrene in groundwater is summarised *Table 7.10.*

Table 7.10. Occurrence of Pyrene in Groundwater

Borehole In Which AC is Exceeded	Position in Groundwater Flow Field	Total Number of Analyses	Method Detection Limit (µg/l)	Number of Analyses Above MDL	Number Analyses Above AC	Maximum Concentration (µg/l)
EBH8	Up-gradient, Site Boundary	3	0.01	1	1	0.160
EBH8A	Up-gradient, Site Boundary	3	0.01	2	1	0.111
ST14	Up-gradient, Site Boundary	5	0.01	1	1	0.238

The occurrence of pyrene at concentrations above the MDL is restricted to boreholes in an up-gradient position and generally off site. The MDL is only occasionally exceeded in individual boreholes, with concentrations only marginally above the AC for total PAH. Pyrene is not therefore considered to be a COC requiring further quantitative risk assessment.

Di-n-butylphthalate

The occurrence of di-n-butylphthalate in groundwater is summarised *Table 7.11.*

Table 7.11. Occurrence of Di-n-butylphthalate in Groundwater

Borehole In Which AC is Exceeded	Position in Groundwater Flow Field	Total Number of Analyses	Method Detection Limit (µg/l)	Number of Analyses Above MDL	Number Analyses Above AC	Maximum Concentration (µg/l)
BH0398	Off-site, on lateral groundwater flow path.	3	1	3	3	3

Di-n-butylphthalate has been observed at concentrations above the AC for total PAH in all three analyses undertaken on samples from borehole BH0398, however concentrations are low ranging between 1 µg/l and 3 µg/l. Di-n-butylphthalate has not been identified in any other boreholes on the site at concentrations above the MDL. Di-n-butylphthalate is not considered a COC requiring further risk assessment as it restricted to off-site boreholes on a lateral flow path relative the application site.

Although no further assessment is required for di-n-butylphthalate it is recommended that speciated PAH are measured in borehole BH0398 in the final scheduled rounds of groundwater monitoring to be undertaken on the site in 2009.

Summary of PAH in Groundwater

Speciated PAH do not indicate an issue regarding PAH contamination of groundwater within the Development Area. No further risk assessment quantitative risk assessment has been recommended although the measurement of speciated PAH within borehole EBH8A and BH0398 has been recommended.

However, a significant discrepancy between the concentration of total PAHs measured in groundwater and speciated PAH in groundwater has been identified. Although this discrepancy may relate in part to the analytical methodology historically used to measure total PAH, further monitoring of speciated PAH in all boreholes during the final monitoring rounds scheduled for the site in 2009/2010 has been recommended. The resultso of this additional analysis will be presented in an addendum report to the Ground Conditions Technical Report, to be produced in 2010.

No link between PAH contamination in groundwater and that observed in shallow soils has been identified.

7.3.3 Ammoniacal Nitrogen

Introduction

The screening assessment for inorganic substance presented in *Section 7.2.4* identified Ammoniacal nitrogen as a COC in groundwater.

Ammoniacal nitrogen concentrations have historically been expressed as either NH_4^+ (ammonium) or simply as N. The entire dataset was screened against the UK DWS for ammonium (NH_4^+) of 0.5 mg/l. For the screening process ammoniacal nitrogen concentrations expressed as N were not corrected to NH_4^+ as the resulting difference is small. As ammonium (NH_4^+) is the dominant form of Ammoniacal nitrogen in aqueous solutions at the pH and temperature typical for groundwater, no attempt was made to correct for the ammonia component of the total Ammoniacal nitrogen. This is considered acceptable for preliminary screening of the water quality dataset. The screening assessment presented in *Section 7.2* demonstrated the AC was exceeded on twenty of the one-hundred occasions it was measured (c. 25%).

For the purpose of this additional assessment ammoniacal nitrogen concentrations expressed as nitrogen (N) have been converted to ammonium (NH_4^+) to enable direct comparison, although no correction for the component of non-ionised ammonia has been made. Time series data for each borehole with concentrations of ammoniacal nitrogen that exceed the MDL are provided in *Appendix G* and summarised below.

Most boreholes with ammoniacal nitrogen concentrations above the MDL are characterised by either:

- Concentrations below the UK DWS (BH0333, BH900, BH902);
- Single excursions above the UK DWS but with remaining analyses below the UK DWS and commonly below the MDL (BH0331, BH909 and BH926); or
- Declining trends in ammoniacal nitrogen to below the UKDWS over the monitoring period (EBH7, EBH8 and EBH8A).

The only exception to the above trends is observed in borehole BH0398, where Ammoniacal nitrogen concentrations in excess of the UK DWS were observed in all three monitoring rounds (with a concentration of 2.5 mg/l to 3.0 mg/l). However, this borehole is located in an off site location and on a groundwater flow path that is unlikely to pass on to the Development Area.

Ammoniacal nitrogen is not therefore considered a COC requiring further assessment on the site.

7.3.4 Summary of Contaminants of Concern

Preliminary screening of the groundwater quality dataset identified the following substances as potential contaminants of concern:

- Diesel Range Organic (DRO) hydrocarbons – specifically aliphatics (>C_{21}-C_{35});
- Polycyclic Aromatic Hydrocarbons (PAH); and
- Ammoniacal nitrogen.

Following more detailed review of the groundwater quality data set it was determined that further quantified risk assessment would be required to demonstrate that aliphatic HCs ($>C_{21}$-C_{35}) in groundwater do not represent an unacceptable risk to controlled waters.

It was also concluded that in the absence of appropriate down-gradient (i.e. site boundary) groundwater monitoring installations in the north-east corner of the Development Area, no assessment regarding the risk to controlled from soil contamination by heavy aromatic (EC_{21} – EC_{35}) hydrocarbons could be made. For this reason it was decided that remedial targets for soils should be determined for this area of the site, to assess whether concentrations observed in soils are likely to be unacceptable in terms of risk to controlled waters.

Although PAH are not considered a risk to control waters on the site, elevated total PAH were identified (principally in the latest monitoring round) in the centre of the site. Although this occurrence is not supported by speciated PAH data for groundwater it is recommended that speciated PAH are measured in groundwater as part of routine groundwater monitoring scheduled for late 2009 on the Application site. It was also recommended that speciated PAH be measured in boreholes EBH8A and BH0398 should these boreholes not be included on the monitoring rounds scheduled for 2009.

7.4 Quantitative Risk Assessment

7.4.1 Introduction

The initial groundwater screening assessment and subsequent detailed evaluation of principal COC in groundwater identified that aliphatic C_{21}-C_{35} as requiring further quantitative risk assessment. Remedial targets for soil are also to be derived for aromatic (EC_{21} – EC_{35}) hydrocarbons, to screen contaminant concentrations observed in shallow soils in the north-east of the site. The additional quantified risk assessment was undertaken in accordance with the Environment Agency's Remedial Targets Methodology (*Ref 40*).

7.4.2 Remedial Targets Methodology

The Environment Agency's Remedial Targets Methodology (*Ref 40*) compares a measured, or modelled, contaminant concentration against a target concentration, which is generally an environmental standard. The target concentration is compared with the measured or calculated concentration at a particular location, known as a compliance point, to determine whether a concentration in, or migrating from, a source is acceptable. To achieve this, the Environment Agency model uses a tiered approach, with increasing complexity and therefore greater data requirements at the higher tiers. In addition to assessing risk based on current contamination, a concentration such that the target concentration is not exceeded can be calculated; this is known as the remedial target. The tiers for a contaminated soil source are briefly summarised below.

Level 1

For the Level 1 (Soil Zone) assessment the compliance point is taken as the soil zone and the remedial target is set as equivalent to the target concentration. No allowance is made for processes such as dilution and attenuation that might affect contaminant concentrations along the pathway between the soil and the identified receptor.

Level 2

At Level 2 the analysis considers whether attenuation of pollutants in the unsaturated zone and by dilution of contaminants leached from the soil in groundwater is sufficient to reduce contaminant concentrations to acceptable levels. This gives a less conservative remedial target than derived at Level 1. The remedial target is determined by multiplying the target concentration by a dilution factor and/or unsaturated zone attenuation factor.

For level 2 the compliance point is taken as groundwater beneath the source area.

Level 3

At Level 3, the assessment considers whether the attenuation of contaminant concentrations along the migration pathway in the saturated aquifer is sufficient to reduce contamination concentrations acceptable levels. Attenuation includes the processes of: contaminant degradation; sorption of contaminants onto soil particles in the saturated zones (generally the organic matter contained within the soils); ion exchange; ion exchange; precipitation of inorganic compounds; volatilization; and dispersion within the aquifer. An attenuation factor (AF) is derived for the site.

For Level 3 the compliance point is located between the source and the identified receptor.

Approach

For the controlled waters Quantified Risk Assessments (QRA) required as part of this work a level 3 assessment was required. For aliphatic C_{21}-C_{35} hydrocarbons a Level 3 Groundwater Assessment was undertaken, which involved evaluating whether observed contaminant concentrations in groundwater constitute an unacceptable risk to controlled waters. For the evaluation of soil contamination by aromatic C_{21} – EC_{35} hydrocarbons in the north-east of the site a Level 3 assessment was undertaken to determine remediation targets for soils, which could then be compared with observed soil concentrations.

7.4.3 Pollutant (Source-Pathway-Receptor) Linkages

Both assessments are based upon the concept of a Pollutant (SPR) Linkage as described in the baseline CSM (*Section 4*).

Source

The sources of contamination identified on the Development Area have been identified as aliphatic (C_{21}-C_{35}) hydrocarbons in groundwater in the centre of the site and aromatic (EC_{21} – EC_{35}) hydrocarbons in soils in the north-east of the site.

Pathway

The shallow, unconfined Silchester Gravel / Bagshot Bed aquifer is considered the principal pathway for the transport of contamination on the site.

Receptor

Groundwater in the shallow, unconfined Silchester Gravel / Bagshot Bed minor aquifer is considered the primary receptor. The Fish Pond, situated approximately 200m east of the down-gradient site boundary also constitutes an important receptor of groundwater.

7.4.4 Model Parameterisation

Controlled waters risk assessment like any other mass transport model require a variety of physical and chemical input parameters. Where possible input parameters used in any assessment are based on site-specific data. Where site-specific data is absent parameters have been derived from published data source and / or professional judgment. The sources of information used in this assessment include:

- Total Petroleum Hydrocarbon Criteria Working Group Series Volume 3 (*Ref 43*);
- ConSim Version 2.02 User Manual (*Ref 44*);
- SCRT 2:B Area North Investigation Report (*Ref 38*);
- AWE Hydrus Geotechnical Interpretative Report (*Ref 25*); and

- Other literature as referenced in the text.

Two Quantified Risk Assessments (QRA) for controlled waters have been undertaken as part of this assessment:

- Model 1 - Aliphatic C_{21}-C_{35} hydrocarbons in groundwater in the centre of the Development Area; and
- Model 2 - Aromatic EC_{21} – EC_{35} hydrocarbons in soils in north-east of the Development Area.

Source Areas and Contaminants of Concern

Model 1 - Aliphatic C_{21}-C_{35} hydrocarbons in groundwater

The source area dimensions and concentrations used for Model 1 are described in *Table 7.12.* Borehole WSHYD-06 was chosen to represent the source term as it is the borehole closest to the site boundary (with no intervening down-gradient boreholes present) and has the highest concentration of aliphatic C_{21}-C_{35} hydrocarbons.

Table 7.12. Source area dimensions and concentrations for model 1

Parameter	Value	Unit	Justification
Width of plume in aquifer at source	5	m	Represent source term for localised contamination of groundwater within a single borehole
Plume thickness at source	0.4	m	Based on saturated full saturated aquifer thickness for Silchester Gravels and top of Bagshot Formation at this location
Initial Contamination concentration	0.335	mg/l	Concentration of aliphatic (C21-C35) observed in borehole WSHYD-06 in June 2009

Model 2 - Aromatic EC_{21} – EC_{35} hydrocarbons in soils

The source area dimensions and concentrations used for Model 2 are described in *Table 7.13.* Trial pits TP1016 and TP1014 are chosen to represent the source term for this model as they are two closest to the site boundary with TP1014 showing the maximum concentration of aromatic EC_{21} – EC_{35} hydrocarbons.

Table 7.13. Source area dimensions and concentrations for model 2

Parameter	Value	Unit	Justification
Length of contaminant source in direction of groundwater flow	10	m	Horizontal distance between trial pits TP1014 and TP1016
Width of contaminant source perpendicular to groundwater flow	40	m	Distance between trial pits TP1014 and TP1016
Soil concentration	900	mg/kg	Max concentration seen in the north-eastern trial pits (seen in trial pit TP1014)

Compliance Points and Target Concentrations

For the purpose of the quantitative risk assessment groundwater contaminant concentrations are modelled from the source area to a "compliance point". The compliance point used in the QRA have been set for groundwater at the down-gradient (i.e. eastern) boundary of the Development Area. Target concentrations equivalent to relevant UK DWS have been used in the QRA and are summarised in *Table 7.14.*

Table 7.14. Target Concentrations

Parameter	Value	Unit	Justification
Model 1 - Aliphatic C_{21}-C_{35} hydrocarbons			
Target concentration	0.01	mg/l	UK Drinking Water Standard for Oils / Hydrocarbons
Model 2 - Aromatic EC_{21} – EC_{35} hydrocarbons			
Target concentration	0.01	mg/l	UK Drinking Water Standard for Oils / Hydrocarbons

This UK DWS is considered appropriate as both source areas are dominated by heavier petroleum fractions, as opposed to more mobile aromatic hydrocarbons which may be represented as BTEX hydrocarbons.

Input Parameters

Model 1 - Aliphatic C_{21}-C_{35} hydrocarbons in groundwater

The input parameters described in *Table 7.15* were used within the risk assessment for Model 1. Key assumptions underlying the input parameters selected for Model 1 are:

- Bulk density values range from 1.36 to 2.19 g/cm^3 in the ConSim Manual, the lowest value was used within the QRA, although using the maximum value did not change the final result;
- Although there is no site-specific hydraulic conductivity data, data for the AWE(A) site ranges from 0.0864 m/d to 0.864 m/d. The lower value was used in the QRA, although using the higher value did not change the final result
- The organic carbon partition coefficient is provided for the EC>16-35 band for aliphatics within *Ref 43*, rather than aliphatic EC>21-35, however this will be a conservative figure
- No biodegradation of the contaminant has been modelled as no literature values are available for the aliphatic C21-C35 carbon band, and;
- As a conservative approach this QRA used the minimum value for the fraction of organic carbon generated within Golder Associates Ltd QRA process

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Table 7.15. Input Parameters to Remedial Targets Worksheet (Model 1)

Parameter	Value	Unit	Justification
Half life for degradation	9×10^{99}	days	No biodegradation within groundwater
Saturated aquifer thickness	0.55	m	Depth of water in borehole WSHYD-06 during monitoring in May 2009
Bulk density of aquifer materials	1.36	g/cm^3	Minimum value for a gravel given in ConSim manual (*Ref 45*)
Effective porosity of aquifer	0.1	fraction	Minimum value of effective porosity for a coarse gravel (*Ref 46*)
Hydraulic gradient	0.013	fraction	Calculated gradient in the direction of groundwater flow across the site between boreholes BAEBH1 and BAEBH3 based on groundwater levels measured in May 2009
Hydraulic conductivity of aquifer	0.0864	m/d	Minimum value taken from Atkins report (*Ref 25*)
Fraction of organic carbon in aquifer	0.00087	fraction	Minimum value used in Golders ConSim risk assessment for Silchester Gravels (*Ref 38*)
Organic carbon partition coefficient	3.98×10^8	l/kg	Value for Total Petroleum Hydrocarbon Criteria Working Group Series, Volume 3, Table 8, log K_{ox} value for Aliphatic EC>16-35
Distance to compliance point	85	m	Distance from borehole WSHYD-06 to eastern boundary of the Application Site (as groundwater is flowing eastwards across the site)
Distance (lateral and depth) to compliance point perpendicular to flow direction	0	m	Recommended by the Remedial Targets Worksheet
Time since pollutant entered groundwater	9×10^{99}	days	Recommended by the Remedial Targets Worksheet

Model 2 - Aromatic EC_{21} – EC_{35} hydrocarbons in soils

The input parameters for each tier of analysis required for Model 2 are described in *Table 7.16* to *Table 7.18.*

Table 7.16 Input Parameters to Remedial Targets Worksheet Level 1 (Model 2)

Parameter	Value	Unit	Justification
Level 1			
Water filled soil porosity	0.01	fraction	The minimum effective porosity value for a gravelly sand in (*Ref 46*) is 0.2, this does not distinguish between that which is water filled and that which is air filled. As the Made Ground is unsaturated 5% of the effective porosity value has been utilised to represent pores that are filled with water.
Air filled soil porosity	0.19	fraction	
Bulk density of soil zone material	1.37	g/cm^3	Minimum density of a gravelly sand in (*Ref 46*)
Henry's Law Constant	$8.2x10^{-5}$	dimensionless	Value from Total Petroleum Hydrocarbon Criteria Working Group Series, Volume 3, Table 8, H value for Aromatic –EC> 21-35
Fraction of organic carbon (in soil)	0.0002	fraction	Minimum value from Golders Report (*Ref 38*) from measurements in Made Ground
Organic carbon partition coefficient	$1.26x10^5$	l/kg	Value for Total Petroleum Hydrocarbon Criteria Working Group Series, Volume 3, Table 8, log K_{ox} value for Aromatic EC>21-35

Key assumptions underlying the input parameters selected for Model 2 include:

- Effective porosity for a gravelly sand ranges from 0.2 to 0.35 (*Ref 46*). However the result of Model 2 is not sensitive to this range for this of parameter;
- The dry bulk density of a gravelly sand ranges from 1.37 to 1.81 g/cm^3 (*Ref 46*). However the results of Model 2 is largely insensitive to this range; and
- *Ref 38* provides a minimum, most likely and maximum value for the fraction of organic carbon in the Made Ground. The minimum value has been utilised in this model as a conservative approach. The most likely and maximum values are utilised in *Section 7.4.5* to determine the sensitivity of the results based on the range of values for the fraction of organic carbon.
- Lowest available literature rates of biodegradation for benzo(a)pyrene representative of the aromatic C21-C35 carbon band has been modelled.

Table 7.17 Input Parameters to Remedial Targets Worksheet Level 2 (Model 2)

Parameter	Value	Unit	Justification
Level 2			
Infiltration	1.64×10^{-3}	m/d	Maximum infiltration value used in *(Ref 38)*
Area of contaminant source	400	m	Based on area around TP1014 and TP1016, two trial pits closest to the site boundary, with TP1014 showing the highest concentration of aromatic C21-C35. Value not used in calculation
Saturated aquifer thickness	1.2	m	Base of borehole minus depth to groundwater measured in May 2009 in borehole BH0333 (closest to north-eastern area of the Application Site)
Hydraulic conductivity of aquifer in which dilution occurs	0.0864	m/d	Minimum value from Atkins report (*Ref 25*)
Hydraulic gradient of the water table	0.013	fraction	Calculated gradient in the direction of groundwater flow across the site between boreholes BAEBH1 and BAEBH3 based on groundwater levels measured in May 2009
Background concentration of contaminant in groundwater beneath site	0	mg/l	Assumption that there is no Aromatic C21-C35 up-gradient of the trial pits

Key assumptions underlying the input parameters selected for Model 2 include:

- The value for infiltration was taken from *Ref 38,* the most likely value of infiltration has been utilised within this QRA to give the most realistic assessment of the situation. The minimum value of infiltration quoted was 1.64×10^{-3} m/d and the maximum was 7.78×10^{-4} m/d; and
- Although there is no site-specific hydraulic conductivity data, data from the wider site ranges from 0.0864 m/d to 0.864 m/d. The lower value was used in the QRA as a conservative approach.

Table 7.18 Input Parameters for Remedial Targets Worksheet Level 3 (Model 2)

Parameter	Value	Unit	Justification
Level 3			
Half life for degradation of contaminant in water	1060	days	Low value for benzo(a)pyrene (C35) in Environmental Degradation Rates Handbook (Howard et al)
Bulk density of aquifer materials	1.36	g/cm^3	Minimum value for a gravel given in ConSim manual (*Ref 45*)
Effective porosity of aquifer	0.1	fraction	Minimum value of effective porosity for a coarse gravel (*Ref 46*)
Distance to compliance point	27	m	Distance from trial pit TP1016 to eastern part of red line boundary
Time since pollutant entered groundwater	$9x10^{99}$	days	Recommended by the Remedial Targets Worksheet
Fraction of organic carbon in aquifer	0.0001	fraction	Minimum value used in Golders ConSim risk assessment for Silchester Gravels (*Ref 38*)
Organic carbon partition coefficient	$1.26x10^5$	l/kg	Value for Total Petroleum Hydrocarbon Criteria Working Group Series, Volume 3, Table 8, log K_{ox} value for Aromatic EC>21-35

All comments regarding aquifer properties that were made for Model 1 (*Table 7.15*) are also relevant o the Level 3 assessment for soils for Model 2.

7.4.5 Results & Discussion

Model 1 – Aliphatic C21-C35 in Groundwater

Table 7.19 shows the modelled concentration of the Aliphatic (C_{21}-C_{35}) hydrocarbons at the compliance point, based on a conservative QRA approach.

Table 7.19 Concentration of contaminant at Compliance Point

Contaminant	Concentration at Compliance Point (mg/l)	Assessment Criteria (mg/l)	Concentration at compliance point > Assessment Criteria
Aliphatic C_{21}-C_{35}	0.00463	0.01	No

Aliphatic (C_{21}-C_{35}) hydrocarbons within groundwater are not predicted to exceed the assessment criteria at the site boundary compliance point.

Model 2 - Soil Remediation Target for Aromatic (C_{21}-C_{35}) Hydrocarbons

The results of the Level 3 assessment for soils for Model2 are summarised in *Table 7.20.* This remedial target is based on using the most conservative values from sources.

Table 7.20 Soil Remedial Target for Aromatics (C_{21}-C_{35}) Hydrocarbons

Contaminant	Soil Remedial Target (mg/kg)	Observed Soil Concentration (mg/kg)
Aromatic C_{21}-C_{35}	10,600	900

The concentrations of aromatic (C_{21}-C_{35}) hydrocarbons observed in soils in the north-west of the Development Area are significantly below the controlled water remedial target for soils.

7.4.6 Summary

Results for both aromatic and aliphatic C_{21}-C_{35} show that the predicted concentration at the Application Site boundary (the compliance point) is below the assessment criteria. No remediation work is required with respect to these COC.

7.5 Explosive Residues in Groundwater

Groundwater samples were scheduled for a suite of explosive analysis which includes picric acid, picrite, HMX, RDX, EGDN, Tetryl, NG, TNT, PETN, 2,4-DNT, and 2,6-DNT and PETN. Sampling locations originated from:

- RPS 2009 site investigation (*Table 3.2.1*) including two rounds of monitoring of 6 boreholes (boreholes BHHYD-01 - 03, and WSHYD-04 – 06).

No explosive residues were encountered above detection limits and therefore it is not considered that the risk posed to the aqueous environment is negligible based on available information.

8 Gas Assessment

8.1 Introduction and Background

Soil gases have the potential to cause a human health risk from asphyxiation (e.g. carbon dioxide) or from explosion (e.g. methane) and when considering the future use for the proposed development the most sensitive receptor of soil gas risk relates to the proposed development buildings that could allow the potential accumulation of soil gas. Borehole soil gas monitoring results at the Application Site indicate that there is the potential for quantities of methane, carbon dioxide and carbon monoxide to be generated by natural soils or Made Ground, and only very low or negligible levels of hydrogen sulphide and VOC which are not considered significant.

Therefore to understand any potential risks posed to the proposed development from ground gas a gas risk assessment was undertaken and is documented in RPS's *Gas Monitoring Interpretative Report* (*Ref 2*, *Appendix I*). This section represents a summary only and RPS's report should be consulted for more detailed information.

RPS's report compiled relevant historical and more current borehole gas monitoring data from boreholes located within or immediately adjacent to the proposed Development Area (see *Drawing JER4214-003a)* which will incorporate all permanent buildings and ancillary facilities. This includes soil gas information from the following boreholes:

Historical Boreholes:

- BH0907, BH0909, BH0333, BH0397, BH0398;
- BAEBH1 – BAEBH3; and,
- EBH8, EBH8A.

Boreholes Installed as part of RPS's Site Investigation (*Ref 2*):

- BHHYD-001 – 003; and,
- WSHYD-004 – 006;

Soil gases which were monitored include:

- Volatile Organic Compounds (VOC) (using a Photo-Ionisation Detector); and,
- Landfill gases including methane, carbon dioxide, oxygen, hydrogen sulphide and carbon monoxide during routine gas monitoring of combined gas / groundwater installations.

8.2 Assessment Approach

The gas risk assessment was undertaken in alignment of current best practise and guidance including recently updated British Standard BS8485 2007 and CIRIA Report C665 (*Ref 47*).

The approaches outlined in the guidance highlight the importance for a robust and representative borehole soil gas data set. The ground gas risk assessment was undertaken from a data set consisted of between 3 to 6 monitoring rounds from RPS's boreholes, and historical borehole gas monitoring data, encompassing a wide range of atmospheric pressures. The data is therefore considered suitable in respect of identifying 'worst case' scenarios regarding soil gas generation rates, risk, and any protection measures which should be incorporated into the design of the proposed development foundation.

The criteria of 1% methane and 1.5% carbon dioxide was adopted to allow an initial assessment of the collected data. Where concentrations exceed these 'threshold' levels, a qualitative risk assessment is undertaken.

Gas Screening Values (GSV) as per CIRIA Report C665 (*Ref 47*) were compared against derived soil gas flux rates (which take into account soil gas concentrations and gas flow rates). Additionally in accordance with BS8485 borehole gas flow rates and concentrations were considered on a location by location basis where there was a comprehensive dataset.

Table 8.1. Gas Risk Screening Criteria

Characteristic Situation (CIRIA C665)	Gas Screening Value (CH_4 or CO_2) (l/hr)*	Additional Factors
1	<0.07	Typically methane ≤1% and/or carbon dioxide ≥5%. Otherwise consider increase to Situation 2
2	<0.7	Borehole air flow rate not to exceed 70l/hr. Otherwise consider increase to characteristic Situation 3
3	<3.5	-
4	<15	Quantitative risk assessment required to evaluate scope of protective measures.
5	<70	-
6	>70	-

Where gas fluxes exceed the criteria set for Characteristic Situation 1, further assessment may be required to assist with detailed design of the mitigation measures.

8.3 Summary of Findings

The report has classed the development as:

- Characteristic Situation 2 (CS2) (*Ref 47*) 'Low Risk' for carbon dioxide;
- Characteristic Situation 1 (CS1) (*Ref 47*) 'Very Low Risk' for methane (it is recommended however that the risk level for methane be increased to CS2, 'Low Risk', based upon the maximum concentrations recorded and the potential permeability of the shallow soils); and,
- Due to the repeated detection of carbon monoxide during previous rounds of gas monitoring it is considered that carbon monoxide poses a low risk to the development.

In respect of the report findings gas protection measures are considered to be required to be installed in new buildings. In areas of the Application Site to be used for temporary Portacabin facilities (welfare) the risk posed by soil gas is negligible to low as these structures will contain raised floors containing a void space underneath to allow dissipation of any soil gas.

As the assessment undertaken is considered 'worst case' for individual boreholes located on the Application Site (incorporating high flow rates and concentrations) it is considered unlikely that existing off-site buildings are at risk. Therefore the risk to off-site receptors from ground gases is considered negligible.

9 Construction and Post-construction Assessment

9.1 Proposed Development Design and Construction

The proposed development design is described in detail within *Chapter 5: The Proposed Development* of the EA and summarised in *Section 3.1.2*. Key aspects of the proposed design that may affect the baseline CSM and the pollutant (SPR) linkages presented in *Section 4* include the following:

- Deep, sub-water table, foundations in the centre of the operations building (as shown in *Drawing JER4214-004a*);
- Hard-standing over centre of the much of the Development Area; and
- Construction of an electricity sub-station.

The deep foundations required in the centre of the site, beneath the operations building, must be constructed in dry excavations. As groundwater is located at shallow depth over much of the site (see *Drawing 4214-007a*) a de-watering scheme will be required. A detailed dewatering strategy has been developed for the site by Lang O'Rouke (LOR, 2010) and is described in *Chapter 5: The Proposed Development* of the EA. Key aspects of the excavation and de-watering scheme are as follows:

- Installation of a circular ring of interlocking (water-tight) heavy duty sheet piling around the perimeter of the Hydrus operations building (approximate diameter 140 m). The sheet piling coffer dam shall be driven / vibrated into the London Clay that underlies the saturated granular minor aquifer.
- Installation of a perimeter well point system around the inside of the coffer dam;
- Reduction of internal water levels to top of London Clay Formation (i.e. Claygate member).
- Excavation in centre of site and installation of additional injector well point vacuum extractor system for lowering pore water pressures in the lower permeability Claygate member.
- Further excavation and construction of building foundations.

A number of sections of sheet piling shall be removed from the coffer dam following the conclusion of dewatering activities to partly restore baseline groundwater flow through the site, although the majority shall be left in place. The top of the coffer dam left in place will be located at approximately 2 mbGL.

9.2 Conceptual Site Model

The proposed de-watering strategy for the Hydrus facility will significantly alter the baseline CSM presented in *Section 4*. The key effects on the CSM in the construction and post-construction phases of the development are identified below.

Construction Phase

During construction groundwater levels within the coffer dam will be reduced to the top of the London Clay Formation (i.e. the top of the Claygate Member). All pathways with down-gradient groundwater receptors will be temporarily severed and the majority of water contained within the granular aquifer (that comprising the Silchester Gravel Member and Bagshot Formation) removed.

Groundwater levels up-gradient (i.e. west) of the coffer dam can be expected to rise in response to the construction of an impermeable barrier to groundwater flow. Groundwater flow will be diverted to the north and south-east, around the coffer dam, as a result of the barrier to flow and elevated up-gradient groundwater levels. This will result in an area of reduced groundwater levels and stagnated flow immediately down gradient (i.e. east) of the coffer dam with the cessation of groundwater inflow from the formerly up-gradient groundwater catchment area. Groundwater flows will however tend to converge to the east as the fish ponds remains the principal receptor to groundwater. Groundwater flow directions immediately north and south of the coffer dam are likely to have a more northerly and southerly component to flow in these areas resulting in boundary parallel groundwater flow.

The significant modifications to the baseline CSM described above are shown in *Drawing JER4214-012b*. It is anticipated that these short-term effects will last for approximately 1 year during the construction phase.

Post-Construction Phase

Following the completion of construction phase and removal of a number of sheet pile sections from the coffer dams, groundwater levels beneath the Hydrus facilities shall recover. The former groundwater flow pattern will generally be re-established in the post-construction phase, with the following alterations probable:

- Diversion of flow around the deep, sub-water table, foundations in the centre of the facility;
- Locally elevated groundwater levels in areas up-gradient of coffer dam remaining in the groundwater flow field and the deep foundations;
- Locally reduced hydraulic gradient down gradient of the facility (i.e. east) owing to reduced recharge over the footprint of the facility and reduced groundwater through-flow beneath the facility.

The changes to the baseline CSM in the post-construction phase will be permanent, but of small magnitude.

9.3 Impact Assessment

9.3.1 Overview

The modifications to the baseline CSM anticipated during the construction and post-construction phase of the development are considered unlikely to have any implication for the human-health, radiological and ground gas assessments presented in preceding sections of this report. However, potentially significant impacts on the physical hydrogeology of the Hydrus Development Area may affect the validity of the controlled waters risk assessment presented in *Section 7*.

The Contaminants of Concern (COC) identified from preliminary screening of the groundwater quality data were:

- Diesel Range Organic (DRO) Hydrocarbons – specifically Aliphatics (>C_{21}-C_{35});
- Polycyclic Aromatic Hydrocarbons (PAH); and
- Ammoniacal nitrogen.

Each COC shall be revaluated in light of the expected alterations to the baseline CSM in the construction and post-construction phase.

Nickel was not considered a COC as repeated occurrences at concentrations above the UK DWS were observed in boreholes situated outside of the Application Site boundary and in lateral or down-gradient positions relative to the groundwater flow field on the site.

This parameter has therefore been re-assessed in light of the modifications to groundwater flow directions expected on the site.

9.3.2 Controlled Waters Risk Assessment

Construction Phase

Long chain aliphatic hydrocarbons (C21-C35) are generally observed within or immediately down gradient of the proposed coffer dam required for dewatering of the site (see *Drawing JER4214-010iia*). Short-term modifications to the groundwater flow field are unlikely to result in significant alteration in flow path distance to the site boundary (e.g. in the vicinity of borehole NH-HYD-01 and BH-HYD-02), hence the results of the controlled water QRA undertaken presented in *Section 7.4* remains valid.

Ammoniacal nitrogen concentrations routinely above the UK DWS are only observed in groundwater from borehole BH0398. However, this borehole remains outside the Hydrus Application site red line boundary and in a lateral or down-gradient position. Ammoniacal Nitrogen is not therefore considered a COC requiring further consideration.

Nickel has been identified in groundwater at concentrations above the UK DWS in only two boreholes, namely BH0364 and BH0398. Both boreholes remain outside the Hydrus Application site red line boundary and in lateral or down-gradient positions. Nickel is not therefore considered a COC requiring further consideration.

Post Construction Phase

The post-construction CSM concludes that there only be a small change to groundwater flow paths and groundwater fluxes beneath the proposed development, assuming appropriate sections of the coffer dam are removed. Thus the controlled waters QRA presented in *Section 7* remains valid.

The removal of the majority of groundwater from within the coffer dam during construction, in addition to the removal of potential sources of contamination in overlying the site may potentially result in improved groundwater quality on the site.

10 Summary of Risks and Conclusions

10.1 Summary of Pollutant (SPR) Linkages

A number of pollutant (SPR) linkages were identified for the Development Area in *Table 4.1* contained is *Section 4.3*. Additional risk assessments were then undertaken to determine the likely risk associated with each pollutant linkage identified for the Development Area. The results of these assessments are summarised below.

Alterations to groundwater flow paths and groundwater fluxes in the aquifer underlying the Hydrus Development site, in the construction and post-construction phase have been considered. No new pollutant linkages were identified in either stage. However, the pollutant linkages associated with groundwater contamination within the coffer dam required for site dewatering were temporarily severed.

10.2 Risks from Chemical Contamination in Soils

10.2.1 Chemical Contamination Human Health Risks

The assessment of soil sample chemical analysis data suggests that the ground conditions in the Development Area do not represent any unacceptable risks to the human health of future site users.

An assessment of soil sample data within the CACE area suggested that the underlying ground conditions do not represent an unacceptable risk to the human health of future site users (most notably construction workers due to the areas use during construction phase works). Further reassurance is provided through the findings and proposed mitigation measures as recommended by the HEFF ES, the short timescales presented for exposure to potential contamination during the construction phase, and the fact that surface cover which is predominantly hardstanding (i.e. creating a barrier between receptors and the underlying ground conditions) and is not proposed to be disturbed.

10.2.2 Excavated Soils

Proposed excavation depths across the Development Area are summarised in *Drawing JER4214-004a*. It estimated that 28,056 m^3 of material shall be excavated within the Development Area (*Chapter 6: Construction Phase* of the EA).

The assessment of soil sample chemical analysis (with the exception of one sample as discussed below as discussed in *Section 5.6*) suggests that no gross contamination is present and the risk posed to construction workers is considered to be low provided that appropriate safe systems of work (SSoW) are implemented to minimise any potential risks posed to construction workers from previously unidentified contamination including asbestos.

All excavated soils should be handled in an appropriate manner and an appropriate end-use for the determined, as defined by their chemical quality. This will involve a review of soil chemical data and a process of validation sampling and analysis. A quantitative risk assessment relating to controlled waters has been undertaken for soils in the north-east of the Development Area as part of this assessment. The results of this QRA are summarised in *Section 7.4.5.*

10.3 Risks from Explosive Residues in Soil and Groundwater

Historical activities undertaken in structures formerly present on the Development Area identifies that explosive residues may occur in soils and groundwater. An assessment of the likely risk posed by explosive residues has therefore been undertaken for both soil and groundwater.

It has been concluded that negligible risks are posed to human health from exposure to explosive residue within soil and sediment at the site. No explosive residues were encountered above detection limits in groundwater and are therefore not considered a risk to human health or controlled waters beneath the Development Area or down hydraulic gradient of the Development Area. No elevated explosive residue concentrations above the AWE explosives threshold of 0.1% (or 1000 mg/kg) have been identified in soils and groundwater and are therefore considered ‘Free from Explosive Hazard’ (FFEH) (*Table 2.3*).

Isolated exceedances in soil samples of HMX above LOD where identified and it cannot be demonstrated that underlying soils contain (or are devoid) any concentrations of explosive residues. Based on the available sample information it is considered unlikely that any remaining residual concentrations would constitute an explosive risk however contingency measures should be in place to mitigate against potential risks posed to construction workers through encountering previously unidentified contamination (including explosive residue and ordnance) through implementation of appropriate SSoW.

10.4 Risks from Radioactivity

10.4.1 Radiological Contamination Human Health Risks

Soils exhibiting gross alpha activity and gross beta activity above the AWE threshold screening levels were identified as originating from natural ground materials, such as clay and gravels. Samples submitted for further radiochemical and gamma spectrometry analysis displayed activity levels indicative of radionuclides representative of Naturally Occurring Radioactive Materials (NORM) at background levels rather than due to sources of contamination from site operations. The levels detected are not considered to represent a significant risk to future site users.

No tritium analysis has been undertaken of soils that are to remain in situ following redevelopment. However, based on the low levels of tritium detected in soils that are to be excavated during redevelopment and no known historical use of tritium at the site it is considered that the risk posed to future site users by tritium is very low.

Although no radioactivity data is available for soils within the CACE area, there is no known historical use of radioactivity, the exposure timescales are short, and as there is widespread hardstanding surface covering that will provide a barrier, therefore the risks posed to construction workers are considered low provided appropriate SSoW are implemented during future groundworks to provide protection against previously unidentified contamination.

No significantly elevated levels of radioactivity in groundwater that could pose a risk to human health were identified during the data assessment.

10.4.2 Excavated Soils

No significant levels of radioactivity were identified in soils proposed to be excavated, and the risks posed to construction workers is considered minimal provided appropriate SSoW are implemented as part of site procedure.

It is anticipated that excavated soils will be subject to either re-use on site (where appropriate) or waste disposal, and soils should be subject to an appropriate suite of analysis (including radiological determinands) on a volume basis to inform and support appropriate waste management activities

10.5 Risks to Groundwater

10.5.1 Chemical Contamination

Controlled waters that may potentially be affected by historical and/or future activities undertaken within the Development Area include:

- Groundwater contained in the shallow unconfined aquifer underlying the site; and
- Groundwater dependent surface water features situated down hydraulic gradient (i.e. east) of the site boundary, most notably Fish Pond and its outlet channel.

Potential impacts on surface waters that may result through run-off into the drainage system present on within the Development Area are not considered in this report. These potential impacts shall be assessed and mitigations provided where required, in the technical assessments undertaken for *Chapter x: Hydrology and Flood Risk* of the EA.

No clear source areas of contamination have been identified in groundwater, although elevated concentrations of some contaminants have been identified. The contaminants of concern identified in groundwater include:

- Diesel Range Organic (DRO) hydrocarbons – specifically Aliphatics ($>C_{21}$-C_{35});
- Polycyclic Aromatic Hydrocarbons (PAH); and
- Ammoniacal nitrogen.

No link between the COC identified in soils and the COC identified in groundwater was evident on the site. However, during the review of soil contamination elevated concentrations of aromatic (EC_{21} – EC_{35}) hydrocarbons were identified in shallow soils (Made Ground) in the north-east corner of the Development Area.

The COC identified in groundwater and soils in the north-east of the Development Area could not be related to specific historic land-uses on the site, or the footprint of former buildings on the site. The source of this contamination is therefore uncertain.

Closer review of speciated PAH in groundwater demonstrated that these do not indicate an issue regarding PAH contamination of groundwater within the Development Area and no further QRA was deemed necessary in relation to PAH. Elevated total PAH concentrations have been identified in the in the centre of the site and towards the northern site boundary (lateral to groundwater flow). This discrepancy may relate in part to the analytical methodology historically used to measure total PAH, and it is therefore recommended that speciated PAH be measured in all boreholes in the final monitoring rounds schedule for the site in 2009.

Detailed review of time series concentration data for ammoniacal nitrogen (*Appendix G*) demonstrated that either:

- Concentrations are below the UK DWS (BH0333, BH900, BH902);
- Single excursions above the UK DWS but with remaining analyses below the UK DWS and commonly below the MDL (BH0331, BH909, BH926);
- Declining trends in Ammoniacal nitrogen to below the UKDWS over the monitoring period (EBH7, EBH8, EBH8A).
- Routinely elevated concentrations are observed in s single borehole situated off site and on a lateral flow path relative to the site.

Ammoniacal nitrogen does not constitute a risk to controlled waters within the Development Area.

Quantified Risk Assessments were undertaken to determine whether aliphatics ($>C_{21}$-C_{35}) in groundwater or aromatic (EC_{21} – EC_{35}) hydrocarbons were identified in shallow soils (Made Ground) in the north-east corner of the Development Area. Groundwater at the site boundary was used within the QRA, with compliance targets set at the UK DWS for oils and hydrocarbons.

The controlled water QRA demonstrated that both the aliphatic and aromatic C_{21}-C_{35} in groundwater and soils respectively do not represent a significant risk to groundwater at the down-gradient site boundary.

No further QRA for controlled waters are deemed necessary for either the construction or post-construction phase of the development as a result of anticipated alteration to groundwater flow paths and groundwater fluxes resulting from the dewatering strategy proposed for the site. The predicted alterations to the flow field are unlikely to exacerbate previously predicted pollutant linkages and will not create new pollutant linkages on the site. The dewatering and resulting deep foundations are therefore considered unlikely to have any adverse impact on controlled waters, most notably groundwater quality at the site boundary.

10.5.2 Radiological Contamination

The levels of radioactivity identified in groundwater are typically low and are considered to be representative of typical background levels. Detectable tritium activity levels were identified within groundwater which fell below risk threshold values and are not considered significant.

10.6 Risks from Soil Gas

Based on the previous gas risk assessment undertaken by RPS (*Ref 2*) it has been identified that the development in classed as:

- Characteristic Situation 2 (CS2) (*Ref 47*) 'Low Risk' for carbon dioxide;
- Characteristic Situation 1 (CS1) (*Ref 47*) 'Very Low Risk' for methane (it is recommended however that the risk level for methane be increased to CS2, 'Low Risk', based upon the maximum concentrations recorded and the potential permeability of the shallow soils); and
- Due to the repeated detection of carbon monoxide during previous rounds of gas monitoring it is considered that carbon monoxide poses a low risk to the development.

In areas of the Application Site to be used for temporary Portacabin facilities (welfare) the risk posed by soil gas is negligible to low as these structures will contain raised floors containing a void space underneath to allow dissipation of any soil gas.

As the assessment undertaken is considered 'worst case' for individual boreholes located on the Application Site (incorporating high flow rates and concentrations) it is considered unlikely that existing off-site buildings are at risk. Therefore the risk to off-site receptors from ground gases is considered negligible.

11 Recommendations

11.1 Summary

All relevant aspects of ground conditions upon the Hydrus Application Site have been reviewed using available historical data, past investigation reports, details of historical land-uses on the site and the results of more recent investigations on the site (RPS, 2009). Qualitative and quantitative risk assessments have been undertaken to assess the potential risk to human health and controlled waters (i.e. groundwater and surface water) and to identify any unacceptable risks from radiological, explosive, chemical or ground gas contamination for the proposed development.

The results of the risk assessment shall have been described in Section 9 and are used as the basis for determining the appropriate mitigation measures described below.

11.2 Mitigation Measures

11.2.1 Soil Gas

Gas protection measures are considered to be required to be installed in new buildings to include measures suitable for CS (characteristic situation) 2 classifications as identified within CIRIA Report C665 (*Ref 47*) to include:

- Reinforced concrete cast in situ floor slab (suspended, non-suspended or raft) with at least 1200g DPM; or
- Beam and block or pre-cast concrete slab and minimum 2000 g DPM / reinforced gas membrane; or
- Possibly under-floor venting or pressurisation in combination with either option above, depending on use.
- All joints and penetrations are to be sealed.

The scope and design of the gas protection measures can be fully refined following final foundation design details for the development.

11.2.2 Groundwater

No contaminants identified in groundwater have been demonstrated to pose a risk to groundwater quality and surface waters down hydraulic gradient from the Development Area.

A significant discrepancy has been identified between the concentration of total PAH measured in groundwater and the concentration, and distribution of, speciated PAH in groundwater. To clarify this uncertainty it is recommended that speciated PAH be measured in all boreholes within the Development Area during the final monitoring rounds schedule for the site in 2009. Furthermore it is recommended that analysis be undertaken by GC-MS to determine 16 speciated PAH (namely: naphthalene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(123cd)pyrene, dibenzo(ah)anthracene, benzo(ghi)perylene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene.

It is also recommended that phenanthrene is measured in borehole EBH8A and di-n-butylphthalate measured in borehole BH0398 in the final scheduled rounds of groundwater monitoring to be undertaken on the site in 2009.

The results of these ongoing groundwater quality analyses shall be reviewed and their implications for the technical assessments contained herein determined. Following completion of the additional groundwater monitoring works in January 2010 the results will be presented as an addendum to this report.

11.2.3 Mitigating Risks to Construction Workers

Any works undertaken on site by construction workers / ground workers should adhere to appropriate safe systems of work (SSoW) to minimise any potential risks posed to construction workers becoming exposed to contamination such as previously unidentified contamination including asbestos, gross inorganic and organic contamination, explosive residues and ordnance. This is usually dealt with through adherence to CDM Regulations 2007 (*Ref 36*). This may include but may not be limited to the following:

- Adherence to AWE Code of Construction Practice (CoCP),
- Contractors are required to produce a Safe System of Work (SSoW) statement, which will include a method statement and an environmental risk assessment(s) to include watching briefs as appropriate.

- Throughout all phases of construction a ‘good housekeeping’ policy will be applied, as outlined in the AWE CoCP. All work areas will be kept tidy and road surfaces will be kept clean and in a good condition. Relevant dust suppression measures and controls will be employed on the Application Site to minimise airborne dust. Further details of dust suppression methods are described in Hydrus ES Chapter 10: Air Quality.

- In order to reduce the risk of pollution, plant and equipment will be continuously maintained in accordance with the manufacturer’s specifications. In addition, plant and equipment will be located away from sensitive receptors and residential areas on or near to the Proposed Development site.

- All site works will comply with relevant Environment Agency Pollution Prevention Guidelines: PPG6 - Working at Construction and Demolition Sites; PPG8 Safe Storage and disposal of used oils, and PPG5 - Works and maintenance in or near water: PPG5.

Cognisance of the construction worker mitigation measures as discussed in the HEFF ES which include:

- Development and implementation of an Environmental Management Plan (EMP), specific to the HEFF project in accordance with AWE Codes of Construction Practice. This will include all appropriate SSoW to mitigate potential impacts and exposure of constructions workers with respect to soil contamination, and to ensure work is carried out in a safe and environmental acceptable manner (i.e. minimising incidents such as accidental spillages, safe material storage / handling procedures, effective procedures to manage spills etc).

- Appropriate measures to minimise dust during construction activities.

- Waste Management Activities in line with the EMP and approach to minimise exposure and risks to workers;

- Long term groundwater monitoring to identify and further assess potential impacts from soil determinants in groundwater.

11.3 Remediation

Soils in north-east corner of the Development Area, in the vicinity of the support buildings, will have to be excavated and disposed of appropriately due to the potential risk posed to controlled waters from concentrations of aromatic (C_{21}-C_{35}) hydrocarbons in soils. The requirements for the excavation of these soils shall be identified in the Remediation Statement and EMP and the works will have to be monitored and validated to ensure this risk to controlled waters is adequately addressed.

No other remediation works have been identified from the technical assessments undertaken for the Application Site.

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Glossary

AC	Assessment Criteria
ALARP	As Low As Reasonably Practicable
AOD	Above Ordnance Datum
AST	Above Ground Storage Tank
AWE	Atomic Weapon Establishment
AWE(A)	Atomic Weapon Establishment (Aldermaston)
BaP	Benzo(a)pyrene
bGL	below Ground Level
BGS	British Geological Survey
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
CACE	Central Area Construction Enclave
COC	Contaminant of Concern
CSM	Conceptual Site Model
DEEA	Defence Exempt Environmental Appraisal
DNAPL	Dense Non-Aqueous Phase Liquid
DOC	Dissolved Organic Carbon
DRO	Diesel Range Organics
DWS	Drinking Water Standard
EA	Environment Appraisal
EMP	Environmental Management Plan
EPA	Environmental Protection Act
EQS	Environmental Quality Standard
ES	Environmental Statement
FFEH	Free From Explosive Hazard
GRO	Gasoline Range Organics
GCTR	Ground Conditions Technical Report

HEFF	High Explosives Fabrication Facility
HSE	Health and Safety Executive
LOD	Limit of Detection
LOR	Laing O'Rourke
mAOD	Meters Above Ordnance Datum
MDL	Method Detection Limit
MG	Made Ground
ML	Multilevel
NAPL	Non-Aqueous Phase Liquid
NGR	National Grid Reference
NII	Nuclear Installations Inspectorate
NSD	Nuclear Safety Directorate
ORP	Oxidation Reduction Potential
PAH	Polycyclic Aromatic Hydrocarbons
PFEH	Potential For Explosive Hazard
PRG	Preliminary Remediation Goal
PRO	Petroleum Range Organics
PWS	Public Water Supply
QRA	Quantitative Risk Assessment
RPS	RPS Planning and Development
sVOC	semi Volatile Organic Compound
SPR	Source-Pathway-Receptor
SPZ	Source Protection Zone
TPH	Total Petroleum Hydrocarbons
WHO	World Health Organisation
WQS	Water Quality Standard