

|                                     |                                                                                      |                        |             |
|-------------------------------------|--------------------------------------------------------------------------------------|------------------------|-------------|
| Project Name     Bryn Lane, Wrexham |                                                                                      | Photographic<br>Record | Borehole ID |
| Project No.     TE1749              |                                                                                      |                        | TP10        |
| Engineer     Eve Rowland            |                                                                                      |                        |             |
| Client     Net World Sports         |                                                                                      |                        |             |
|                                     |   |                        | Pit         |
|                                     |                                                                                      |                        |             |
|                                     |                                                                                      |                        |             |
|                                     |  |                        | Spoil       |
|                                     |                                                                                      |                        |             |
|                                     |                                                                                      |                        |             |
| Photographed By                     |   | Date                   |             |
| ER                                  |                                                                                      | 05.06.2023             |             |

|                                     |                                                                                      |                        |                     |
|-------------------------------------|--------------------------------------------------------------------------------------|------------------------|---------------------|
| Project Name     Bryn Lane, Wrexham |                                                                                      | Photographic<br>Record | Borehole ID<br>TP11 |
| Project No.     TE1749              |                                                                                      |                        |                     |
| Engineer     Eve Rowland            |                                                                                      |                        |                     |
| Client     Net World Sports         |                                                                                      |                        |                     |
|                                     |   |                        | Pit                 |
|                                     |                                                                                      |                        |                     |
|                                     |                                                                                      |                        |                     |
|                                     |  |                        | Spoil               |
|                                     |                                                                                      |                        |                     |
|                                     |                                                                                      |                        |                     |
| Photographed By                     |   | Date                   |                     |
| ER                                  |                                                                                      | 05.06.2023             |                     |

|                                     |                                                                                      |                        |             |
|-------------------------------------|--------------------------------------------------------------------------------------|------------------------|-------------|
| Project Name     Bryn Lane, Wrexham |                                                                                      | Photographic<br>Record | Borehole ID |
| Project No.     TE1749              |                                                                                      |                        | TP12        |
| Engineer     Eve Rowland            |                                                                                      |                        |             |
| Client     Net World Sports         |                                                                                      |                        |             |
|                                     |   |                        | Pit         |
|                                     |                                                                                      |                        |             |
|                                     |                                                                                      |                        |             |
|                                     |  |                        | Spoil       |
|                                     |                                                                                      |                        |             |
|                                     |                                                                                      |                        |             |
| Photographed By                     |   | Date                   |             |
| ER                                  |                                                                                      | 05.06.2023             |             |

|                                                                                      |                                                                                     |                        |                     |
|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|------------------------|---------------------|
| Project Name     Bryn Lane, Wrexham                                                  |                                                                                     | Photographic<br>Record | Borehole ID<br>TP13 |
| Project No.     TE1749                                                               |                                                                                     |                        |                     |
| Engineer     Eve Rowland                                                             |                                                                                     |                        |                     |
| Client     Net World Sports                                                          |                                                                                     |                        |                     |
|   |                                                                                     | Pit                    |                     |
|                                                                                      |                                                                                     |                        |                     |
|  |                                                                                     | Spoil                  |                     |
|                                                                                      |                                                                                     |                        |                     |
| Photographed By                                                                      |  | Date                   |                     |
| ER                                                                                   |                                                                                     | 05.06.2023             |                     |

|                                    |                                                                                      |                        |                     |
|------------------------------------|--------------------------------------------------------------------------------------|------------------------|---------------------|
| Project Name    Bryn Lane, Wrexham |                                                                                      | Photographic<br>Record | Borehole ID<br>TP14 |
| Project No.    TE1749              |                                                                                      |                        |                     |
| Engineer    Eve Rowland            |                                                                                      |                        |                     |
| Client    Net World Sports         |                                                                                      |                        |                     |
|                                    |   |                        | Pit                 |
|                                    |                                                                                      |                        |                     |
|                                    |                                                                                      |                        |                     |
|                                    |  |                        | Spoil               |
|                                    |                                                                                      |                        |                     |
|                                    |                                                                                      |                        |                     |
| Photographed By                    |   | Date                   |                     |
| ER                                 |                                                                                      | 05.06.2023             |                     |

|                                                                                      |                                                                                     |                        |             |
|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|------------------------|-------------|
| Project Name                                                                         | Bryn Lane, Wrexham                                                                  | Photographic<br>Record | Borehole ID |
| Project No.                                                                          | TE1749                                                                              |                        | TP15        |
| Engineer                                                                             | Eve Rowland                                                                         |                        |             |
| Client                                                                               | Net World Sports                                                                    |                        |             |
|   |                                                                                     |                        | Pit         |
|  |                                                                                     |                        | Spoil       |
| Photographed By                                                                      |  | Date                   |             |
| ER                                                                                   |                                                                                     | 05.06.2023             |             |

|                                                                                      |                                                                                     |                        |             |
|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|------------------------|-------------|
| Project Name     Bryn Lane, Wrexham                                                  |                                                                                     | Photographic<br>Record | Borehole ID |
| Project No.     TE1749                                                               |                                                                                     |                        | TP16        |
| Engineer     Eve Rowland                                                             |                                                                                     |                        |             |
| Client     Net World Sports                                                          |                                                                                     |                        |             |
|   |                                                                                     | <div>Pit</div>         |             |
|  |                                                                                     | <div>Spoil</div>       |             |
| Photographed By                                                                      |  | Date                   |             |
| ER                                                                                   |                                                                                     | 05.06.2023             |             |

|                                     |                                                                                      |                        |                     |
|-------------------------------------|--------------------------------------------------------------------------------------|------------------------|---------------------|
| Project Name     Bryn Lane, Wrexham |                                                                                      | Photographic<br>Record | Borehole ID<br>TP17 |
| Project No.     TE1749              |                                                                                      |                        |                     |
| Engineer     Eve Rowland            |                                                                                      |                        |                     |
| Client     Net World Sports         |                                                                                      |                        |                     |
|                                     |   |                        | Pit                 |
|                                     |  |                        | Spoil               |
| Photographed By                     |   | Date                   |                     |
| ER                                  |                                                                                      | 05.06.2023             |                     |

**APPENDIX H - GROUNDSURE REPORT (AVAILABLE AS A SEPARATE DOCUMENT)**

**APPENDIX I - PREVIOUS SITE INVESTIGATION REPORT (AVAILABLE AS A SEPARATE DOCUMENT)**

## **APPENDIX J - DEFINITIONS OF TERMS USED IN QUALITATIVE AND QUANTITATIVE RISK ASSESSMENTS**

## CIRIA C552 Terminology

For the qualitative and quantitative assessment of risks posed by potential pollutant linkages have been undertaken using the risk matrix adapted from CIRIA C552 and outlined in the table below.

|                            | Category        | Definition                                                                                                                                                                                         |
|----------------------------|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Potential severity</b>  | Severe          | Acute (short term) risk to human health,<br>Major pollution of sensitive controlled waters, ecosystems or habitat.<br>Catastrophic damage to buildings or property or crops.                       |
|                            | Medium          | Chronic (Medium / long term) risk to human health<br>Pollution of sensitive controlled waters, ecosystems or species,<br>Significant damage to crops, buildings or structures                      |
|                            | Mild            | Easily preventable permanent health effects on humans.<br>Pollution of non-sensitive controlled waters.<br>Minor damage to buildings or structures.                                                |
|                            | Minor           | Easily preventable non-permanent health effects on humans, or no effects.<br>Minor, low level and localised contamination of on-site soil.<br>Easily repairable damage to buildings or structures. |
| <b>Probability of risk</b> | High Likelihood | Pollutant linkage may be present, and the risk is almost certain to occur , or there is evidence of harm already occurring.                                                                        |
|                            | Likely          | Pollutant linkage may be present, and it is probable that the risk will occur over the long term.                                                                                                  |
|                            | Low Likelihood  | Pollutant linkages may be present and there is a possibility of the risk occurring, although there is no certainty that it will do so.                                                             |
|                            | Unlikely        | Pollutant linkage may be present but the circumstances under which harm would occur are improbable.                                                                                                |

|                            |                        | Potential Severity  |                     |                     |                     |
|----------------------------|------------------------|---------------------|---------------------|---------------------|---------------------|
|                            |                        | Severe              | Medium              | Mild                | Minor               |
| <b>Probability of risk</b> | <b>High Likelihood</b> | Very high risk      | High risk           | Moderate risk       | Moderate / low risk |
|                            | <b>Likely</b>          | High risk           | Moderate risk       | Moderate / low risk | Low risk            |
|                            | <b>Low Likelihood</b>  | Moderate risk       | Moderate / low risk | Low risk            | Very low risk       |
|                            | <b>Unlikely</b>        | Moderate / low risk | Low risk            | very low risk       | Very low risk       |

## **APPENDIX K - HUMAN HEALTH ASSESSEMENT CRITERIA**

# HUMAN HEALTH ASSESSMENT CRITERIA

## Context

Contaminated Land is defined under law through Part IIA of the Environmental Protection Act 1990, implemented through Section 57 of the Environment Act 1995 and associated guidance ("Part IIA"). These specify that a "suitable for use" approach is to be applied in the assessment of potentially contaminated land, implemented through a phased programme of site investigation and risk assessment appropriate to the site under consideration.

The assessment of potential risks posed by contaminated land is based upon the assessment of plausible contaminant source - pathway - receptor linkages ("pollutant linkages") for the current and/or proposed future use of the site. The process for the assessment of contaminated land adopted in this report is in line with guidance issued by the [Environment Agency Land contamination risk management \(LCRM\)](https://www.gov.uk/government/publications/land-contamination-risk-management) - GOV.UK ([www.gov.uk](https://www.gov.uk))

Land contamination can harm:

- human health
- drinking water supplies, groundwater and surface water
- soils
- ecosystems including wildlife, animals and wetlands
- property

It can also affect the current and future land use. Dealing with land contamination helps make the environment clean and safe. Through regeneration it can:

- enhance the health and wellbeing of all
- add to the economic, ecological and amenity value of the area

Use land contamination risk management (LCRM) to:

- identify and assess if there is an unacceptable risk
- assess what remediation options are suitable to manage the risk
- plan and carry out remediation
- verify that remediation has worked

You can use LCRM in a range of regulatory and management contexts. For example, voluntary remediation, planning, assessing liabilities or under the Part 2A contaminated land regime. The Environment Agency expects you to follow LCRM if you are managing the risks from land contamination.

We support the use of the National Quality Mark Scheme (NQMS). You can use it for any type of land contamination report.

Using the NQMS:

- will make sure all legislative requirements and necessary standards related to managing land contamination are met
- can provide increased confidence by submitting reports of the quality we expect
- can result in cost and time savings by 'getting it right first time'

LCRM is made up of 4 guides.

1. LCRM: Before you start.
2. LCRM: Risk assessment.
3. LCRM: Options appraisal.
4. LCRM: Remediation and verification.

We use a staged risk based approach. There are 3 stages, and each stage is broken down into tiers or steps.

### Stage 1: Risk assessment

You will use a tiered approach to risk assessment. The 3 tiers are:

1. Preliminary risk assessment.
2. Generic quantitative risk assessment.
3. Detailed quantitative risk assessment.

Stage 1 includes information for intrusive site investigations.

### Stage 2: Options appraisal

There are 3 steps to follow.

1. Identify feasible remediation options.
2. Do a detailed evaluation of options.
3. Select the final remediation option.

### Stage 3: Remediation and verification

There are 4 steps to follow.

1. Develop a remediation strategy.
2. Remediate.
3. Produce a verification report.
4. Do long term monitoring and maintenance, if required

You must always start with a preliminary risk assessment.

The risk assessment stage is an iterative process. You can do the 3 tiers in order or progress from a preliminary risk assessment to a detailed quantitative risk assessment. As part of a generic or detailed quantitative risk assessment you will need to collect detailed information about the site. This is usually through an intrusive site investigation.

Depending on the level of risk or regulatory requirements, you can proceed from a preliminary risk assessment to the options appraisal stage. If you proceed direct to the options appraisal stage, you still need to collect the detailed site investigation information required by the generic and detailed quantitative risk assessments. This is to confirm that your approach is viable and acceptable.

Following the risk assessment stage, if you conclude that the risks are acceptable, with agreement from the relevant regulator, you can end the process.

If there are unacceptable risks, then remediation or mitigation is required. Follow stages 2 and 3 in order.

In stage 2 options appraisal, you will:

- look at the most feasible options
- produce a shortlist of options
- use evaluation criteria to assess them
- select which ones are the most suitable to take forward to stage 3

In stage 3 remediation and verification, you will produce a remediation strategy, do the remediation and then produce a verification report.

You will decide at the options appraisal stage if long term monitoring and maintenance is the remediation option. You may need to do post-remediation monitoring for further verification.

The risk assessment and subsequent investigation, remediation and verification must address all potential sources of pollutants that may be present on the site (the "hazards"), all receptors that may be harmed by these (e.g., human health, controlled waters, ecological receptors) and the pathways by which the contamination may be transported from the contaminant source(s) to the receptor(s). This is defined within the conceptual model for the site, which represents the characteristics of the site in a form that shows the possible pollutant linkages. As further information becomes available (for example, through site investigation), so the conceptual model will be refined.

Remedial action can be specified at any phase within this assessment process to break the identified pollutant linkage in determining whether or not to undertake further assessment or to undertake remediation, the potential cost-savings arising from a more thorough assessment of the pollutant linkages and more tightly defined remedial strategy must be considered against the direct costs involved in the work and the time that this will take to execute and gain regulatory approval.

A different approach to the statistical appraisal of data is required depending on whether the assessment is being undertaken to assess land as Contaminated Land in accordance with the regulations or whether the assessment is to assess whether the site is suitable for new development in accordance with the Planning regime. The statistical approach to assessment is discussed further in CL:AIRE:2020 "Professional Guidance: Comparing Soil Contamination Data with a Critical Concentration".

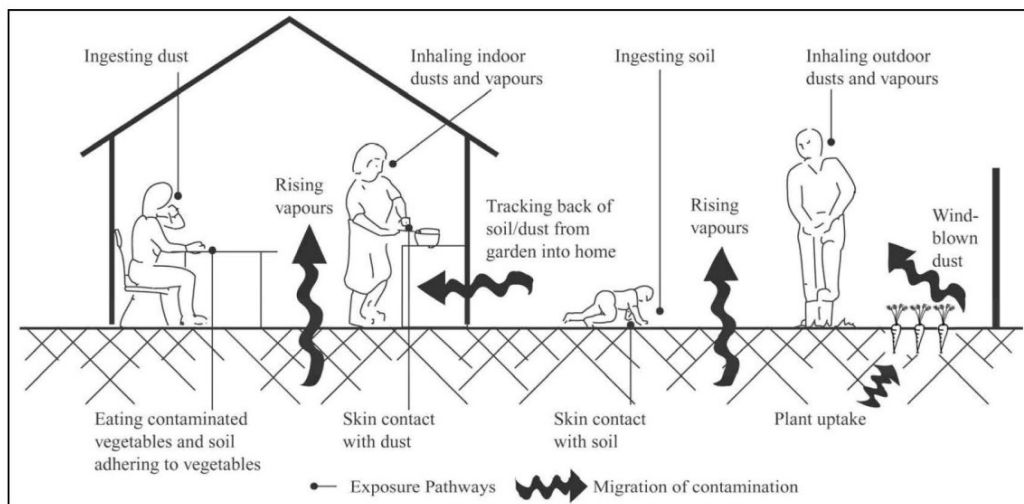
Some form of Detailed Quantitative Risk Assessment (DQRA) will be essential for those cases where appropriate GAC values cannot be established for the contaminant linkages under consideration.

## Generic Assessment Criteria for Human Health Risk Assessment

In March 2002, the Department for Environment, Food and Rural Affairs (DEFRA) and the Environment Agency (EA) published the Contaminated Land Exposure Assessment (CLEA) Model and a series of related reports and guidance. These were designed to provide a scientifically based framework for the assessment of chronic risks to human health from contaminated land. The initial documents (CLR7 – 10) were withdrawn and replaced with revised guidance issued by the Environment Agency including:

- “Using Soil Guideline Values”; EA, 2009; [Land contamination: using soil guideline values \(SGVs\) - GOV.UK \(www.gov.uk\)](http://www.gov.uk/government/publications/using-soil-guideline-values)
- “Human Health toxicology assessment of contaminants in soil” EA, 2009; <https://www.gov.uk/government/publications/human-health-toxicological-assessment-of-contaminants-in-soil>
- “Update technical background to the CLEA model” 2009; <https://www.gov.uk/government/publications/updated-technical-background-to-the-clea-model>
- CLEA Software (Version 1.05) Handbook 2015; <https://www.gov.uk/government/publications/contaminated-land-exposure-assessment-clea-tool>
- Compilation of Data for priority Organic Contaminants for Derivation of Soil Guideline Values; Science Report SC050021/SR7, 2008; and,
- “Professional Guidance: Comparing Soil Contamination Data with a Critical Concentration”. CL:AIRE:2020 <https://www.claire.co.uk/component/phocadownload/category/9-other-cl-aire-documents?download=745:2020-stats-guidance>

The CLEA model and associated guidance was developed to calculate an estimated tolerable daily intake (TDI) of contaminants for site users given a set of ‘typical’ human health exposure pathways which are detailed in “SR3: Updated technical background to the CLEA model”



(Science Report SC050021/SR3, EA, 2009) and reproduced below.

### Ingestion

- Outdoor soil;
- Indoor dust;
- Home grown produce;
- Soil attached to home grown produce.

### Dermal Contact

- Outdoor soil;
- Indoor dust.

### Inhalation

- Outdoor dust;
- Indoor dust;
- Outdoor vapour;
- Indoor vapour.

It should be noted that the CLEA model does not include an exhaustive list of potential exposure pathways, e.g. certain compounds can pass through plastic water pipes into drinking water supply.

The potential significance of each of the exposure pathways is dependent upon the type of land use and the nature of the contaminant being considered. The CLEA model considers principal 'default' land use scenarios and makes a series of assumptions with regards to building type (where applicable), identification of the critical human receptor group, exposure frequency and duration. The definitions of the principal land use types given in SR3 (EA, 2009) are:

#### **Residential land use;**

- A typical residential property consisting of a two-storey terraced house built on a ground-bearing slab of 0.15m thickness with a private garden consisting of lawn, flowerbeds, and a small fruit and vegetable patch. The occupants are assumed to be parents with young children, who make regular use of the garden. The critical receptor is a 0 – 6-year-old female.
- Active exposure pathways are ingestion of outdoor soil, ingestion of indoor dust, ingestion of home grown produce and soil adhering to home grown produce; direct dermal contact with outdoor soil and indoor dust; inhalation of outdoor dust and vapour and indoor dust and vapour

#### **Allotments**

- A plot of open space commonly made available by the Local Authority to tenants to grow fruit and vegetables for their own consumption. There are usually several plots to a site and the overall site area may cover more than one hectare. The tenants are assumed to be the parents or grandparents and that young children make occasional accompanied visits to the plots. The critical receptor is a 0 – 6-year-old female and there is no building present on Site.
- Active exposure pathways are ingestion of outdoor soil, ingestion of home grown produce and soil adhering to home grown produce; direct dermal contact with outdoor soil; inhalation of outdoor vapour.

#### **Commercial and industrial land use.**

- A typical commercial or light industrial property consisting of a three-story office building (pre-1970) with a ground bearing floor slab at which employees spend most time indoors and are involved in office based or related light physical work. The critical receptor is a working female adult aged 16 – 65 years.
- Active exposure pathway is ingestion of outdoor soil, ingestion of indoor dust; direct dermal contact with outdoor soil and indoor dust; inhalation of outdoor dust and vapour and inhalation of indoor dust and vapour.

## **Soil Guideline Values**

Based on the assumption of each land use type, the EA and DEFRA developed and published Soil Guideline Value (SGV) using the CLEA model for a number of principal contaminants and 'default' end-use scenarios of residential, allotments and commercial/industrial use. The primary purpose of the SGVs is as trigger value for the tolerable daily intake (TDI), below which it can be assumed that the soil does not pose an unacceptable risk to the identified receptor. Where soils contamination is present above this level further assessment may be required. SGVs were developed for the following contaminants:

- Heavy metals and other inorganic compounds: arsenic, cadmium, chromium, cyanide, lead (now withdrawn), mercury, nickel and selenium.
- Benzene, ethylbenzene, toluene and xylenes.
- Phenol.
- Dioxins and dioxin-like polychlorinated biphenyls (PCBs)
- Polycyclic aromatic hydrocarbons (PAHs) – 11 substances

## **LQM/CIEH Generic Assessment Criteria for Human Health Risk Assessment**

In addition, in 2009 CIEH through LQM and EIC published generic assessment criteria (GACs) for 82 substances including metals, petroleum hydrocarbons, PAHs and explosive substances for a variety of soil types and the three 'default' land uses – (residential, allotments and commercial end-uses) as described in SR3 (EA, 2009). These have been superseded as described below.

## **Category 4 Screening Values**

In 2013 "SP1010: Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination" (CL:AIRE 2013) was issued which detailed findings of a research project undertaken by CL:AIRE to set out the framework by which potential Category 4 Screening Levels (pC4SL) may be derived for 6 contaminants of concern, Arsenic, Benzene, Benzo(a)pyrene, Cadmium, Chromium VI and Lead.

This was supplemented in 2014 by "SP1010: Development of Category 4 Screening Levels for the Assessment of Land Affected by Contamination – Policy Companion Document" (DEFRA, 2014). SP1010 proposed several updated toxicology information relating to contaminant behaviour updated assumptions relating to the modelling of human exposure to soil contaminants, derivation of separate C4SLs for residential with the consumption of home grown produce, residential without the consumption of home grown produce, and two new land uses: public open spaces near residential housing (POS resi) and public parks (POS park).

#### **Public Open Space: Residential**

- For public open space in close proximity to residential housing and the central green area around which houses are located, as on many housing estates from the 1930s to 1970s. It is also applicable for smaller areas commonly incorporated in newer developments as informal grassed areas or more formal landscaped areas with a mixture of open space and covered soil with planting. It is considered to be a generally grassed area up to 0.5ha with up to 50% bare soil. The land use is an important resource

for children and the area is near the homes. The critical receptor is a female child age >3 - <9 years old (CLEA age class 4 – 9) as younger children are unlikely to play outdoors unsupervised.

- Active exposure pathways are ingestion of outdoor soil, ingestion of indoor dust; direct dermal contact with outdoor soil and indoor soil derived dust; inhalation of outdoor and indoor dust and inhalation of outdoor vapour.

#### **Public Open Space: Park**

- A public park is defined as an area of open space provided for recreational use and usually owned and maintained by the Local Authority. It is anticipated the park could be used for a wide range of activities, including the following:
  - Family visits and picnics;
  - Children's play area;
  - Sporting activities such as football on an informal basis (i.e. not a dedicated sports pitch); and
  - Dog walking.
- The park is modelled as an area >0.5 ha of predominantly grasses open space with no more than 25% of exposed soil.
- The critical receptor is a female child with CLEA age classes 1 – 6.
- Active exposure pathway are: ingestion of outdoor soil; direct dermal contact with outdoor soil; inhalation of outdoor dust and inhalation of outdoor vapour.

Furthermore, the C4SLs are based on a different toxicological benchmark, the 'low level of toxicological concern' (LLTC). This difference in approach was adopted because the C4SLs were primarily intended for use under Part 2A of the EPA 1990 to quickly screen out Category 4 sites where there is "*no risk or that the level of risk posed is low*". SGVs and LQM GACs are based on the more conservative 'minimal or tolerable level of risk' as defined in SR2 (EA, 2009) and were derived for assessment of contamination for the Planning process.

### **LQM/CIEH Suitable 4 Use Levels (S4ULs)**

The publication of the C4SLs resulted in considerable and inconclusive debate about the applicability of the lower level of protection of the C4SL, which are underlain by the LLTC, outside of the Part 2A context for which they were derived. In 2014 LQM/CIEH presented a Suitable 4 Use Levels (S4ULs), which incorporate the updated assumption exposure derived for the production of the C4SLs but within the context of deriving screening criteria above which further assessment of the risks or remedial action may be needed. The S4ULs replace the 82 substances, species and fractions and congeners contained in the previous LQM/CIEH GACs issued in 2009. Additionally, following changes and new land uses proposed in the C4SL research project, S4ULs have also been derived for the majority of substances for which the EA derived SGVs in 2009 with the exception of lead (see below).

### **Lead**

The C4SL for lead provides a technically robust and conservative assessment tool using significantly updated toxicological modelling than the withdrawn SGV and derived in line with current science of lead toxicology.

### **EIC/AGS/CL:AIRE Soil Generic Assessment Criteria (2010)**

In some instances, EIC/AGS/CL:AIRE GACs for certain VOC / SVOC potential contaminants of concern have been used *in lieu* of available LQM / CIEH S4UL values.

| Parameter           | Residential with homegrown produce |       |    | Residential without homegrown produce |       |    | Allotment                        |       |    | Commercial / Industrial          |       |    | Public Open Space near Residential |       |    | Public Open Space - Park         |       |    | Source     |
|---------------------|------------------------------------|-------|----|---------------------------------------|-------|----|----------------------------------|-------|----|----------------------------------|-------|----|------------------------------------|-------|----|----------------------------------|-------|----|------------|
|                     | (mg/kg, unless otherwise stated)   |       |    | (mg/kg, unless otherwise stated)      |       |    | (mg/kg, unless otherwise stated) |       |    | (mg/kg, unless otherwise stated) |       |    | (mg/kg, unless otherwise stated)   |       |    | (mg/kg, unless otherwise stated) |       |    |            |
| SOM                 | 1%                                 | 2.50% | 6% | 1%                                    | 2.50% | 6% | 1%                               | 2.50% | 6% | 1%                               | 2.50% | 6% | 1%                                 | 2.50% | 6% | 1%                               | 2.50% | 6% |            |
| Metals/metalloids   |                                    |       |    |                                       |       |    |                                  |       |    |                                  |       |    |                                    |       |    |                                  |       |    |            |
| Arsenic             | 37                                 |       |    | 40                                    |       |    | 43                               |       |    | 640                              |       |    | 79                                 |       |    | 170                              |       |    | LQM (2014) |
| Beryllium           | 1.7                                |       |    | 1.7                                   |       |    | 35                               |       |    | 12                               |       |    | 2.2                                |       |    | 63                               |       |    | LQM (2014) |
| Boron               | 290                                |       |    | 11000                                 |       |    | 45                               |       |    | 240000                           |       |    | 21000                              |       |    | 46000                            |       |    | LQM (2014) |
| Cadmium             | 11                                 |       |    | 85                                    |       |    | 1.9                              |       |    | 190                              |       |    | 120                                |       |    | 532                              |       |    | LQM (2014) |
| Chromium III        | 910                                |       |    | 910                                   |       |    | 18000                            |       |    | 8600                             |       |    | 1500                               |       |    | 33000                            |       |    | LQM (2014) |
| Chromium VI         | 6                                  |       |    | 6                                     |       |    | 1.8                              |       |    | 33                               |       |    | 7.7                                |       |    | 220                              |       |    | LQM (2014) |
| Copper              | 2400                               |       |    | 7100                                  |       |    | 520                              |       |    | 68000                            |       |    | 12000                              |       |    | 44000                            |       |    | LQM (2014) |
| Lead                | 200                                |       |    | 310                                   |       |    | 80                               |       |    | 2330                             |       |    | 630                                |       |    | 1300                             |       |    | C4SL       |
| Mercury (elemental) | 1.2                                |       |    | 1.2                                   |       |    | 21                               |       |    | 58 (25.8)                        |       |    | 16                                 |       |    | 30 (25.8)                        |       |    | LQM (2014) |
| Mercury (Inorganic) | 40                                 |       |    | 56                                    |       |    | 19                               |       |    | 1100                             |       |    | 120                                |       |    | 240                              |       |    | LQM (2014) |
| Methylmercury       | 11                                 |       |    | 15                                    |       |    | 6                                |       |    | 320                              |       |    | 40                                 |       |    | 68                               |       |    | LQM (2014) |
| Nickel              | 180                                |       |    | 180                                   |       |    | 230                              |       |    | 980                              |       |    | 230                                |       |    | 3400                             |       |    | LQM (2014) |
| Selenium            | 250                                |       |    | 430                                   |       |    | 88                               |       |    | 12000                            |       |    | 1100                               |       |    | 1800                             |       |    | LQM (2014) |
| Vanadium            | 410                                |       |    | 1200                                  |       |    | 91                               |       |    | 9000                             |       |    | 2000                               |       |    | 5000                             |       |    | LQM (2014) |

| Parameter                    | Residential with homegrown produce |       |       | Residential without homegrown produce |            |            | Allotment                        |       |      | Commercial / Industrial          |             |        | Public Open Space near Residential |       |       | Public Open Space - Park         |        |        | Source     |
|------------------------------|------------------------------------|-------|-------|---------------------------------------|------------|------------|----------------------------------|-------|------|----------------------------------|-------------|--------|------------------------------------|-------|-------|----------------------------------|--------|--------|------------|
|                              | (mg/kg, unless otherwise stated)   |       |       | (mg/kg, unless otherwise stated)      |            |            | (mg/kg, unless otherwise stated) |       |      | (mg/kg, unless otherwise stated) |             |        | (mg/kg, unless otherwise stated)   |       |       | (mg/kg, unless otherwise stated) |        |        |            |
| SOM                          | 1%                                 | 2.50% | 6%    | 1%                                    | 2.50%      | 6%         | 1%                               | 2.50% | 6%   | 1%                               | 2.50%       | 6%     | 1%                                 | 2.50% | 6%    | 1%                               | 2.50%  | 6%     |            |
| Zinc                         | 3700                               |       |       | 40000                                 |            |            | 620                              |       |      | 730000                           |             |        | 81000                              |       |       | 170000                           |        |        | LQM (2014) |
| Other                        |                                    |       |       |                                       |            |            |                                  |       |      |                                  |             |        |                                    |       |       |                                  |        |        |            |
| Total Sulphate               | 2,400                              |       |       | 2,400                                 |            |            | 2,400                            |       |      | 2,400                            |             |        | 2,400                              |       |       | 2,400                            |        |        | BRE (2005) |
| Water Soluble Sulphate (g/l) | 0.5                                |       |       | 0.5                                   |            |            | 0.5                              |       |      | 0.5                              |             |        | 0.5                                |       |       | 0.5                              |        |        | BRE (2005) |
| PAHs                         |                                    |       |       |                                       |            |            |                                  |       |      |                                  |             |        |                                    |       |       |                                  |        |        |            |
| Acenaphthene                 | 210                                | 510   | 1100  | 3000 (57)                             | 4700(141)  | 6000 (336) | 34                               | 85    | 200  | 84000 (57)                       | 97000 (141) | 100000 | 15000                              | 15000 | 15000 | 29000                            | 30000  | 30000  | LQM (2014) |
| Acenaphthylene               | 170                                | 420   | 920   | 2900 (86.1)                           | 4600 (212) | 6000 (506) | 28                               | 69    | 160  | 8300 (86.1)                      | 97000 (212) | 100000 | 15000                              | 15000 | 15000 | 29000                            | 30000  | 30000  | LQM (2014) |
| Anthracene                   | 2400                               | 5400  | 11000 | 31000 (1.17)                          | 35000      | 37000      | 380                              | 950   | 2200 | 520000                           | 540000      | 540000 | 74000                              | 74000 | 74000 | 150000                           | 150000 | 150000 | LQM (2014) |
| Benzo(a)anthracene           | 7.2                                | 11    | 13    | 11                                    | 14         | 15         | 2.9                              | 6.5   | 13   | 170                              | 170         | 180    | 29                                 | 29    | 29    | 49                               | 56     | 62     | LQM (2014) |
| Benzo(a)pyrene               | 2.2                                | 2.7   | 3     | 3.2                                   | 3.2        | 3.2        | 0.97                             | 2     | 3.5  | 35                               | 35          | 36     | 5.7                                | 5.7   | 5.7   | 11                               | 12     | 13     | LQM (2014) |
| Benzo(b)fluoranthene         | 2.6                                | 3.3   | 3.7   | 3.9                                   | 4          | 4          | 0.99                             | 2.1   | 3.9  | 44                               | 44          | 45     | 7.1                                | 7.1   | 7.1   | 13                               | 15     | 16     | LQM (2014) |
| Benzo(g,h,i)perylene         | 320                                | 340   | 350   | 360                                   | 360        | 360        | 290                              | 470   | 640  | 3900                             | 4000        | 4000   | 640                                | 640   | 640   | 1400                             | 1500   | 1600   | LQM (2014) |
| Benzo(k)fluoranthene         | 77                                 | 93    | 100   | 110                                   | 110        | 110        | 37                               | 75    | 130  | 1200                             | 1200        | 1200   | 190                                | 190   | 190   | 370                              | 410    | 440    | LQM (2014) |
| Chrysene                     | 15                                 | 22    | 27    | 30                                    | 31         | 32         | 4.1                              | 9.4   | 19   | 350                              | 350         | 350    | 57                                 | 57    | 57    | 93                               | 110    | 120    | LQM (2014) |

| Parameter                          | Residential with homegrown produce |       |      | Residential without homegrown produce |             |            | Allotment                        |       |       | Commercial / Industrial          |                   |                   | Public Open Space near Residential |       |       | Public Open Space - Park         |                  |                   | Source     |
|------------------------------------|------------------------------------|-------|------|---------------------------------------|-------------|------------|----------------------------------|-------|-------|----------------------------------|-------------------|-------------------|------------------------------------|-------|-------|----------------------------------|------------------|-------------------|------------|
|                                    | (mg/kg, unless otherwise stated)   |       |      | (mg/kg, unless otherwise stated)      |             |            | (mg/kg, unless otherwise stated) |       |       | (mg/kg, unless otherwise stated) |                   |                   | (mg/kg, unless otherwise stated)   |       |       | (mg/kg, unless otherwise stated) |                  |                   |            |
| SOM                                | 1%                                 | 2.50% | 6%   | 1%                                    | 2.50%       | 6%         | 1%                               | 2.50% | 6%    | 1%                               | 2.50%             | 6%                | 1%                                 | 2.50% | 6%    | 1%                               | 2.50%            | 6%                |            |
| Dibenz(a,h)anthracene              | 0.24                               | 0.28  | 0.3  | 0.31                                  | 0.32        | 0.32       | 0.14                             | 0.27  | 0.61  | 3.5                              | 3.6               | 3.6               | 0.57                               | 0.57  | 0.58  | 1.1                              | 1.3              | 1.4               | LQM (2014) |
| Fluoranthene                       | 280                                | 560   | 890  | 1500                                  | 1600        | 1600       | 52                               | 130   | 290   | 23000                            | 23000             | 23000             | 3100                               | 3100  | 3100  | 63                               | 6300             | 6400              | LQM (2014) |
| Fluorene                           | 170                                | 400   | 860  | 2800 (30.9)                           | 3800 (76.5) | 4500 (183) | 27                               | 67    | 160   | 63000 (30.9)                     | 68000             | 71000             | 9900                               | 9900  | 9900  | 20000                            | 20000            | 20000             | LQM (2014) |
| Indeno(1,2,3-cd)pyrene             | 27                                 | 36    | 41   | 45                                    | 46          | 46         | 9.5                              | 21    | 39    | 500                              | 510               | 510               | 82                                 | 82    | 82    | 150                              | 170              | 180               | LQM (2014) |
| Naphthalene                        | 2.3                                | 5.6   | 13   | 2.3                                   | 5.6         | 13         | 4.1                              | 10    | 24    | 190 (76.4)                       | 460 (183)         | 1100 (432)        | 4900                               | 4900  | 4900  | 1200 (76.4)                      | 1900 (183)       | 3000              | LQM (2014) |
| Phenanthrene                       | 95                                 | 220   | 440  | 1300 (36)                             | 1500        | 1500       | 15                               | 38    | 90    | 22000                            | 22000             | 23000             | 3100                               | 3100  | 3100  | 6200                             | 6200             | 6300              | LQM (2014) |
| Pyrene                             | 620                                | 1200  | 2000 | 3700                                  | 3800        | 3800       | 110                              | 270   | 620   | 54000                            | 54000             | 54000             | 7400                               | 7400  | 7400  | 15000                            | 15000            | 15000             | LQM (2014) |
| Coal Tar (BaP as surrogate marker) | 0.79                               | 0.98  | 1.1  | 1.2                                   | 1.2         | 1.2        | 0.32                             | 0.67  | 1.2   | 15                               | 15                | 15                | 2.2                                | 2.2   | 2.2   | 4.4                              | 4.7              | 4.8               | LQM (2014) |
| BTEX and TPH                       |                                    |       |      |                                       |             |            |                                  |       |       |                                  |                   |                   |                                    |       |       |                                  |                  |                   |            |
| Benzene                            | 0.087                              | 0.17  | 0.37 | 0.38                                  | 0.7         | 1.4        | 0.017                            | 0.034 | 0.075 | 27                               | 47                | 90                | 72                                 | 72    | 73    | 90                               | 100              | 110               | LQM (2014) |
| Toluene                            | 130                                | 290   | 660  | 880 vap (869)                         | 1900        | 3900       | 22                               | 51    | 120   | 56000 vap (869)                  | 110000 vap (1920) | 180000 vap (4360) | 56000                              | 56000 | 56000 | 87000 vap (869)                  | 95000 vap (1920) | 100000 vap (4360) | LQM (2014) |
| Ethylbenzene                       | 47                                 | 110   | 260  | 83                                    | 190         | 440        | 16                               | 39    | 91    | 5700 vap (518)                   | 13000 vap (1220)  | 27000 vap (2840)  | 24000                              | 24000 | 25000 | 17000 vap (518)                  | 22000 vap (1220) | 27000 vap (2840)  | LQM (2014) |
| Xylene - o                         | 60                                 | 140   | 330  | 88                                    | 210         | 480        | 28                               | 67    | 160   | 6600 (478)                       | 15000 (1120)      | 33000 (2620)      | 41000                              | 42000 | 43000 | 17000 (478)                      | 24000 (1120)     | 33000 (2620)      | LQM (2014) |

| Parameter           | Residential with homegrown produce |            |            | Residential without homegrown produce |            |            | Allotment                        |        |         | Commercial / Industrial          |               |               | Public Open Space near Residential |        |         | Public Open Space - Park         |              |               | Source     |
|---------------------|------------------------------------|------------|------------|---------------------------------------|------------|------------|----------------------------------|--------|---------|----------------------------------|---------------|---------------|------------------------------------|--------|---------|----------------------------------|--------------|---------------|------------|
|                     | (mg/kg, unless otherwise stated)   |            |            | (mg/kg, unless otherwise stated)      |            |            | (mg/kg, unless otherwise stated) |        |         | (mg/kg, unless otherwise stated) |               |               | (mg/kg, unless otherwise stated)   |        |         | (mg/kg, unless otherwise stated) |              |               |            |
| SOM                 | 1%                                 | 2.50%      | 6%         | 1%                                    | 2.50%      | 6%         | 1%                               | 2.50%  | 6%      | 1%                               | 2.50%         | 6%            | 1%                                 | 2.50%  | 6%      | 1%                               | 2.50%        | 6%            |            |
| Xylene - m          | 59                                 | 140        | 320        | 82                                    | 190        | 450        | 31                               | 74     | 170     | 6200 (625)                       | 14000 (1470)  | 31000 (3460)  | 41000                              | 42000  | 43000   | 17000 (625)                      | 24000 (1470) | 32000 (3460)  | LQM (2014) |
| Xylene - p          | 56                                 | 130        | 310        | 79                                    | 180        | 430        | 29                               | 69     | 160     | 5900 (576)                       | 14000 (1350)  | 30000 (3170)  | 41000                              | 42000  | 43000   | 17000 (576)                      | 23000 (1350) | 31000 (3170)  | LQM (2014) |
| Aliphatic EC 5-6    | 42                                 | 78         | 160        | 42                                    | 78         | 160        | 730                              | 1700   | 3900    | 3200 (304)                       | 5900 (558)    | 12000 (1150)  | 570000 (304)                       | 590000 | 60000 0 | 95000 (304)                      | 130000 (558) | 180000 (1150) | LQM (2014) |
| Aliphatic EC >6-8   | 100                                | 230        | 530        | 100                                   | 230        | 530        | 2300                             | 5600   | 13000   | 7800 (144)                       | 17000 (322)   | 40000 (736)   | 600000                             | 610000 | 62000 0 | 150000 (144)                     | 220000 (322) | 320000 (736)  | LQM (2014) |
| Aliphatic EC >8-10  | 27                                 | 65         | 150        | 27                                    | 65         | 150        | 320                              | 770    | 1700    | 2000 (78)                        | 4800 (190)    | 11000 (451)   | 13000                              | 13000  | 13000   | 14000 (78)                       | 18000 (190)  | 21000 (451)   | LQM (2014) |
| Aliphatic EC >10-12 | 130 (48)                           | 330 (118)  | 760 (283)  | 130 (48)                              | 330 (118)  | 760 (283)  | 2200                             | 4400   | 7300    | 9700 (48)                        | 23000 (118)   | 47000 (283)   | 13000                              | 13000  | 13000   | 21000 (48)                       | 23000 (118)  | 24000 (283)   | LQM (2014) |
| Aliphatic EC >12-16 | 1100 (24)                          | 2400 (59)  | 4300 (142) | 1100 (24)                             | 2400 (59)  | 4300 (142) | 11000                            | 13000  | 13000   | 59000 (24)                       | 82000 (59)    | 90000 (142)   | 13000                              | 13000  | 13000   | 25000 (24)                       | 25000 (59)   | 26000 (142)   | LQM (2014) |
| Aliphatic EC >16-35 | 65000 (8.48)                       | 92000 (21) | 11000 0    | 65000 (8.48)                          | 92000 (21) | 110000     | 26000 0                          | 270000 | 27000 0 | 160000 0                         | 1700000       | 180000 0      | 250000                             | 250000 | 25000 0 | 450000                           | 480000       | 490000        | LQM (2014) |
| Aliphatic EC >35-44 | 65000 (8.48)                       | 92000 (21) | 11000 0    | 65000 (8.48)                          | 92000 (21) | 110000     | 26000 0                          | 270000 | 27000 0 | 160000 0                         | 1700000       | 180000 0      | 250000                             | 250000 | 25000 0 | 450000                           | 480000       | 490000        | LQM (2014) |
| Aromatic EC 5-7     | 70                                 | 140        | 300        | 370                                   | 690        | 1400       | 13                               | 27     | 57      | 26000 (1220)                     | 46000 (2260)  | 86000 (4710)  | 56000                              | 56000  | 56000   | 76000 (1220)                     | 84000 (2260) | 92000 (4710)  | LQM (2014) |
| Aromatic EC >7-8    | 130                                | 290        | 660        | 860                                   | 1800       | 3900       | 22                               | 51     | 120     | 56000 (869)                      | 110000 (1920) | 180000 (4360) | 56000                              | 56000  | 56000   | 87000 (869)                      | 95000 (1920) | 100000 (4360) | LQM (2014) |
| Aromatic EC >8-10   | 34                                 | 83         | 190        | 47                                    | 110        | 270        | 8.6                              | 21     | 51      | 3500 (613)                       | 8100 (1500)   | 17000 (3580)  | 5000                               | 5000   | 5000    | 7200 (613)                       | 8500 (1500)  | 9300 (3580)   | LQM (2014) |
| Aromatic EC >10-12  | 74                                 | 180        | 380        | 250                                   | 590        | 1200       | 13                               | 31     | 74      | 16000 (364)                      | 28000 (899)   | 34000 (2150)  | 5000                               | 5000   | 5000    | 9200 (364)                       | 9700 (899)   | 10000         | LQM (2014) |

| Parameter                                 | Residential with homegrown produce |       |       | Residential without homegrown produce |            |       | Allotment                        |        |       | Commercial / Industrial          |       |       | Public Open Space near Residential |        |        | Public Open Space - Park         |              |               | Source     |
|-------------------------------------------|------------------------------------|-------|-------|---------------------------------------|------------|-------|----------------------------------|--------|-------|----------------------------------|-------|-------|------------------------------------|--------|--------|----------------------------------|--------------|---------------|------------|
|                                           | (mg/kg, unless otherwise stated)   |       |       | (mg/kg, unless otherwise stated)      |            |       | (mg/kg, unless otherwise stated) |        |       | (mg/kg, unless otherwise stated) |       |       | (mg/kg, unless otherwise stated)   |        |        | (mg/kg, unless otherwise stated) |              |               |            |
| SOM                                       | 1%                                 | 2.50% | 6%    | 1%                                    | 2.50%      | 6%    | 1%                               | 2.50%  | 6%    | 1%                               | 2.50% | 6%    | 1%                                 | 2.50%  | 6%     | 1%                               | 2.50%        | 6%            |            |
| Aromatic EC >12-16                        | 140                                | 330   | 660   | 1800                                  | 2300 (419) | 2500  | 23                               | 27     | 130   | 36000 (169)                      | 37000 | 38000 | 5100                               | 5100   | 5000   | 10000                            | 10000        | 10000         | LQM (2014) |
| Aromatic EC >16-21                        | 260                                | 540   | 930   | 1900                                  | 1900       | 1900  | 46                               | 110    | 260   | 28000                            | 28000 | 28000 | 3800                               | 3800   | 3800   | 7600                             | 7700         | 7800          | LQM (2014) |
| Aromatic EC >21-35                        | 1100                               | 1500  | 1700  | 1900                                  | 1900       | 1900  | 370                              | 820    | 1600  | 28000                            | 28000 | 28000 | 3800                               | 3800   | 3800   | 7800                             | 7800         | 7900          | LQM (2014) |
| Aromatic EC >35-44                        | 1100                               | 1500  | 1700  | 1900                                  | 1900       | 1900  | 370                              | 820    | 1600  | 28000                            | 28000 | 28000 | 3800                               | 3800   | 3800   | 7800                             | 7800         | 7900          | LQM (2014) |
| Aromatic EC >44-75                        | 1600                               | 1800  | 1900  | 1900                                  | 1900       | 1900  | 1200                             | 2100   | 3000  | 28000                            | 28000 | 28000 | 3800                               | 3800   | 3800   | 7800                             | 7800         | 7900          | LQM (2014) |
| VOCs                                      |                                    |       |       |                                       |            |       |                                  |        |       |                                  |       |       |                                    |        |        |                                  |              |               |            |
| 1,2-dichloroethane (1,2-DCA)              | 0.0071                             | 0.011 | 0.019 | 0.0092                                | 0.013      | 0.023 | 0.0046                           | 0.0083 | 0.016 | 0.67                             | 0.97  | 1.7   | 29                                 | 29     | 29     | 21                               | 24           | 28            | LQM (2014) |
| 1,1,1-trichloroethane                     | 8.8                                | 18    | 39    | 9                                     | 18         | 40    | 48                               | 110    | 240   | 660                              | 1300  | 3000  | 140000                             | 140000 | 140000 | 57000 (1425)                     | 76000 (2915) | 100000 (6392) | LQM (2014) |
| 1,1,2,2,tetrachloroethane                 | 1.6                                | 3.4   | 7.5   | 3.9                                   | 8          | 17    | 0.41                             | 0.89   | 2     | 270                              | 550   | 1100  | 1400                               | 1400   | 1400   | 1800                             | 2100         | 2300          | LQM (2014) |
| tetrachloroethene                         | 0.18                               | 0.39  | 0.9   | 0.18                                  | 0.4        | 0.92  | 0.65                             | 1.5    | 3.6   | 19                               | 45    | 95    | 1400                               | 1400   | 1400   | 810 (424)                        | 1100 (951)   | 1500          | LQM (2014) |
| tetrachloromethane (Carbon tetrachloride) | 0.026                              | 0.056 | 0.13  | 0.026                                 | 0.056      | 0.13  | 0.45                             | 1      | 2.4   | 2.9                              | 6.3   | 14    | 890                                | 920    | 950    | 190                              | 270          | 400           | LQM (2014) |
| Trichloroethene                           | 0.016                              | 0.034 | 0.075 | 0.017                                 | 0.036      | 0.08  | 0.041                            | 0.091  | 0.21  | 1.2                              | 2.6   | 5.7   | 120                                | 120    | 120    | 70                               | 91           | 120           | LQM (2014) |
| Trichloromethane (chloroform)             | 0.91                               | 1.7   | 3.4   | 1.2                                   | 2.1        | 4.2   | 0.42                             | 0.83   | 1.7   | 99                               | 170   | 350   | 2500                               | 2500   | 2500   | 2600                             | 2800         | 3100          | LQM (2014) |

| Parameter                     | Residential with homegrown produce |         |        | Residential without homegrown produce |             |             | Allotment                        |       |        | Commercial / Industrial          |              |              | Public Open Space near Residential |       |       | Public Open Space - Park         |              |              | Source     |
|-------------------------------|------------------------------------|---------|--------|---------------------------------------|-------------|-------------|----------------------------------|-------|--------|----------------------------------|--------------|--------------|------------------------------------|-------|-------|----------------------------------|--------------|--------------|------------|
|                               | (mg/kg, unless otherwise stated)   |         |        | (mg/kg, unless otherwise stated)      |             |             | (mg/kg, unless otherwise stated) |       |        | (mg/kg, unless otherwise stated) |              |              | (mg/kg, unless otherwise stated)   |       |       | (mg/kg, unless otherwise stated) |              |              |            |
| SOM                           | 1%                                 | 2.50%   | 6%     | 1%                                    | 2.50%       | 6%          | 1%                               | 2.50% | 6%     | 1%                               | 2.50%        | 6%           | 1%                                 | 2.50% | 6%    | 1%                               | 2.50%        | 6%           |            |
| Chloroethene (Vinyl chloride) | 0.00064                            | 0.00087 | 0.0014 | 0.00077                               | 0.001       | 0.0015      | 0.00055                          | 0.001 | 0.0018 | 0.059                            | 0.077        | 0.12         | 3.5                                | 3.5   | 3.5   | 4.8                              | 5            | 5.4          | LQM (2014) |
| 2,4,6 Trinitrotoluene (TNT)   | 1.6                                | 3.7     | 8.1    | 65                                    | 66          | 66          | 0.24                             | 0.58  | 1.4    | 1000                             | 1000         | 1000         | 130                                | 130   | 130   | 260                              | 270          | 270          | LQM (2014) |
| RDX                           | 120                                | 250     | 540    | 13000                                 | 13000       | 13000       | 17                               | 38    | 85     | 210000                           | 210000       | 210000       | 26000                              | 26000 | 27000 | 49000 (18.7)                     | 51000        | 53000        | LQM (2014) |
| HMX                           | 5.7                                | 13      | 26     | 6700                                  | 6700        | 6700        | 0.86                             | 1.9   | 3.9    | 110000                           | 110000       | 110000       | 13000                              | 13000 | 13000 | 23000 (0.35)                     | 23000 (0.39) | 24000 (0.48) | LQM (2014) |
| Aldrin                        | 5.7                                | 6.6     | 7.1    | 7.3                                   | 7.4         | 7.5         | 3.2                              | 6.1   | 9.6    | 170                              | 170          | 170          | 18                                 | 18    | 18    | 30                               | 31           | 31           | LQM (2014) |
| Dieldrin                      | 0.97                               | 2       | 3.5    | 7                                     | 7.3         | 7.4         | 0.17                             | 0.41  | 0.96   | 170                              | 170          | 170          | 18                                 | 18    | 18    | 30                               | 30           | 31           | LQM (2014) |
| Atrazine                      | 3.3                                | 7.6     | 17.4   | 610                                   | 620         | 620         | 0.5                              | 1.2   | 2.7    | 9300                             | 9400         | 9400         | 1200                               | 1200  | 1200  | 2300                             | 2400         | 2400         | LQM (2014) |
| Dichlovos                     | 0.032                              | 0.066   | 0.014  | 6.4                                   | 6.5         | 6.6         | 0.0049                           | 0.01  | 0.022  | 140                              | 140          | 140          | 16                                 | 16    | 16    | 26                               | 26           | 27           | LQM (2014) |
| Alpha-Endosulfan              | 7.4                                | 18      | 41     | 160 (0.003)                           | 280 (0.007) | 410 (0.016) | 1.2                              | 2.9   | 6.8    | 5600 (0.003)                     | 7400 (0.007) | 8400 (0.016) | 1200                               | 1200  | 1200  | 2400                             | 2400         | 2500         | LQM (2014) |
| alpha-Hexachlorocyclohexane   | 0.23                               | 0.55    | 1.2    | 6.9                                   | 9.2         | 11          | 0.035                            | 0.087 | 0.21   | 170                              | 180          | 180          | 24                                 | 24    | 24    | 47                               | 48           | 48           | LQM (2014) |
| beta-hexachlorocyclohexanes   | 0.085                              | 0.2     | 0.46   | 3.7                                   | 3.8         | 3.8         | 0.013                            | 0.032 | 0.077  | 65                               | 65           | 65           | 8.1                                | 8.1   | 8.1   | 15                               | 15           | 16           | LQM (2014) |
| gamma-hexachlorocyclohexanes  | 0.06                               | 0.14    | 0.33   | 2.9                                   | 3.3         | 3.5         | 0.0092                           | 0.023 | 0.054  | 67                               | 69           | 70           | 8.2                                | 8.2   | 8.2   | 14                               | 15           | 15           | LQM (2014) |

| Parameter                  | Residential with homegrown produce |       |     | Residential without homegrown produce |       |     | Allotment                        |       |      | Commercial / Industrial          |             |              | Public Open Space near Residential |       |       | Public Open Space - Park         |              |              | Source     |
|----------------------------|------------------------------------|-------|-----|---------------------------------------|-------|-----|----------------------------------|-------|------|----------------------------------|-------------|--------------|------------------------------------|-------|-------|----------------------------------|--------------|--------------|------------|
|                            | (mg/kg, unless otherwise stated)   |       |     | (mg/kg, unless otherwise stated)      |       |     | (mg/kg, unless otherwise stated) |       |      | (mg/kg, unless otherwise stated) |             |              | (mg/kg, unless otherwise stated)   |       |       | (mg/kg, unless otherwise stated) |              |              |            |
| SOM                        | 1%                                 | 2.50% | 6%  | 1%                                    | 2.50% | 6%  | 1%                               | 2.50% | 6%   | 1%                               | 2.50%       | 6%           | 1%                                 | 2.50% | 6%    | 1%                               | 2.50%        | 6%           |            |
| Chlorobenzene              | 0.46                               | 1     | 2.4 | 0.46                                  | 1     | 2.4 | 5.9                              | 14    | 32   | 56                               | 130         | 290          | 11000                              | 13000 | 14000 | 1300 (675)                       | 2000 (1520)  | 2900         | LQM (2014) |
| 1,2-Dichlorobenzene        | 23                                 | 55    | 130 | 24                                    | 57    | 130 | 94                               | 230   | 540  | 2000 (571)                       | 4800 (1370) | 11000 (3240) | 90000                              | 95000 | 98000 | 24000 (571)                      | 36000 (1370) | 51000 (3240) | LQM (2014) |
| 1,3-Dichlorobenzene        | 0.4                                | 1     | 2.3 | 0.44                                  | 1.1   | 2.5 | 0.25                             | 0.6   | 1.5  | 30                               | 73          | 170          | 300                                | 300   | 300   | 390                              | 440          | 470          | LQM (2014) |
| 1,4-Dichlorobenzene        | 61                                 | 150   | 350 | 61                                    | 150   | 350 | 15                               | 37    | 88   | 4400 (224)                       | 10000 (540) | 25000 (1280) | 17000                              | 17000 | 17000 | 36000 (224)                      | 36000 (540)  | 36000 (1280) | LQM (2014) |
| VOCs Continued             |                                    |       |     |                                       |       |     |                                  |       |      |                                  |             |              |                                    |       |       |                                  |              |              |            |
| 1,2,3-Trichlorobenzene     | 1.5                                | 3.6   | 8.6 | 1.5                                   | 3.7   | 8.8 | 4.7                              | 12    | 28   | 102                              | 250         | 590          | 1800                               | 1800  | 1800  | 770 (134)                        | 1100 (330)   | 1600 (789)   | LQM (2014) |
| 1,2,4-Trichlorobenzene     | 2.6                                | 6.4   | 15  | 2.6                                   | 6.4   | 15  | 55                               | 140   | 320  | 220                              | 530         | 1300         | 15000                              | 17000 | 19000 | 1700 (318)                       | 2600 (786)   | 4000 (1880)  | LQM (2014) |
| 1,3,5-Trichlorobenzene     | 0.33                               | 0.81  | 1.9 | 0.33                                  | 0.81  | 1.9 | 4.7                              | 12    | 28   | 23                               | 55          | 130          | 1700                               | 1700  | 1800  | 380 (36.7)                       | 580 (90.8)   | 860 (217)    | LQM (2014) |
| 1,2,3,4-Tetrachlorobenzene | 15                                 | 36    | 78  | 24                                    | 56    | 120 | 4.4                              | 11    | 26   | 1700 (122)                       | 3080 (304)  | 4400 (728)   | 830                                | 830   | 830   | 1500 (122)                       | 1600         | 1600         | LQM (2014) |
| 1,2,3,5-Tetrachlorobenzene | 0.66                               | 1.6   | 3.7 | 0.75                                  | 1.9   | 4.3 | 0.38                             | 0.9   | 2.2  | 49 (39.4)                        | 120 (98.1)  | 240 (235)    | 78                                 | 79    | 79    | 110 (39)                         | 120          | 130          | LQM (2014) |
| 1,2,4,5-Tetrachlorobenzene | 0.33                               | 0.77  | 1.6 | 0.73                                  | 1.7   | 3.5 | 0.06                             | 0.16  | 0.37 | 42 (19.7)                        | 72 (49.1)   | 96           | 13                                 | 13    | 13    | 25                               | 26           | 26           | LQM (2014) |
| Pentachlorobenzene         | 5.8                                | 12    | 22  | 19                                    | 30    | 38  | 1.2                              | 3.1   | 7    | 640 (43)                         | 770 (107)   | 830          | 100                                | 100   | 100   | 190                              | 190          | 190          | LQM (2014) |

| Parameter                                    | Residential with homegrown produce |           |      | Residential without homegrown produce |           |           | Allotment                        |       |      | Commercial / Industrial          |                             |                             | Public Open Space near Residential |                             |                             | Public Open Space - Park         |                             |                             | Source     |
|----------------------------------------------|------------------------------------|-----------|------|---------------------------------------|-----------|-----------|----------------------------------|-------|------|----------------------------------|-----------------------------|-----------------------------|------------------------------------|-----------------------------|-----------------------------|----------------------------------|-----------------------------|-----------------------------|------------|
|                                              | (mg/kg, unless otherwise stated)   |           |      | (mg/kg, unless otherwise stated)      |           |           | (mg/kg, unless otherwise stated) |       |      | (mg/kg, unless otherwise stated) |                             |                             | (mg/kg, unless otherwise stated)   |                             |                             | (mg/kg, unless otherwise stated) |                             |                             |            |
| SOM                                          | 1%                                 | 2.50%     | 6%   | 1%                                    | 2.50%     | 6%        | 1%                               | 2.50% | 6%   | 1%                               | 2.50%                       | 6%                          | 1%                                 | 2.50%                       | 6%                          | 1%                               | 2.50%                       | 6%                          |            |
| Hexachlorobenze ne                           | 1.8 (0.2)                          | 3.3 (0.5) | 4.9  | 4.1 (0.2)                             | 5.7 (0.5) | 6.7 (1.2) | 0.47                             | 1.1   | 2.5  | 110 (0.2)                        | 120                         | 120                         | 16                                 | 16                          | 16                          | 30                               | 30                          | 30                          | LQM (2014) |
| Phenol                                       | 280                                | 550       | 1100 | 750                                   | 1300      | 2300      | 66                               | 140   | 280  | 760 <sup>dir</sup> (31000)       | 1500 <sup>dir</sup> (35000) | 3200 <sup>dir</sup> (37000) | 760 <sup>dir</sup> (31000)         | 1500 <sup>dir</sup> (35000) | 3200 <sup>dir</sup> (37000) | 760 <sup>dir</sup> (31000)       | 1500 <sup>dir</sup> (35000) | 3200 <sup>dir</sup> (37000) | LQM (2014) |
| Chlorophenols (excluding pentachlorophen ol) | 0.87 (g)                           | 2         | 4.5  | 94                                    | 150       | 210       | 0.13 (g)                         | 0.3   | 0.7  | 3500                             | 4000                        | 4300                        | 620                                | 620                         | 620                         | 1100                             | 1100                        | 1100                        | LQM (2014) |
| Pentachlorophen ol                           | 0.22                               | 0.52      | 1.2  | 27 (16.4)                             | 29        | 31        | 0.03                             | 0.08  | 0.19 | 400                              | 400                         | 400                         | 60                                 | 60                          | 60                          | 110                              | 120                         | 120                         | LQM (2014) |
| Carbon Disulphide                            | 0.14                               | 0.29      | 0.62 | 0.14                                  | 0.29      | 0.62      | 4.8                              | 10    | 23   | 11                               | 22                          | 47                          | 11000                              | 11000                       | 12000                       | 1300                             | 1900                        | 2700                        | LQM (2014) |
| Hexachlorobutadi ene                         | 0.29                               | 0.7       | 1.6  | 0.32                                  | 0.78      | 1.8       | 0.25                             | 0.61  | 1.4  | 31                               | 66                          | 120                         | 25                                 | 25                          | 25                          | 48                               | 50                          | 51                          | LQM (2014) |

(g) derived based on 2,3,4,6-tetrachlorophenol; dir - based on a threshold protective of direct skin contact with phenol (guideline in brackets based on health effects following long term exposure provided for illustration only); (vap) calculated for vapour phase only. SOM – Soil Organic Matter; (4.5) solubility.

## **APPENDIX L - CONTROLLED WATERS RISK ASSESSMENT**

## CURRENT GUIDANCE FOR CONTROLLED WATERS RISK ASSESSMENT

### Regulatory Context

Government policy is based upon a “suitable for use approach,” which is relevant to both the current use of land and also to any proposed future use. When considering the current use of land, Part IIA of the Environment Protection Act 1990 (EPA 1990) provides the regulatory regime, which was introduced by Section 57 of the Environment Act 1995, which came into force in England on 1 April 2000. The main objective of introducing the Part IIA regime is to provide an improved system for the identification and remediation of land where contamination is causing unacceptable risks to human health, controlled waters or the wider environment given the current use and circumstances of the land. Part IIA provides a statutory definition of contaminated land under Section 78A(2) 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.”*

Part IIA provides a statutory definition of the pollution of controlled waters under Section 78A(9) as:

*“the entry into controlled waters of any poisonous, noxious or polluting matter or any solid waste matter”*

Controlled Waters are defined Section 104 of the Water Resources Act 1991. In summary, they comprise relevant territorial waters which extend seaward for three miles from the low-tide limit from which the territorial sea adjacent to England and Wales is measured.

The Environment Agency has powers under Part 7 of The Water Resources Act (1991) to take action to prevent or remedy the pollution of controlled waters, including circumstances where the pollution arises from contamination in the land. This is reinforced in The Contaminated Land (England) (Amendment) Regulations 2012 and Contaminated Land Statutory Guidance (DEFRA, 2012) which came into force in early April 2012.

Part IIA introduces the concept of a contaminant linkage; where for potential harm to exist there must be a connection between the source of the hazard and the receptor via a pathway. Risk assessment in contaminated land is therefore directed towards identifying the contaminants, pathways and receptors that can provide contaminant linkages. This is known as the contaminant-pathway-receptor link (CPR or contaminant linkage).

Part IIA places contaminated land responsibility as a part of the planning and redevelopment process, rather than Local Authority or Environment Agency directly, except in cases of very high pollution risk or where harm is occurring. In the planning process, guidance is provided by National Planning Policy Framework (NPPF) of March 2012. The NPPF requires that a site which has been developed shall not be capable of being determined “contaminated land” under Part IIA. Therefore, appropriate risk-based investigation is required to identify the contaminant linkages that can then be assessed, and then mitigated using methods that can be agreed with the planners.

### Source Protection Zones

Source Protection Zones (SPZs) are defined by the Environment Agency (for England and Wales), SEPA (Scotland) and the Environment and Heritage Service (Northern Ireland) for groundwater sources such as wells, boreholes and springs that are used for public drinking water supply. The zones show the risk of contamination from activities that might cause groundwater pollution in the area. The size and shape of a zone depends upon subsurface conditions, how the groundwater is removed, and other environmental factors.

SPZs are classified into four categories:

- **Zone 1 (Inner protection zone).** Any pollution that can travel to the abstraction point within 50 days from any point within the zone is classified as being inside Zone 1. This applies at and below the groundwater table. This zone also has a minimum 50 m protection radius around the abstraction point. These criteria are designed to protect against the transmission of toxic chemicals and water-borne disease.
- **Zone 2 (Outer protection zone).** The outer zone covers pollution that takes up to 400 days to travel to the abstraction point, or 25% of the total catchment area, whichever area is the largest. This travel time is the minimum period over which the Environment Agency considers that pollutants need to be diluted, reduced in strength or delayed by the time they reach the abstraction point.
- **Zone 3 (Total catchment).** This is the total area needed to support removal of water from the abstraction point, and to support any discharge from this.
- **Zone of special interest.** This may occasionally be defined as a special case. This is usually where local conditions mean that industrial sites and other potential sources of contamination could affect the groundwater source, even though they are outside the normal catchment area.

### Groundwater Vulnerability Assessments

From 1 April 2010 The Environment Agency Groundwater Protection Policy began to use aquifer designations which are consistent with the Water Framework Directive. These designations reflect the importance of aquifers in terms of groundwater as a resource (drinking water supply) but also their role in supporting surface water flows and wetland ecosystems.

The aquifer designation data is based on geological mapping provided by the British Geological Survey. It is updated regularly to reflect their ongoing programme of improvements to these maps. The maps are split into two different types of aquifer designation:

- Superficial (Drift) - permeable unconsolidated (loose) deposits. For example, sands and gravels.
- Bedrock - solid permeable formations e.g. sandstone, chalk and limestone.

The maps display the following aquifer designations:

**Table 1. Aquifer Classification ("Geological Classification").**

| Classification                               | Definition                                                                                                                                                                                                                                                                                                                           |
|----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Principal Aquifers (Highly Permeable)</b> | These are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer. |
| <b>Secondary A Aquifers</b>                  | Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.                                                                                              |
| <b>Secondary B Aquifers</b>                  | Predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers.                                                                         |
| <b>Secondary Undifferentiated Aquifers</b>   | This has been assigned in cases where it has not been possible to attribute either category A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.                    |
| <b>Unproductive Strata</b>                   | These are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.                                                                                                                                                                                                 |

## Environment Agency Guidance

The Environment Agency's stance on groundwater resources is:

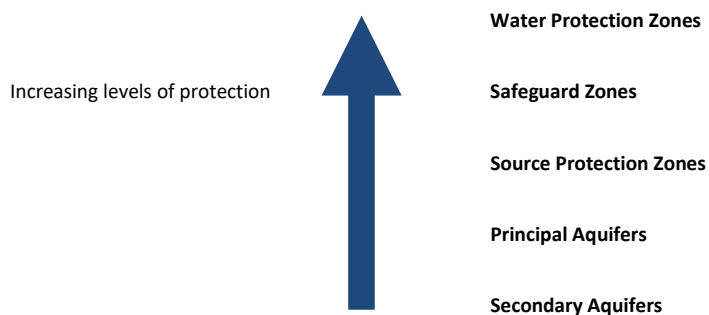
*"to protect and manage groundwater resources for present and future generations in ways that are appropriate for the risks we identify"*  
(Groundwater Protection: Policy and Practice GP3, 2012).

At present, the legislation and guidance pertaining to the protection of controlled waters in the UK is complex; however, the core objectives seek to enforce the position given above.

In 1992, the National Rivers Authority published their Policy and Practice for the Protection of Groundwater (PPPG), this document introduced areas of focus for developments such as Source Protection Zones (SPZs) and Groundwater Vulnerability Maps. The Policy was revised in 1998, since which there have been substantial changes in legislation, driven by key European Directives relating to groundwater include the Groundwater Directive (80/68/EEC) and the Water Framework Directive (2000/60/EC). Aspects of these directives are controlled by primary UK legislation such as the Water Resources Act 1991 as amended by the Water Act 2003. Gaps in the 1998 PPPG that emerged as the result of further legislative changes were addressed in the Environment Agency Policy document Groundwater Protection: Policy and Practice (GP3), Version 1 of November 2012. The three main parts of GP3 were:

- Groundwater principals;
- Position statements and legislation; and
- Technical information.

The Environment Agency has a tiered risk based approach to drinking water protection as summarised below:



## Controlled Waters Risk Assessment

A number of tools are available (as detailed in GP3) in order for a developer of a potentially contaminated site to fulfil their obligations under the legislation. A site assessment would be required in order to identify any potential risks to controlled waters and to derive suitable clean up criteria, if required, to ensure the protection of controlled waters.

There are three main stages to any risk assessment of controlled waters:

1. Risk Screening (devise Conceptual Site Model, making reference to groundwater vulnerability maps, site setting, controlled waters context etc)
2. Generic Risk Assessment (EA Remedial Targets Methodology Tier 1 / Comparison of groundwater data with relevant standards)
3. Detailed Quantitative Risk Assessment (Consideration of aquifer properties and site specific parameters, EA Remedial Targets Methodology Tiers 2 & 3)

### Risk Screening

Here, the Conceptual Site Model (CSM) is a critical tool to assessing any potentially contaminated site. The information from a robust CSM can be used to establish any pathways or receptors that do not require further assessment at an early stage. For example, it may be possible to confirm the absence of a particular sensitive controlled water receptor (such as a surface water feature) within the vicinity of the Site thereby breaking the associated source-pathway-receptor pollutant linkage. Information from subsequent tiers of risk assessment, such as following intrusive investigations, are used to update the CSM accordingly.

### Generic Risk Assessment - England and Wales

When undertaking the Generic Hydrogeological Risk Assessment (EA Remedial Targets Methodology Tier 1), comparison of chemical analytical results is made with those screening criteria.

In accordance with Part 2A of the Environmental Protection Act 1990, Tier Environmental has made regard to all of the Water Quality Standards (WQS) that are relevant to the specific site and a judgment has been made against the most stringent of those relevant standards:

- EQS Directive 2008/105/EC
- Priority Substances Directive 2013/39/EU
- Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015
- UK Drinking Water Standards (UK DWS)
- World Health Organisation (WHO Guidelines) for Drinking Water Quality
- Council Directive 98/83/EC on the quality of water intended for human consumption (Drinking water directive)

In some instances, the laboratory method detection limit is greater than the appropriate EQS/UKDWS value. In these instances, only measured concentrations in excess of the laboratory method detection limit have been considered likely to potentially represent a possible significant risk to controlled waters.

Please note that there is no quantitative criterion for total petroleum hydrocarbons (TPH), or speciated TPH fractions. Historically, standards provided for petroleum hydrocarbons ranges from 10µg/l (Private Water Supply Regulations 1991, removed from the 2009 regulations) to 50µg/l-1000µg/l (Surface Waters (Abstraction for Drinking Water) Regulations 1989) which related to the degree of treatment of water prior to use as drinking water. Over time, the legislative standards have been rescinded and no alternative standard provided, although the Environment Agency planned to release speciated TPH criteria (Fretwell et al., 2009).

In order to assess whether there is a potentially unacceptable risk of pollution of controlled waters, the results of the groundwater chemical analysis for TPH and BTEX were evaluated against Water Quality Standards (WQS) appropriate to the conceptual model for the site:

**Table 2. Summary of Selected TPH and BTEX Water Quality Standards Selected for Tier 1 Screening**

| Determinand          | Units | WQS Selected | Source of WQS              |
|----------------------|-------|--------------|----------------------------|
| Aliphatics >C5-C6    | µg/l  | 15000        | Table 5.4 of CL:AIRE 2017# |
| Aliphatics >C6-C8    | µg/l  | 15000        | Table 5.4 of CL:AIRE 2017# |
| Aliphatics >C8-C10   | µg/l  | 300          | Table 5.4 of CL:AIRE 2017# |
| Aliphatics >C10-C12  | µg/l  | 300          | Table 5.4 of CL:AIRE 2017# |
| Aliphatics >C12-C16  | µg/l  | 300          | Table 5.4 of CL:AIRE 2017# |
| Aliphatics >C16-C21  | µg/l  | -            | Table 5.4 of CL:AIRE 2017# |
| Aliphatics >C21-C35  | µg/l  | -            | Table 5.4 of CL:AIRE 2017# |
| Aromatics >C5-EC7    | µg/l  | 10           | Table 5.4 of CL:AIRE 2017# |
| Aromatics >EC7-EC8   | µg/l  | 700          | Table 5.4 of CL:AIRE 2017# |
| Aromatics >EC8-EC10  | µg/l  | 300          | Table 5.4 of CL:AIRE 2017# |
| Aromatics >EC10-EC12 | µg/l  | 100          | Table 5.4 of CL:AIRE 2017# |

|                      |      |     |                                                                                                                                                                                                                                                |
|----------------------|------|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Aromatics >EC12-EC16 | µg/l | 100 | Table 5.4 of CL:AIRE 2017#                                                                                                                                                                                                                     |
| Aromatics >EC16-EC21 | µg/l | 90  | Table 5.4 of CL:AIRE 2017#                                                                                                                                                                                                                     |
| Aromatics >EC21-EC35 | µg/l | 90  | Table 5.4 of CL:AIRE 2017#                                                                                                                                                                                                                     |
| Benzene              | µg/l | 10  | Priority Substance Water Framework Directive 2015 and Table 5.3 of CL:AIRE 2017#                                                                                                                                                               |
| Toluene              | µg/l | 74  | Table 1 Water Framework Directive 2015 and Table 5.3 of CL:AIRE 2017#                                                                                                                                                                          |
| Ethylbenzene         | µg/l | 20  | R&D Technical Report P2-115/TR4, 2002                                                                                                                                                                                                          |
| Total xylenes        | µg/l | 30  | DoE (1997c) Hedgecott S. and Lewis S, An update on proposed environmental quality standards for xylenes in water, final report to the Department of the Environment. Report No. DoE 4273/1. Medmenham: WRc; and;<br>Table 5.3 of CL:AIRE 2017# |

Notes - # = CL:AIRE document 'Petroleum Hydrocarbons in Groundwater: Guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies' (ISBN 978-1-905046-31-7, dated 2017),

Table 5.3 was referenced in the first instance from the CL:AIRE document 'Petroleum Hydrocarbons in Groundwater: Guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies' (ISBN 978-1-905046-31-7, dated 2017), the to select appropriate Freshwater EQS values for benzene, toluene and total xylenes. The selected value for Ethylbenzene was derived from the proposed EQS value of 20µg/l from the Environment Agency R&D Technical Report P2-115/TR4, 2002. This represents a more conservative value than the 300µg/l value in Table 5.3.

With respect to speciated TPH CWG fractions, Table 5.3 states and refers the reader to 'See Table 5.4'. On this basis, Tier Environmental selected the World Health Organization (WHO) guide values for TPHCWG fractions in drinking water that are presented in Table 5.4 which may be considered appropriately protective of the controlled waters environment based on the conceptual site model.

Generic Risk Assessment is generally undertaken via comparison of reported leachate and/or groundwater concentrations against selected assessment criteria for the potential contaminants of concern identified for the Site from a preliminary desk based assessment.

The selected Generic Assessment Criteria (GAC) derived from a Water Quality Standard (WQS) for any specific substance may not necessarily be a simple number and can often be found to be expressed as:

- Annual mean concentration;
- Maximum allowable concentration;
- 95th percentile concentration for *n* samples;
- Total concentration;
- Dissolved concentration (applicable to filtered samples)

The values may sometimes be expressed for individual substances (e.g. arsenic or for groups of substances e.g. total xylenes or sums of certain PAHs).

Environmental Quality Standards (EQS) have been used where available for Priority Substances and Priority Hazardous Substances set at a European level:

- Priority Substances Directive 2013/39/EU;
- Amending 2008/105 and 2000/118/EC

In addition, EQS values derived for Specific Pollutants have been used as presented in The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.

For assessing risks to potable water abstraction supplies, UK Drinking Water Standards presented in the Water Supply (Water Quality) Regulations 2000 (SI/2000/3184) (as amended) have been applied.

In selecting a GAC for a particular Site, Tier Environmental considers the following factors:

- Current use/function of the groundwater (e.g. drinking water, irrigation water, industrial use, base-flow to rivers and streams);
- Plausible, proposed or planned future uses of the water and nearby waters;
- Sensitivity of the critical receptor (e.g. human health, aquatic life); and,
- Requirements to trigger action under the legal context

In accordance with Part 2A:

*"in deciding whether pollution of controlled waters is occurring, the assessor will have regard to all of the water quality standards that are relevant to the specific site and make a judgment against the most stringent of those relevant standards"*

Should the Level 1 or 2 assessments indicate threshold levels to be exceeded, then there are three alternative ways in which to proceed:

- To devise suitable remedial solutions;
- To carry out more investigation, sampling and analysis;
- To conduct a site-specific Detailed Quantitative Risk Assessment (DQRA) to whether or not the soil materials are suitable for their site-specific intended use or to devise a site-specific clean-up level.

### **Detailed Quantitative Risk Assessment (DQRA)**

The decision to carry out a DQRA will be informed by the initial qualitative and generic assessment. The scope of any such assessment will be accurately defined by the outcomes of the former two stages. The robust CSM will be sufficiently refined by this stage that only certain contaminants of concern, certain pathways and certain receptors will require further assessment.

Additional site specific data is normally required for this stage of assessment, as explained above, more processes that are capable of affecting contaminant concentrations are considered (such as dilution and attenuation).

Remediation criteria derived will therefore be specific to each site and will be based on a detailed assessment of the potential impact at the identified receptor or compliance point. A greater level of confidence can be placed on the predicted impact on the compliance point following a DQRA.

### **Hazardous and Non Hazardous Substances**

The Groundwater (England and Wales) Regulations 2009 control the disposal to the hydrogeological environment of potentially polluting substances which are divided into Hazardous Substances and Non-hazardous Contaminants (this roughly approximates to the former List 1 and List 2 substances).

Hazardous Substances are the most damaging and toxic and must be prevented from directly or indirectly entering the groundwater environment. Hazardous Substances include mineral oils and hydrocarbons, pesticides, biocides, herbicides, solvents and some metals. Discharge of Hazardous Substances to Controlled Waters must be prevented.

Non-hazardous Pollutants are any contaminants other than Hazardous Substances. Non-hazardous Pollutants are potentially toxic but are less harmful than Hazardous Substances, but their direct discharge to groundwater is generally not permitted and any indirect discharge to groundwater must be limited and be controlled by technical precautions in order to prevent pollution. Non-hazardous Pollutants include ammonia and nitrites, many metals and fluorides.

## **APPENDIX M - ASSESSMENT CRITERIA APPLIED FOR GROUND GAS**

## Ground Gas Monitoring Methodology

Monitoring for the following is generally performed as part of ground gas assessment:

- Methane (CH<sub>4</sub>): an odourless, flammable gas. Mixtures of methane with air containing between 5 and 15% v/v methane are explosive.
- Carbon dioxide (CO<sub>2</sub>): an asphyxiant at elevated concentrations. Denser than air, it can accumulate in excavations, and within low points inside buildings
- Oxygen (O<sub>2</sub>): important in the assessment of the potential formation of explosive mixtures with methane. Monitoring normally measures both methane and oxygen concentrations in ground gas to derive an indication of the risk of explosive mixture formation, expressed as a percentage of the Lower Explosive Limit (LEL). Low concentrations of oxygen in ground gas can also exacerbate the risk of CO<sub>2</sub> asphyxiation.
- Hydrogen sulphide (H<sub>2</sub>S): odorous and toxic, capable of forming flammable mixtures with air.

In addition, depending on the Conceptual Site Model, monitoring may also include for measurements of Volatile Organic Compounds (VOCs); present as chemical contaminants of soil and sometimes also biologically produced in low concentrations.

### Assessment of methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>)

Methane and carbon dioxide can arise from natural geological sources, mine workings, rotting organic matter (peat, landfilled materials, etc.) and/or contaminant biodegradation. Assessment of ground gas composition and flows is therefore an essential part of site assessment. The need to adequately address potential risks from ground gas on development sites is therefore required under the planning regime.

In order to appropriately assess the site risks, the Construction Industry Research and Information Association (CIRIA) and others have issued several guidance documents on landfill and ground gas that are intended to provide advice on how to investigate and deal with gas contaminated ground with respect to development. These are:

- Report 149: 'Protecting Development from Methane' (CIRIA, 1995a)
- Report 150: 'Methane Investigation Strategies' (CIRIA, 1995b)
- Report 151: 'Interpreting Measurement of Gas in the Ground' (CIRIA, 1995c)
- Report 152: 'Risk Assessment for Methane and Other Gases from the Ground' (CIRIA, 1995d)

More recent guidance has been published to update the documents detailed above to collaborate and promote industry 'good practice'. These are:

- CIRIA Report 665: 'Assessing risks posed by hazardous ground gases to buildings (CIRIA, 2008)
- NHBC: 'Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present' (NHBC, 2007)
- BS8485:201+A1:2019: Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings (BSI Group, 2019)
- BS8576:2013: Guidance on investigations for ground gas. Permanent gases and Volatile Organic Compounds (VOCs) (BSI Group, 2013)
- SoBRA Report Development of Generic Assessment Criteria for Assessing Vapour Risks to Human Health from Volatile Contaminants in Groundwater (Feb 2017)
- CL:AIRE Technical Bulletin TB17 Ground Gas Monitoring and 'Worst Case' Conditions (CL:AIRE Aug 2018)

The earlier CIRIA 149 approach is now considered to be too conservative. A more realistic measure of the risk posed by methane and CO<sub>2</sub> in ground gas can be established by determining an appropriate Gas Screening Value (GSV), using the methods described in the NHBC and CIRIA 659 documents. These values are based upon earlier work undertaken by Wilson and Card (1999).

GSVs are calculated by multiplying the borehole flow rate (l/hr) by the percentage (% v/v) concentration in the gas stream of the specific component, i.e.:

$$\text{GSV} = (\text{Concentration} / 100) \times \text{Flow rate.}$$

A risk-based methodology for deriving GSVs is defined for two situations (designated A and B), which are adequate for the great majority of site cases (as per CIRIA 665 Section 8.3):

- **Situation A:** Any development other than Situation B, e.g. factories, shops, commercial, warehouses, schools, cinemas, sports centres, stadiums, high rise housing, housing with basements, etc
- **Situation B:** Low rise building with minimum ventilated under floor void (min 150 mm)

Under Situation A, classification of the scope of protection required is determined from the site GSV, summarised in Table 1. For Situation B, GSVs derived are used in a 'Traffic Light' classification (summarised in Table 2) which determines the required level and scope of protection measures. Tables 1 and 2 are summaries only: the details provided in the body text, footnotes and appendices of the above-referenced documents should be read in conjunction with the results to determine the appropriate level of protection.

For conservatism, Tier Environmental **initially** uses the maximum concentration and gas flow rate of methane detected in any borehole during all of the monitoring visits in deriving recommendations on appropriate protection measures. This represents the worst-case risk of forming an explosive mixtures. For carbon dioxide, steady state concentrations and flow data are applied, as these determine the development of an asphyxiating mixture. All values are selected whether or not they occurred in the same borehole or during the same monitoring event.

Exceedances of the maximum concentrations used in a Tier 1 Gas Risk Assessment can be tolerated, when the conceptual site model indicates that it is safe to do so. However, appropriately derived GSV values must never be exceeded - where site-specific circumstances permit the derivation of alternative GSVs according to the defined conceptual model, then the appropriate GSV values should be applied.

**Table 1. GSV Categories Defined for Situation A (Summarised from CIRIA Report 665).**

| Risk classification | GSV (CH <sub>4</sub> or CO <sub>2</sub> ; l/hr) | Additional factors                                                                               | Characteristic Situation |
|---------------------|-------------------------------------------------|--------------------------------------------------------------------------------------------------|--------------------------|
| Very low            | <0.07                                           | Typically methane <=1% and/or CO <sub>2</sub> <=5%, otherwise consider increase to Low Risk.     | 1                        |
| Low                 | <0.7                                            | Typically borehole ground gas flow rate <=70 l/hr; otherwise consider increase to Moderate Risk. | 2                        |
| Moderate            | <3.5                                            | ---                                                                                              | 3                        |
| Moderate to high    | <15                                             | QRA required to evaluate scope of remediation measures.                                          | 4                        |
| High                | <70                                             | ---                                                                                              | 5                        |
| Very high           | >70                                             | ---                                                                                              | 6                        |

**Table 2. GSV Categories Defined for Situation B (Summarised from NHBC, 2007).**

| Methane                    |            | CO <sub>2</sub>            |            | "Traffic light" classification |
|----------------------------|------------|----------------------------|------------|--------------------------------|
| Typical max. conc. (% v/v) | GSV (l/hr) | Typical max. conc. (% v/v) | GSV (l/hr) |                                |
|                            |            |                            |            | Green                          |
| 1                          | 0.13       | 5                          | 0.78       | Amber 1                        |
| 5                          | 0.63       | 10                         | 1.60       |                                |
|                            |            |                            |            | Amber 2                        |
| 20                         | 1.60       | 30                         | 3.10       | Red                            |
|                            |            |                            |            |                                |

## Assessment of hydrogen sulphide (H<sub>2</sub>S)

H<sub>2</sub>S is toxic and highly odorous ("rotten eggs") gas. It is often a minor component within mine gases, in ground gas within or overlying strata rich in pyrites or other sulphide-rich ores, and in most natural gas fields.

H<sub>2</sub>S can be generated biologically in significant concentrations by the decomposition by sulphate-reducing bacteria of natural or anthropogenic organic matter under oxygen-free conditions. Its potential generation will be greater in environments containing elevated sulphate concentrations (including sea water). H<sub>2</sub>S is therefore common within the gas arising from estuarine and marine sediments, pond sediment, stagnant water bodies, bogs and marshlands and landfilled waste, for example.

It must be noted that H<sub>2</sub>S normally occurs together with other potentially hazardous ground gases. The measures adopted for protection against these will prove equally protective against H<sub>2</sub>S.

There are no standards by which H<sub>2</sub>S concentrations in ground gas can be assessed directly. Therefore, the significance of measured H<sub>2</sub>S concentrations in ground gas must be evaluated on a case-by-case basis, taking into account the measured concentrations of other components and the specific conceptual site and exposure models. To assist in this process, the following standards and guidance may be applied.

### General protection of land users

There are no UK air quality standards for general exposure to H<sub>2</sub>S. The World Health Organisation has derived ambient air quality standards (WHO, 2000) for this gas, which may be used to inform risk assessment and decision-making:

The 24 hour average exposure guideline value for ambient air: 0.15 mg/m<sup>3</sup> (0.1 ppmv, approx.; this was derived by the application of a 100x safety factor to the LOAEL for long-term exposure).

This is significantly above the odour threshold, which is typically around 0.01 mg/m<sup>3</sup>. To avoid substantial nuisance odour complaints, WHO (2000) recommends that the 30 minute average H<sub>2</sub>S concentration in ambient air should not exceed: 0.007 mg/m<sup>3</sup> (0.005 ppmv, approx.).

### Occupational exposures

For occupational exposure, the HSE (2005) limits for H<sub>2</sub>S are applicable:

- 8 hour time weighted average occupational exposure limit: 5 ppmv (7 mg/m<sup>3</sup>).
- Short-term exposure limit (15 minute reference period): 10 ppmv (14 mg/m<sup>3</sup>).

## VOC Data Collection, Sampling and Assessment

### **BS8576 Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs).**

Volatile organic compounds (VOCs) include, for example, halogenated hydrocarbons such as trichloroethene, non-halogenated hydrocarbons such as benzene, and organosulfur compounds such as thiols (mercaptans). They can occur as a component of ground gas originating from historically contaminated ground, spills and leaks from industry, commercial or residential properties (e.g. from pipelines, storage facilities, and at the point of use or dispensing), land-filled wastes and from naturally occurring sources.

The migration of VOCs in ground gas can be via three primary mechanisms:

- diffusive flow (movement of constituent along a concentration gradient);
- advective flow (movement of constituent due to motion of a transporting fluid);
- dispersion (transport resulting from local variations in fluid flow, e.g. due to friction effects in the matrix).

The choice of sampling and monitoring techniques should be based upon the conceptual model and be designed to achieve the objectives of the investigation, bearing in mind the requirements of any subsequent analytical procedures and the need to provide relevant data of sufficient quantity and quality. Consideration should also be given to the nature of ground under investigation, as well as the nature and distribution of contamination, the geology and the hydrogeology. Every effort should be made to avoid cross-contamination and at no point should underlying aquifers be put at risk.

Where the response zone extends below the water table, gas present in the groundwater will tend to produce an equilibrium concentration in the well headspace. This applies to both permanent gases and VOCs but can be particularly misleading in the latter case. Testing for dissolved gases in groundwater is useful to help interpret monitoring results in such a situation. Similarly, any VOCs in a floating non-aqueous hydrocarbon layer will produce an equilibrium concentration in the well headspace.

The monitoring period and frequency of monitoring for VOCs in ground gases should be developed on a site-specific basis from the conceptual site model and investigation data quality objectives.

Ground gas samples can be collected from the unsaturated zone adjacent to, or above, the known or suspected source of VOCs in ground gas through installation of a ground gas monitoring point in the unsaturated zone (see 10.2), and from a near-surface location beneath hardstanding or a floor or foundation slab through installation of a near- or sub-slab monitoring point (see 10.3). For monitoring of VOCs in ground gas the monitoring well should be installed into unsaturated ground to allow sampling for VOCs to take place. The borehole should not be progressed below the groundwater table or the surface of any floating non-aqueous layer. The borehole should be progressed to the target sampling depth within the unsaturated zone. Full details can be found in BS8576 Section 10.2 onwards.

Assessment of VOC concentrations have been made for limited number of VOCs by SoBRA with the Development of Generic Assessment Criteria for Assessing Vapour Risks to Human Health from Volatile Contaminants in Groundwater in Feb 2017.

The assessment of VOC concentrations is not covered by above-referenced reports. These data can be used to inform the human health risk assessment for site occupants but should not be relied upon to assess human health risk due to uncertainties in the ground gas flow regime, variability in the (generally low) contaminant concentrations measured and inaccuracies in the concentrations measured by PID instruments.

Data on the VOC concentration in ground gas can also help inform potential occupational exposure risks to construction and similar workers. For this purpose, the measured values can be compared to the relevant occupational exposure limit (OEL) for the contaminant(s) of concern, as given in HSE (2005). In cases of doubt as to the identity of the organic contaminants within the ground gas or when these are present as a complex mixture, then the 8 hour time-weighted average (TWA) exposure limit for benzene (1 ppmv) will be applied for screening purposes. This is a reasonably conservative approach since the OEL for benzene is lower than that for the great majority of organic contaminants commonly encountered in soil and groundwater at contaminated sites

## **APPENDIX N - CHEMICAL AND GEOTECHNICAL TEST SAMPLING**

Samples were selected by a representative of Tier Environmental during the site investigation works in accordance with the sampling approach described elsewhere in this report.

## Samples for geotechnical and related testing

Bulk samples were placed within robust heavy duty plastic bags and sealed, together with small disturbed samples, within airtight 1 litre plastic containers.

100 mm diameter ‘undisturbed’ samples (“U100 samples”) were obtained where possible from cable percussive and large diameter window sample boreholes within cohesive materials.

## Samples for chemical analysis

All samples for chemical analysis were placed into clean new containers as summarised in Table 1. Unless explicitly stated elsewhere in this report, no preservatives were used to eliminate the risk that preservatives cause contaminant dissolution or analytical interference. Containers for VOC analysis were fully filled to exclude headspace.

Soil samples were dispensed as soon as possible after collection using reusable stainless steel spatulas, trowels or similar implements.

Ground water samples were collected from boreholes using single-use Teflon bailers or dedicated Waterra tubing with foot valves, except as otherwise noted within this report. Caution was taken to avoid excessive agitation during collection

New disposable gloves were used by the engineer for the collection of each sample.

Reusable equipment was washed down with distilled or deionised water between samples, except where tarry or similarly sticky materials were present. In such cases specific cleaning procedures were adopted as specifically described elsewhere in this report.

All sub-samples taken for chemical analysis were placed into refrigerators or cool boxes containing frozen ice packs immediately after aliquoting. All samples were transferred in cool boxes containing frozen ice packs to the relevant UKAS/MCERTS accredited laboratory as soon as possible. Recommended maximum holding times before analysis are summarised in Table 1.

**Table 1. Sample containers and holding times.**

| Analysis                         | Container/special requirements                                                                                                                                                                                                                   | Max. holding time at 4°C before analysis |
|----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|
| <b>Soil and sediment samples</b> |                                                                                                                                                                                                                                                  |                                          |
| VOCs                             | 30-60 g brown or green glass jar with VOC-resistant cap and inert cap liner.<br>Must be fully filled.                                                                                                                                            | 14 days                                  |
| TPHCWG                           | 30-60 g brown or green glass jar with VOC-resistant cap and inert cap liner <b>PLUS</b> 250-500 g brown or green glass jar with unwaxed cap liner. <sup>1</sup><br>The former must be fully filled.                                              | 14 days                                  |
| All other organics               | 250-500 g brown or green glass jar with unwaxed cap liner.                                                                                                                                                                                       | 7 days                                   |
| Inorganics                       | Air-tight 0.5-2.0 kg plastic container (250-500 g brown or green glass jar may also be used).                                                                                                                                                    | 14 days <sup>2</sup>                     |
| <b>Water samples</b>             |                                                                                                                                                                                                                                                  |                                          |
| VOCs                             | 40-50 ml glass vial with VOC resistant screw cap and inert liner.<br>Must be fully filled.                                                                                                                                                       | 14 days                                  |
| TPHCWG                           | 40-50 ml glass vial with VOC resistant screw cap and inert liner <b>PLUS</b> 500-1000 ml brown or green glass bottle with screw cap and unwaxed liner. <sup>1</sup><br>The former must be fully filled, the latter should be filled if possible. | 14 days                                  |
| All other organics               | 500-1000 ml brown or green glass bottle with screw cap.<br>Fill if possible.                                                                                                                                                                     | 7 days                                   |
| Inorganics                       | 500-1000 ml translucent or opaque screw cap plastic <i>or</i> brown or green glass bottles.<br>Fill if possible.                                                                                                                                 | 14 days <sup>3</sup>                     |

<sup>1</sup> The smaller vessel is used for analysis of the volatile components within the TPH mixture and the larger one is for the non-volatile components.

<sup>2</sup> 14 days is set as a reasonable limit for all routine analyses of soil for those inorganic components vulnerable to chemical and/or biological breakdown. Samples for sulphate analysis are vulnerable to biological sulphate-reduction but can be held for up to 28 days. For total metals, a holding period of up to 6 months is acceptable.

<sup>3</sup> 14 days applies for all routine analyses of most inorganic components that may be vulnerable to chemical and/or biological reactions. In the specific cases of sulphide, nitrite, nitrate and phosphate analyses, storage time must not exceed 48 hours. For total metals, a holding time of up to 6 months is acceptable.

## Tier Environmental standard analytical suites

The analyses included with Tier Environmental's standard analytical suites for soil, soil leachate and water samples are presented in Table 2. Other individual analyses were specified as described within this report.

**Table 2. Tier Environmental Standard Analytical Suites.**

| Parameter                        | Sample type |                                          |                       |                            |       |                            |
|----------------------------------|-------------|------------------------------------------|-----------------------|----------------------------|-------|----------------------------|
|                                  | Soil        |                                          | Leachate <sup>1</sup> |                            | Water |                            |
|                                  |             | LoD <sup>2</sup><br>(mg/kg or as stated) |                       | LoD<br>(µg/l or as stated) |       | LoD<br>(µg/l or as stated) |
| <b>Metals and metalloids</b>     |             |                                          |                       |                            |       |                            |
| Arsenic                          | ✓           | 1                                        | ✓                     | 10                         | ✓     | 10                         |
| Cadmium                          | ✓           | 1                                        | ✓                     | 5                          | ✓     | 5                          |
| Chromium                         | ✓           | 1                                        | ✓                     | 5                          | ✓     | 5                          |
| Mercury                          | ✓           | 1                                        | ✓                     | 1                          | ✓     | 1                          |
| Lead                             | ✓           | 1                                        | ✓                     | 4                          | ✓     | 4                          |
| Selenium                         | ✓           | 2                                        | ✓                     | 10                         | ✓     | 10                         |
| Copper                           | ✓           | 1                                        | ✓                     | 1                          | ✓     | 1                          |
| Nickel                           | ✓           | 1                                        | ✓                     | 50                         | ✓     | 50                         |
| Zinc                             | ✓           | 1                                        | ✓                     | 8                          | ✓     | 8                          |
| <b>Other inorganics</b>          |             |                                          |                       |                            |       |                            |
| Ammonia (as NH <sub>4</sub> -N)  |             |                                          |                       |                            | ✓     | 15                         |
| Total sulphate                   | ✓           | 100                                      |                       |                            | ✓     | 50 mg/l                    |
| Water-soluble sulphate           | ✓           | 0.1 g/l                                  |                       |                            |       |                            |
| Hardness (as CaCO <sub>3</sub> ) |             |                                          |                       |                            | ✓     | 1 mg/l                     |
| <b>Organics</b>                  |             |                                          |                       |                            |       |                            |
| Monohydric phenol                | ✓           | 1                                        | ✓                     | 0.5                        | ✓     | 0.5                        |
| Speciated PAHs (USEPA 16)        | ✓           | 0.1                                      | ✓                     | 0.01                       | ✓     | 0.01                       |
| Total Organic Carbon             | ✓           | 0.1 wt%                                  |                       |                            |       |                            |
| <b>Others</b>                    |             |                                          |                       |                            |       |                            |
| Electrical conductivity          |             |                                          |                       |                            | ✓     | NA                         |
| pH                               | ✓           | NA                                       | ✓                     | NA                         | ✓     | NA                         |

NA - Not applicable

<sup>1</sup> Leachate preparation according to NRA (1994), 10:1 liquid to solid ratio.

<sup>2</sup> The table presents the desired limit of detection for the analysis. Higher LoDs may be reported on analytical data sheets due to interference between analytes within specific samples or if the laboratory needed to dilute samples to achieve results within the calibrated range for that instrument.

## Analytical QA procedures

### Introduction

Quality Assurance (QA) is a system of review and audit that assesses the effectiveness of that product and assures the producer and user that defined standards of quality have been met. If we consider site investigation and chemical analysis, QA is the management system that ensures these measures are in place and working as intended.

QA within the laboratory form part of relevant certification programmes (such as UKAS and MCERTS) and, indeed, will be undertaken in some form by any reputable analyst, whether for a certified technique or not. Laboratory QA/QC is beyond the control of Tier Environmental and will not be considered further in this document, although the relevant laboratory documentation can be obtained upon request. QA must also form part of the design and execution of a site investigation.

Two parameters often used to assess measurement quality objectives are bias and precision. Bias is a systematic deviation in the data. For example, a positive bias (concentrations higher than in reality) would be introduced if sampling bottles were a source of the analyte and this fact was unknown. Precision is the variation in the measurements around a central 'expected' value. This could be due both to real variability in the environmental medium being measured and random errors in the analytical process. Both precision and bias can be assessed by the use of appropriate blanks and replicates within the site investigation programme.

The objectives of the QA activities undertaken in this present site investigation were to recognise and quantify systematic bias within the analytical dataset and to obtain an indication of precision. In environmental samples, much of the observed variability is likely to result from heterogeneity in the sampled medium, particularly for soil and sediment samples.

Such QA practice within the sampling programme is required by current guidance (e.g., Environment Agency report P5-065/TR (2000); Environment Agency LFTGN02 (2002); BS 10175:2001).

Alternative QA procedures to the generic approach presented in this appendix may be specified for a project, provided case-specific justification is given.

### QA checking procedure (data validation)

The responsible Engineer and Project Reviewer are required to undertake data validation and provide comment on data quality within the main body of the report(s) issued, when noteworthy matters arise. This QA checking should involve:

Confirming that data reported by the laboratory have achieved the standards specified by the certification scheme (MCERTS or UKAS). This will be indicated on the analytical certificates issued by the laboratory.

Checking that the limit of detection (LoD) and limit of quantification (LoQ) achieved by the laboratory for an individual analyte is appropriate for the purposes of the report. LoD and LoQ will vary dependent upon analyte concentrations, sample matrix properties and interference from co-contaminants.

A check that the reported range of concentrations are reasonable for the analyte. For example, the dissolved concentration of an analyte in a water sample should not exceed saturation. If it does, then this merits further consideration (e.g., was colloidal organic matter or other solid-phase material present or could there have been unobserved free-phase organic liquid?) and explicit comment. At its simplest, there may be a unit error.

Where analysis involves reporting of Tentatively Identified Compounds (TICs; normally by mass spectrometry), the reviewers should check that these might reasonably be expected at the site under consideration. The uncertainties in identification by MS mean that it is not uncommon that TICs are incorrectly assigned. In cases of doubt, the analytical laboratory can re-check the raw data and confirm.

A review of the analytical precision by comparing data obtained for duplicate samples. There is no absolute threshold - variability is entirely dependent upon the sample matrix and manner in which the contaminant has entered the sample. Variability that cannot reasonably be assigned to such factors (for example a very high apparent variability in data for sediment-free water samples) should be reviewed with the laboratory. Variability that is attributable to the sample matrix can nevertheless provide important pointers to improve understanding of contaminant transport pathways and the risks posed by pollutant linkages (e.g., soil heterogeneity, the association of contamination with particular soil fractions, the presence of residual NAPL within soil pores or the role of suspended sediments in contaminant transport).

Confirmation that no errors have been introduced by data transcription, unit conversion or corrections between preliminary and certificates issued by the laboratory. The reviewer should audit a proportion (typically 5-10%) of all data from the original (final) certificates of analysis through to the equivalent values in the report for those specific samples.

It is important to consult the analytical laboratory if apparent QA issues arise. Many apparent concerns can be adequately resolved on the basis of revisiting the raw analytical data or by obtaining a better understanding of the inherent limitations of the analysis for a particular matrix or sample type.

## **APPENDIX O - COMPLYING WITH CONTROL OF ASBESTOS REGULATIONS 2012**

## Complying with Control of Asbestos Regulations (CAR): Risk Assessments, Licensing and Training

This appendix outlines CAR risk assessments and where they should be applied in relation to assessing and remediating brownfield sites. The information below details the different classifications of work with asbestos under CAR, summarises the legal requirements for asbestos awareness training for all involved in the investigation and management of asbestos containing soil (ACS), and details the potential requirements for suitable proficiency training relating specifically to ACS.

### CAR RISK ASSESSMENTS

A CAR Risk Assessment is required for any work which may expose employees to asbestos. It is recommended that a precautionary approach is adopted if there is any doubt about risks associated with asbestos.

There are three main activities for potential asbestos exposure during work on brownfield sites:

- Site reconnaissance visits;
- Site investigation works; and
- Site remediation.

CAR risk assessments are needed at each stage but may be incorporated during the site investigation stage into the overarching health and safety risk assessments.

The CAR risk assessment must:

- Identify the type of asbestos to which employees are liable to be exposed, where possible, or assume it is present in different forms;
- Determine the type and extent of exposures to asbestos that may occur during the work
- Identify the steps to be taken to prevent exposure or reduce it to the lowest level reasonably practicable; and,
- Consider the effects of control measures that have been or will be taken.

The CAR risk assessment should include any information used to inform the risk assessment such as asbestos reports or desk study information. In the event that this information is not available, the assessor should be assumed that all forms of asbestos may be present on Site.

For all investigation and remediation of ACSs, a detailed written work plan should be produced and followed as detailed on the HSE website and in the CAR.

The CAR risk assessments for specific investigations or remediation projects, will determine whether or not work is 'licensable work' (LW), notifiable non-licensable work' (NNLW) or 'non-licensed work' (NLW). In addition, training requirements are also defined by the CAR risk assessment.

Some examples of control measures that apply during site reconnaissance, site investigation works, and site remediation are given below and should be applied depending on the asbestos risks identified for the Site at each stage of investigation:

- Avoiding stirring up dust;
- Cleaning footwear after site works;
- Removing and bagging any overalls for disposal/laundry;
- Respirators and hygiene facilities for high risk sites;
- Segregated welfare units;
- Wetting ground
- Minimising soil disturbances;
- Implementation or retention of capping/break layers;
- Implementation of awareness training;
- Air monitoring;
- Managing stockpiles;
- Area segregation;
- Wheel washing
- Road washing/cleaning

It is important to note that during Site reconnaissance visits, Site investigation works and Site remediation that asbestos should not be considered in isolation and control measures are likely to form part of a wider health and safety precautions.

### Respiratory protective equipment (RPE)

RPE is the last line of defence and its requirement would be defined by the CAR risk assessment. HSE (2013b) advises that RPE should have an assigned protection factor of 20 or more for all work with asbestos. In certain instances, full face-piece, positive pressure respirators with a protection factor of 40 are necessary (to EN 12942:1998, TM3).

Suitable types of RPE for most **short** duration non-licensed asbestos work:

- Disposable respirator to standards EN149 (type FFP3) or EN1827 (type FMP3)
- Half mask respirator (to standard EN140) with P3 filter
- Semi-disposable respirator (to EN405) with P3 filter

These filters are not suitable for people with beards/stubble or for long or continuous use.

## LICENSING

CAR defined certain types of activities involving asbestos as 'licensable work' (LW) or as 'notifiable non-licensable work' (NNLW). All other work would be 'non-licensable work' (NLW).

LW is defined as:

- work where exposure is not 'sporadic and low intensity'
- work where the risk assessment cannot demonstrate that the control limits (four hour and 10 minute limits) will not be exceeded
- work on asbestos coating
- work on AIB or insulation where risk assessment is either of first two points above or not of short duration (where short duration is defined for any work liable to disturb asbestos as taking less than two hours per week (including ancillary work) and no one person carries out that work for more than one hour').

NNLW includes work with:

- AIB or asbestos insulation of short duration that is not licensable
- fire-damaged asbestos cement or asbestos cement damaged so as to create significant dust and debris
- asbestos ropes, yarns, woven cloths in poor condition or handling cutting or breaking up the materials
- asbestos papers, felts and cardboard in poor condition, unencapsulated or not bound into another material.

Work with weathered asbestos cement, air monitoring and collecting samples of ACM in buildings would not normally be notifiable.

It is impossible to specify definitively what activities will and will not be licensable. This decision should be made as part of the CAR risk assessment. CAR is not primarily aimed at work with ACSs and there is little published information on airborne asbestos concentrations during work with ACSs. Nevertheless, CAR will require some remediation projects, and occasionally site investigations, to be LW. Investigations on other sites may involve NNLW. The decision as to whether work is LW or NNLW should be made during the CAR risk assessment by those in charge of the brownfield site investigations and remediation projects.

## TRAINING REQUIREMENTS

Asbestos health and safety courses are offered by a number of providers in the UK. Training courses that include the problem of identifying ACMs in soil should be undertaken at regular intervals by those involved in the investigation, assessment and management of sites where ACs are known or suspected. It is the role of the employer to identify the level of training required for an employee based on their role, experience and duties. Reference to Regulation 10 of CAR should be referred to for more information on training requirements.

Recognising asbestos within soils is challenging due to the heterogeneity of such soils and the discolouration of asbestos by smeared soil. Specific training for ground workers should include understanding fibre release potential, potential control measures in the field, how to take representative ACSs safely, sample labelling and what analytical tests are available and when they should be implemented.

Health and safety training required under CAR includes asbestos awareness, non-licensable work (including notifiable non-licensable work) and licensable work with asbestos.

In addition to health and safety training, some staff involved in the technical identification on site of ACMs, sampling and analysis may require technical proficiency training (competency training).

### Training vs. Competence

HSE (2005) identifies that 'training alone does not make people competent. Training must be consolidated by practical experience so that the person becomes confident, skilful and knowledgeable in practice on the job'. It is critical that ACS surveyors demonstrate competency with details of relevant field experience alongside training and examples of previous works/references.